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Semelparidade em *Gracilinanus agilis* (Didelphimorphia, Didelphidae): variação demográfica e fisiológica em remanescentes naturais de Cerrado do Distrito Federal

Semelparity in *Gracilinanus agilis* (Didelphimorphia, Didelphidae): demographic and physiological variation in remaining patches of Cerrado in the Federal District - Brazil.

Priscilla Lóra Zangrandi

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Orientador: Dr. Emerson M. Vieira

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"You never notice what has already been done,

you always only see what remains to be done."- Marie Curie

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RESUMO GERAL

Marsupiais ocupam habitats diversos e consequentemente apresentam uma ampla variedade de padrões de história de vida. Duas famílias de marsupiais (Dasyridae e Didelphidae) são os únicos representantes mamíferos da estratégia reprodutiva extrema chamada semelparidade (morte após evento reprodutivo único). As alterações fisiológicas subjacentes à mortalidade dos dasiurídeos machos estão associadas à falha na retroalimentação do eixo do estresse e aos efeitos da elevação do cortisol livre. Em marsupiais didelfídeos, a maioria dos estudos se baseia em estimativas demográficas, com exceção de um com metabólitos fecais do cortisol (FCM) de *Gracilinanus agilis*. O objetivo desta tese foi avaliar as mudanças nos parâmetros populacionais e fisiológicos do marsupial *G. agilis* em relação à estratégia semélpara, assim como aos efeitos de suplementação alimentar, sazonalidade e parasitismo por mosca cuterebrídea. Os resultados foram consistentes com as predições para a estratégia semélpara em *G. agilis*. As populações estudadas apresentaram sazonalidade na estrutura etária, reprodução e parâmetros populacionais. A suplementação alimentar teve efeitos menores no esforço reprodutivo de ambos os sexos, mas não alterou o padrão populacional. *G. agilis* apresentou alterações características da resposta adaptativa ao estresse em concentrações hormonais, razão neutrófilo/linfócito, condição corporal e concentração de hemoglobina. A suplementação não foi importante para a variação nos parâmetros fisiológicos e teve apenas um pequeno efeito nos níveis de FCM e cortisol livre, embora contrário às predições. Níveis de FCM não refletiram os níveis de cortisol livre e, portanto, não é uma boa indicação da atividade adrenal para *G. agilis*. Na avaliação do impacto da mosca cuterebrídea na saúde dos indivíduos, a concentração de hemoglobina, mas não a condição corporal, diminuiu em animais parasitados. Houve também uma interação entre o efeito da desidratação e da anemia induzida pelo parasita, de modo que os animais parasitados apresentavam uma pior condição de saúde nos dias mais secos.

Palavras-chave: estresse, história de vida, marsupial, parasitismo, sazonalidade, suplementação alimentar

GENERAL ABSTRACT

Marsupials occupy a great diversity of habitats and present a wide range of life-history patterns accordingly. Two marsupial families (Dasyuridae and Didelphidae) are the only mammal representatives of an extreme reproductive strategy called semelparity (death after single reproductive event). The physiological changes underlying male dasyurid mortality are associated with the failure of the stress axis feedback and the effects of the high free cortisol levels. In didelphid marsupials, most studies are based on demographic estimates, except for one on faecal cortisol metabolites (FCM) of *Gracilinanus agilis*. The objective of this thesis was to evaluate the changes in population and physiological parameters of the marsupial *G. agilis* in relation to its semelparous life-history strategy as well as to food supplementation, seasonality and botfly parasitism. The results were consistent with the predictions of the semelparous strategy for *G. agilis*. The populations had seasonality in age structure, reproduction and population parameters. Food supplementation had minor effects on reproductive effort in both sexes, and did not change the population pattern. *G. agilis* had changes in hormone concentrations, neutrophil/lymphocyte ratio, body condition, and haemoglobin concentration characteristic of the adaptive stress response. Food supplementation was not important for the variation in the physiological parameters and had only a small effect in FCM and free cortisol levels, though contrary to our predictions. The FCM levels did not reflect free plasma cortisol and, therefore, is not a good indication of adrenal activity for *G. agilis*. In the evaluation of the impact of the botfly on the health of the individuals, haemoglobin concentration but not body condition decreased in parasitized animals. Also, the effect of dehydration interacted with the parasite-induced anaemia so that parasitized animals had the worst health condition during the driest days.

Keywords: food supplementation, life history, marsupial, parasitism, seasonality, stress.

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INTRODUÇÃO GERAL

Dinâmica de populações e histórias de vida

Entender os padrões e as causas das mudanças temporais no tamanho populacional é o objetivo central do estudo de populações (Royama 1992). Essas mudanças ao longo do tempo, denominadas dinâmica populacional, são determinadas pelos processos de natalidade, mortalidade e movimentos dos indivíduos, e tais processos são influenciados por uma combinação de fatores exógenos e endógenos (Berryman 1999). Os fatores exógenos são aqueles independentes e externos a uma população, como o clima (e.g. Kausrud et al. 2008, Korpela et al. 2013) e predadores generalistas (e.g. Eagan et al. 2011, Andrén & Liberg 2015). Já os fatores endógenos são aqueles que afetam e também são afetados pela população, criando assim um sistema fechado de retroalimentação, podendo ser externo à população, como um predador ou patógeno especialista (e.g. Kallio et al. 2007, 2009, Sundell et al. 2013), ou interno à população, como a competição intraespecífica (Berryman 1999). A importância relativa desses fatores é o que molda as respostas demográficas e, consequentemente, a dinâmica populacional.

A competição intraespecífica por recursos, como alimento ou espaço, pode exercer um efeito sobre a taxa de crescimento da população. Isso porque mudanças nas condições ambientais conferem mudanças na aptidão individual através de variações na sobrevivência, no crescimento e/ou na reprodução, como resultado de respostas fisiológicas e comportamentais dos indivíduos (Batzli 1992, Caswell 2001). Assim, entender como variam as características individuais que afetam diretamente a aptidão, ou seja, a história de vida dos indivíduos, ajuda a entender também a variação demográfica das populações.

Existe uma grande diversidade de estratégias de história de vida entre as espécies. As combinações entre os seus componentes refletem uma alocação de recurso ótima, visto que os recursos são finitos e o investimento em uma determinada característica limita o investimento em outra (Caswell 1980, Stearns 1989, 1992). Essas relações são conhecidas como *trade-offs* e as mais estudadas são as relacionadas aos custos de reprodução, ou seja, quando o aumento na reprodução atual reduz o sucesso reprodutivo ao afetar a sobrevivência ou fecundidade futuras (Caswell 1980, Stearns 1989, 1992). Mecanismos fisiológicos também são um componente fundamental das estratégias de história de vida, visto que podem limitar as possíveis respostas adaptativas ao ambiente em eixos principais de variação (Ricklefs & Wikelski 2002, Speakman 2008, Gaillard et al. 2016).

Semelparidade

A semelparidade, também conhecida como "reprodução suicida", é uma estratégia de história de vida extrema na qual os indivíduos se reproduzem uma única vez (Cole 1954). Ao contrário dos indivíduos iteróparos, que apresentam diversos eventos reprodutivos ao longo da vida, os semélparos investem a energia disponível por um período curto de reprodução intensa, representando, assim, um *trade-off* de sobrevivência por reprodução (Lee & Cockburn 1985). Antes vista como uma categoria discreta de história de vida (Cole 1954), a semelparidade *stricto sensu* (*die-off*) passou a representar um ponto extremo no gradiente de estratégias reprodutivas (Fisher et al. 2013, Hughes 2017). Esse gradiente passa pela chamada semelparidade parcial (Martins et al. 2006, Boonstra et al. 2007), semelparidade facultativa (Mills & Bencini 2000, Christiansen et al. 2008) e iteroparidade facultativa (Fisher & Blomberg 2011).

A estratégia semélpara ocorre em diferentes grupos, como plantas, invertebrados e peixes, porém é raramente presente em mamíferos. Isso devido, possivelmente, à baixa taxa reprodutiva máxima, associada ao cuidado parental das fêmeas, atuando como uma restrição evolutiva (Braithwaite & Lee 1979). No entanto, a semelparidade em mamíferos aparentemente se restringe a machos, cuja taxa reprodutiva máxima sofreria, a princípio, menos restrições evolutivas. Casos de semelparidade em mamíferos foram registrados em apenas duas famílias de marsupiais: Dasyuridae, na Australásia (Braithwaite & Lee 1979, Boonstra 2005, Holleley et al. 2006) e Didelphidae, nas Américas (Pine et al. 1985, Lorini et al. 1994, Martins et al. 2006, Leiner et al. 2008). Essa estratégia reprodutiva provavelmente evoluiu independentemente diversas vezes dentro das famílias marsupiais (Krajewski et al. 2000), até mesmo em gêneros da mesma tribo (*Antechinus* e *Phascogale*; Westerman et al. 2016). A hipótese subjacente para o surgimento da semelparidade é que a reprodução ocorreria em um momento ideal para as fêmeas, mas não para os machos, já que a abundância de recursos coincidiria com o período de lactação tardia de marsupial, o período de maior demanda energética para as fêmeas, e não com o período de acasalamento, o período de maior demanda energética para os machos (Braithwaite & Lee 1979, Boonstra 2005). Assim, a semelparidade está associada a habitats fortemente sazonais e previsíveis (Braithwaite & Lee 1979). De fato, espécies marsupiais insetívoras têm períodos de reprodução mais curtos e menor sobrevivência pós-reprodutiva de machos em ambientes com maior previsibilidade sazonal na abundância de insetos (Fisher et al. 2013).

O conjunto das causas fisiológicas subjacentes à mortalidade associada à semelparidade *stricto sensu* é denominado "resposta adaptativa ao estresse" (Lee & Cockburn 1985, Boonstra

& Boag 1992) ou "síndrome da semelparidade" (Woods & Hellgren 2003). Vários estudos avaliaram o resultado fisiológico da semelparidade no gênero dasiurídeo *Antechinus*, no qual as fêmeas possuem estro anual sincronizado, enquanto os machos se dedicam intensamente a obter parceiras e morrem imediatamente após esse curto período (Naylor et al. 2008). A ação do cortisol está diretamente relacionada a essa mortalidade: os altos níveis de cortisol promovem o catabolismo proteico via gliconeogênese, o que permite o uso de proteína como estoque alimentar a curto prazo, mas causam falhas nos sistemas imune e inflamatório a médio prazo (Bradley 2003, Naylor et al. 2008). Como a resposta adaptativa ao estresse se caracteriza pela falha dos mecanismos de retroalimentação do eixo do estresse e, consequentemente, pela elevação do cortisol circulante do início do período reprodutivo até o fim da vida dos machos, resultam em imunossupressão, perda de peso e pelos, anemia, ulcerações gastrointestinais, disfunção renal e deterioração geral da condição (Bradley 2003, Boonstra 2005, Holleley et al. 2006).

Na América do Sul, a estratégia de vida semélpara em mamíferos foi descrita para três gêneros de marsupiais didelfídeos, *Monodelphis* (Pine et al. 1985), *Marmosops* (Lorini et al. 1994, Macedo 2007, Leiner et al. 2008) e *Gracilinanus* (Martins et al. 2006a, Puida & Paglia 2015, Lopes & Leiner 2015, Hernandez et al. 2018). Ao contrário dos machos dasiurídeos, que morrem algumas semanas após o início do período reprodutivo, a mortalidade dos machos didelfídeos pode demorar até três meses após a cópula, o que sugere diferenças nos mecanismos fisiológicos que culminam com a morte (Macedo 2007). Apesar de ocorrer em área de Mata Atlântica, a princípio com pouca sazonalidade de chuvas e, consequentemente, recursos alimentares, a disponibilidade de frutos parece controlar o período reprodutivo de *M. paulensis*, e pode exercer papel importante na expressão da semelparidade nessa espécie (Leiner et al. 2008). Por outro lado, *G. agilis* no Cerrado, um domínio fitogeográfico com forte sazonalidade da precipitação, não teve seus parâmetros demográficos influenciados pela produtividade primária (Puida & Paglia 2015).

Suplementação alimentar

Os estudos que avaliam o efeito da disponibilidade de um recurso limitante na dinâmica populacional, principalmente alimento, podem apresentar dois tipos de abordagem. Os estudos podem ser observacionais, baseando-se na busca de correlações entre as variações naturais dos recursos e as variações na abundância das espécies (Gurnell 1996, Leiner & Silva 2007, Sale et al. 2008, Mendel et al. 2008), ou experimentais, através de manipulação de recursos por

restrição ou, mais frequentemente, por suplementação (Klemola et al. 2000, Huitu et al. 2003, Boonstra & Krebs 2006, Forbes et al. 2014). Enquanto a primeira abordagem permite uma avaliação de diferentes fatores em qualquer escala espacial ou temporal, a segunda abordagem permite inferências mais confiáveis sobre as relações de causa e efeito, apesar de limitada a escalas menores (Gotelli & Ellison 2004).

A suplementação alimentar leva a um aumento em média de 50 % da densidade (Prevedello et al. 2013). Porém, outros fatores podem determinar o resultado final do experimento na população além de mudanças no crescimento, sobrevivência e reprodução dos indivíduos. Os fatores "de confusão", apontados por Prevedello e colaboradores (2013) como os principais nesses estudos, foram a imigração de indivíduos, atraídos pela maior disponibilidade de alimento, e o aumento da predação, que pode levar a uma redução no aumento populacional.

Estudos de suplementação alimentar com mamíferos semélparos se limitam aos realizados com o dasiurídeo *A. stuartii* (Dickman 1988, 1989, Banks & Dickman 2000). Nesses, foi encontrada uma relação entre adição de alimento e investimento maternal em *A. stuartii*, pois fêmeas de áreas manipuladas apresentaram tamanho de corpo maior na fase da lactação, além de ter aumentada a massa corporal e a sobrevivência de seus filhotes machos no desmame (Dickman 1988). A oferta adicional de alimento contribuiu, diretamente, para o aumento do tamanho populacional, da sobrevivência e da massa corporal e, indiretamente, para a redução do contato antagonístico intraespecífico pela redução das áreas de vida (Dickman 1988, 1989).

Objetivo e estrutura da tese

O objetivo da presente tese foi avaliar alterações na dinâmica populacional do marsupial didelfídeo *Gracilinanus agilis* e em aspectos fisiológicos da espécie (especialmente relacionados à semelparidade) em função de fatores extrínsecos às populações, incluindo suplementação alimentar, sazonalidade e parasitismo. Dessa forma, pretendi avaliar se os padrões encontrados seriam passíveis de alteração, em função da variação na disponibilidade de recursos, ou programados na espécie. Para isso, estudei quatro populações naturais de *G. agilis* em manchas de cerradão no Brasil central, sendo que duas receberam o suplemento alimentar e duas representaram o controle do experimento. No capítulo 1, investiguei a estrutura etária, o padrão reprodutivo, a abundância e as taxas demográficas das populações. No capítulo 2, avaliei os hormônios relacionados à resposta ao estresse caracterizado pelo esforço

reprodutivo – cortisol plasmático, metabólitos fecais de cortisol e globulina ligadora de corticosteroide – e os efeitos fisiológicos resultantes desses níveis hormonais. Já no capítulo 3, estudei os efeitos do parasitismo pela mosca cuterebrídea na condição corporal e na concentração de hemoglobina, além da influência da sazonalidade climática nesta interação.

Os resultados populacionais e fisiológicos foram em geral consistentes com a estratégia semélpara esperada para *G. agilis*, porém tiveram pouca ou nenhuma influência do experimento de suplementação alimentar. As populações estudadas apresentaram sazonalidade na reprodução, na estrutura etária, nas taxas de recrutamento e sobrevivência, levando ao declínio populacional ao final da estação reprodutiva. A resposta fisiológica dos indivíduos foi semelhante ao esperado para uma ativação crônica do eixo do estresse, com níveis elevados de cortisol livre e efeitos em cascata desse aumento na razão neutrófilo/linfócito, na concentração de hemoglobina e na condição corporal. As diferenças populacionais e fisiológicas entre o didelfídeo *G. agilis* e as espécies dasiurídeas semélparas apoiam a ideia crescente de que existe uma diversidade entre as possibilidades de histórias de vida mesmo para estratégias extremas como a semelparidade. Além disso, a presença da mosca cuterebrídea gerou um efeito anêmico nos indivíduos parasitados, e este efeito se tornava pior quando ocorria juntamente com o efeito de desidratação nos dias mais secos e quentes, característicos do auge da estação seca. Tal piora na condição de saúde dos indivíduos não se refletiu na condição corporal, demonstrando que a condição de saúde pode não estar sendo detectada em estudos ecológicos que utilizam apenas dados de medidas corporais.

A questão se as populações de *G. agilis* são limitadas por alimento permanece em aberto. Apesar de evidências de que indivíduos de *G. agilis* tiveram acesso aos comedouros, consumiram o alimento fornecido, e de que o alimento atendia os requerimentos proteicos da espécie e foi fornecido *ad libitum*, não pude avaliar de forma sistemática as taxas de consumo: a proporção consumida pela espécie marsupial em relação às espécies de roedores arborícolas, a proporção de indivíduos que consumiram em relação à população total, ou a proporção de consumo individual de ração em relação ao total de alimentos da dieta desses animais. O período do experimento também pode ter contribuído para os poucos e sutis efeitos encontrados com a suplementação.

Novos estudos na área de ecologia do estresse de populações naturais são cruciais para a região neotropical. Para um entendimento mais completo dos padrões encontrados em *G. agilis*, são ainda necessários estudos com foco nos hormônios sexuais, que devem cumprir um papel importante na resposta adaptativa ao estresse, além de outras informações do ciclo reprodutivo (espermatogênese em machos, ciclo oestral, tempo de gestação e de lactação em

fêmeas, por exemplo). Além disso, outras espécies marsupiais também precisam ser contempladas em estudos fisiológicos, para efeitos de comparação entre as espécies didelfídeas entre si e em relação aos marsupiais australianos. Estudos experimentais e observacionais contribuiriam de forma complementar para o conhecimento dos mecanismos por trás das características de história de vida dos marsupiais didelfídeos. Por fim, sugeri que o termo semelparidade fosse evitado, já que atualmente não representa uma única estratégia em mamíferos diante da complexidade de histórias de vida possíveis.

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GENERAL METHODS

Studied species

Gracilinanus agilis (Burmeister 1854), the gracile mouse opossum (Didelphimorphia, Didelphidae; Figure 1) has a wide geographical distribution, occurring mainly in forest environments in the Cerrado, Caatinga and Pantanal (Creighton & Gardner 2007, Paglia et al. 2012). Individuals of this species are small (13-40 g), nocturnal, solitary and scansorial (Emmons & Feer 1997, Creighton & Gardner 2007, Paglia et al. 2012). They are mainly captured in the understorey and canopy, where they build nests with grasses and plant fibers (Emmons & Feer 1997, Oliveira et al. 2007). Their diet is composed of fruits, invertebrates and small vertebrates (Bocchiglieri et al. 2010, Camargo et al. 2014). The gracile mouse opossum shows size-related sexual dimorphism (females = 13-25 g, males = 15-40 g; Costa et al. 2003). The reproductive activity of this marsupial is synchronized and begins at the end of the dry season, leading to recruitment in the rainy season, a period of greater resource availability (Mares & Ernest 1995, Andreazzi et al. 2011, Puida & Paglia 2015, Lopes & Leiner 2015). Population reduction occurs after the breeding season (Aragona & Marinho-Filho 2009, Andreazzi et al. 2011), as observed in the study area (Mendonça et al. 2015).

The species is characterized as semelparous, as no adults were recaptured between reproductive seasons in a population from a semi-deciduous tropical forest in the Pantanal (Andreazzi et al. 2011), and adult males disappear in the post-mating period in a population from the cerrado *sensu stricto* (Lopes & Leiner 2015). Parasite loads and stress hormone levels were associated with this strategy in the latter population (Strona et al. 2015, Hernandez et al. 2018). However, a population from a "cerradão" area in southeastern Brazil, previously identified as *G. microtarsus* but recently suggested as *G. agilis* (Vieira et al. 2017), was described as partially semelparous as not all males died after the reproductive event (Martins et al. 2006).

Figure 1. The gracile mouse opossum *Gracilinanus agilis.*

Study area

This study was inserted in a long-term project developed in the Laboratory of Vertebrate Ecology/UnB, entitled "Effect of bottom-up factors on the population regulation of *Gracilinanus agilis* (Didelphimorphia, Didelphidae) in natural fragments of "cerradão" in central Brazil". The study had already capture-mark-recapture (CMR) data of *G. agilis* before and during food supplementation.

We conducted the study in the Gama-Cabeça de Veado Environmental Protection Area (APA), located near the city of Brasília in the Federal District of Brazil. The APA has about 11,400 ha of continuous protected area, which includes the ecological and agricultural field station of the University of Brasília (Fazenda Água Limpa - UnB), the Botanical Garden of Brasília (JBB-GDF) and the Ecological Reserve of the Brazilian Institute of Geography and Statistics (RECOR-IBGE) (Fonseca & Silva Júnior 2004).

The study comprised four patches of "cerradão" (savannah woodland) immersed in a cerrado *sensu stricto* matrix (Figure 2). The "cerradão" is one of the physiognomies of the Cerrado biome, with xeromorphic and semi-deciduous formation, presenting a 8-12 m canopy height, a 50-90 % tree coverage (Oliveira-Filho et al. 2002), and predominance of tree species common to cerrado *sensu stricto* and seasonal forest (Felfili & Silva-Júnior 2001). The sampled patches were at least 800 m apart and in two localities: three patches in the Botanical Garden

of Brasília (JBB-GDF), JB1 (23.83 ha; 15°56’49.0”S 47°56’42.8”W), JB2, (27.33 ha; 15°55’25.6”S 47°49’59.3”W) and JB4, (3.32 ha; 15º51’55.32”S 47º49’40.34”W), and one - FAL - at Fazenda Água Limpa (7.53 ha; 15º55’32.8”S 47º49’58.4”W).

According to the Köppen-Geiger classification, the climate is equatorial savannah with dry winter (Aw) (Kottek et al. 2006), with the dry season between May and September and the wet season between October and April (Eiten 1972). Since the beginning of the long-term study in 2009, the average monthly temperature ranged from 19.8 to 24.8 ºC and monthly rainfall, from 0 to 441 mm (data from the meteorological station RECOR-IBGE).

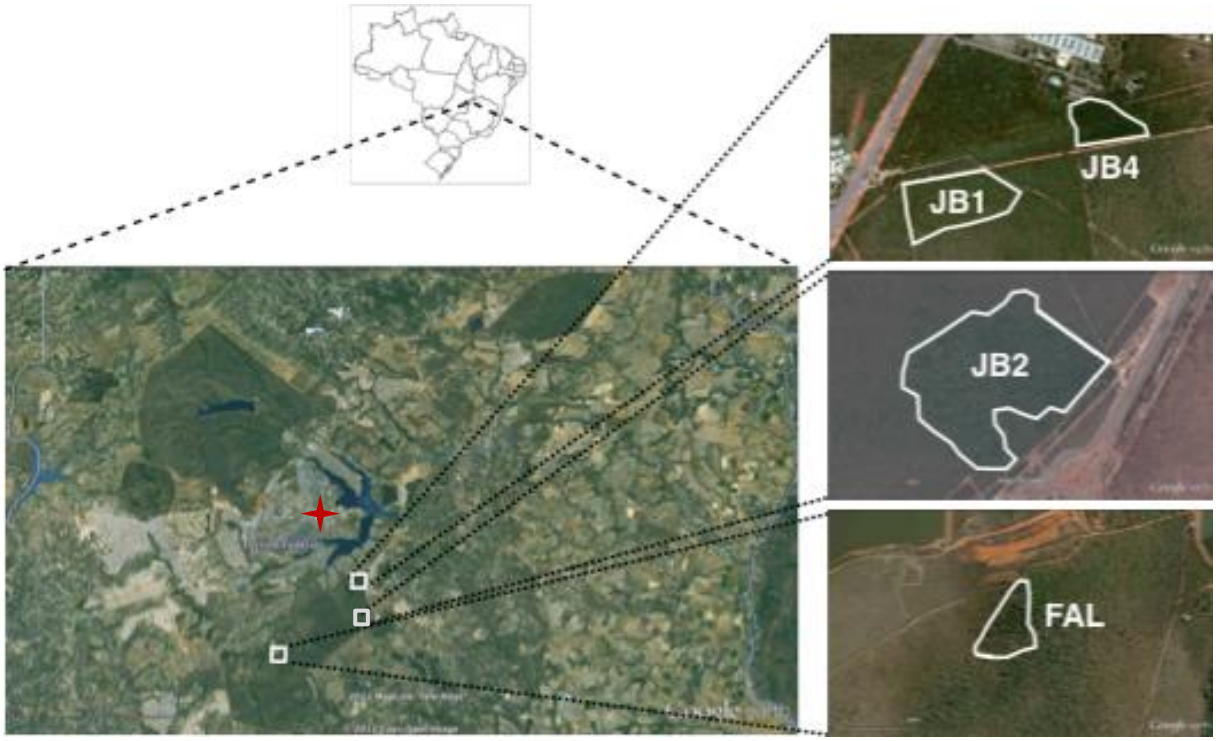

Figure 2. Location of the four sampled patches of “cerradão” in the Gama-Cabeça de Veado Environmental Protection Area (APA) in central Brazil. The location of the city of Brasília is marked with a cross for distance reference. JB2 and JB4 were the food-supplemented areas whereas JB1 and FAL were the control areas.

Trapping procedures

We set four 1.44-ha trapping grids (120 m x 120 m), each comprising 81 capture stations 15 m apart. Each capture station had one Sherman live trap (H.B. Sherman Traps, Tallahassee,

Florida; 23 cm x 9 cm x 8 cm) on the ground and one in the understory (1.5 - 2.0 m). The food-supplemented grids JB2 and JB4 had additional external zones which consisted of one trap in the understory in 30 and 25 capture stations, respectively. Traps were baited daily with a mixture of banana, peanut butter, maize flour, cod liver oil, and vanilla essence. Each capture session lasted six consecutive nights and totaled 4,218 trap-nights. From July 2009 to December 2016, we sampled the grids FAL and JB2 31 times, the grid JB1 30 times, and the grid JB4 19 times (2012-2016).

We equipped traps in the understory with timers adapted from Dal Berto (2012). For the assembly of the device, we used a battery-powered digital clock and electric wires between 10 and 20 cm in length (Figure 3). We built two versions of timers: the first version was based on bare wires and crocodile metal clips to close the circuit and activate the timer when the trap was closed, whereas the second version was based on magnetic proximity sensors (Metaltex Ltda, São Paulo, Brazil). The second version functioned better, especially in rainy days. The timers were attached to the side of the traps with SilverTape or Velcro Tape, and were protected from the rain with either PVC film, silicone sealer or polystyrene box. The traps placed on the ground were not equipped with timers because capture success of *G. agilis* is low for this stratum, and during the long-term study only 10 % of individuals had been captured exclusively on the ground (unpublished data).

Individuals captured for the first time were tagged (model 1005-1; National Band, Tag and Co., Newport, USA) on both ears to prevent identification loss. We recorded the individual number, species, sex, body mass (to the nearest 0.1 g), head-body and tail lengths (to the nearest mm), scrotal width for males (to the nearest 0.01 mm), dental eruption pattern, reproductive status and presence of ectoparasites / botflies. Individuals that occasionally died during the capture sessions were taxidermized and deposited in the Mammal Collection of the University of Brasília (CMUNB). All field methods were approved by the Institutional Animal Care and Use Committee of the University of Brasília (CEUA – UnB; No. 62274/2015) and complied with the requirements of The Brazilian Institute for the Environment and Natural Resources (IBAMA) (Permit No. 15424–1, IBAMA Registration No. 15778628).

Figure 3. a) An opened digital clock to show the welded wires used to open the electric circuit. b) A clock with its electric circuit closed by magnets. c) Trap equipped with the first version of timer device protected with PVC. d) Red arrow indicates the bare wire that is on the inner side of the trap and touches the door when the trap is closed. e) Trap equipped with the second version of timer device inside a polystyrene box. f) Timer sealed with acetic silicone.

Food supplementation experiment

The food supplementation occurred in the grids JB2 and JB4 from June 2014 to December 2016. We provided milled cat food (Golden Gatos salmon, Grandfood, Dourado, SP, Brazil, 3.91 kcal/g) through feeders specifically developed for this long-term study experiment (Mendonça et al. 2017). The cat food was an appropriate food resource as it had a percentage of crude protein (310 g / kg, or 31 %) similar to the estimated protein requirement for *G. agilis* (20.2 % and 26.4 % of protein content selected by young and adults respectively; Astúa de Moraes et al. 2003).

The feeder consisted of a polypropylene plant pot (18 cm x 14 cm - diameter x depth), a polypropylene plant saucer (17 cm x 3 cm), a PVC tube (4 cm x 15 cm), and a plastic smaller pot (7 cm x 4.5 cm) attached to the bottom of the feeder by VHB^{TM} adhesive tape (Figure 4). We used entomological glue (Colly Química Ltda., Capivari, SP, Brazil) on the internal walls to make it difficult for arthropods to access the food.

Figure 4. a) Feeder fixed on a tree branch by an elastic band. b) Interior of the feeder with the partially-eaten food in the center and the entomological glue on the wall.

We installed the feeders only in the understory and opened a small entrance (4 cm diameter) to avoid the access by other species, such as terrestrial rodents, and larger species such as the marsupials *Caluromys philander* and *Didelphis albiventris* and marmosets. We

confirmed which species visited the feeders by analyzing hairs retained in the double-sided tape fixed inside the PVC tube and by a few camera traps installed in front of the feeders. We found hair from *G. agilis*, but also from *D. albiventris* and five rodent species (*Hylaeamys megacephalus*, *Oecomys* cf. *cleberi*, *Oligoryzomys nigripes*, *O. fornesi* and *Rhipidomys macrurus*) (unpublished data). Moreover, we saw that both *G. agilis* and the *R. macrurus* occasionally used the feeders as a nest with a layer of leaves to house their litter.

We placed the feeders in 27 of the 81 capture stations inside each manipulated grid, and in 25-30 stations in the external zone, which was designed to minimize the crowding effect by increased immigration. We visited the supplemented areas every two to three weeks according to the proportion of consumption from the previous visit to each grid. In each visit we removed the remaining food (for further drying and weighing) and replenished with a fixed amount of fresh food. We emptied the feeders just before the capture sessions because the trap bait could become less attractive for animals with the availability of cat food in the area. During the experiment we replenished food in 41 visits to JB2 and 35 visits to JB4, and the total consumption in each grid was 151.67 kg and 94.53 kg, respectively.

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CHAPTER 1: Effects of food supplementation on demography and dynamics of the semelparous marsupial *Gracilinanus agilis* (Didelphimorphia, Didelphidae) in savannah woodland patches, central Brazil

Introduction

Population is a fundamental unit in Ecology that can be defined as a group of conspecific individuals inhabiting an area of sufficient size to allow dispersion and/or migration, and in which its numerical changes are mainly determined by birth and death processes (Berryman 2002). These processes of population change (natality, mortality and movement) are controlled by the average individual properties acting with the environment, and affect the population variables such as density, distribution, age structure, and gene frequencies (Berryman & Kindlmann 2008).

In order to understand the population dynamics, that is, the temporal variation in abundance of a species, we must understand the changes in the demographic parameters, which are subject to ecological and evolutionary forces (Caswell 2001). In this manner, changes in environmental conditions such as resource availability or habitat quality confer changes in demography, which reflect the performance of individuals (growth, reproduction and survival), as a result of behavioral and physiological responses of these individuals (Batzli 1992). Thus, understanding temporal variation in demography also helps understand life histories of individuals, their interactions with each other and with the environment and, consequently, the mechanisms of population variation.

Population regulation is a process resulting from the combination of exogenous and endogenous factors (Berryman 1999). Independent processes outside a population are considered exogenous, and their examples are climatic factors (e.g. Kausrud et al. 2008, Korpela et al. 2013), as well as predators that influence but are not influenced by prey populations (e.g. Eagan et al. 2011, Andrén & Liberg 2015). Endogenous factors cause changes in the population, but are also affected in turn, generating a feedback loop. Examples of such effects are predator/pathogenic agent (e.g. Kallio et al. 2007, 2009, Sundell et al. 2013) and food resources (e.g. Huitu et al. 2003).

Studies assessing the effects of limiting resource availability on a population, mainly food, can be observational or manipulative. The first approach correlates natural variation of resources and variation in the abundance of species (Gurnell 1996, Leiner & Silva 2007a, Sale

et al. 2008, Mendel et al. 2008), while the second approach changes resources availability by means of restriction or, more commonly used, supplementation (Klemola et al. 2000, Huitu et al. 2003, Boonstra & Krebs 2006, Forbes et al. 2014). The second approach has the advantage of allowing more reliable inferences regarding cause and effect, although limited to smaller scales (Gotelli & Ellison 2004).

Food supplementation studies with small mammal populations indicated changes in behaviour, life history, population demography and dynamics (for reviews: Boutin 1990, Prevedello et al. 2013). In general, the addition of food sometimes causes a positive effect on densities, through increased reproduction, survival or immigration, but no changes in population fluctuations (Boutin 1990, Prevedello et al. 2013). Distinct results were found in studies with a semelparous species, *Antechinus stuartii* (Dickman 1988, 1989, Banks & Dickman 2000). In one experiment, the food was provided in the understory, and therefore only available to the brown antechinus (*A. stuartii*) and not to its sympatric congener of terrestrial habits, the dusky antechinus (*A. swainsonii*) (Dickman 1988, 1989). Increased food availability led to increased parental investment, biased sex ratio of offspring for males, and increased male body mass before mating (Dickman 1988). Supplemented populations did not respond rapidly due to increased reproduction or immigration, but responded more slowly due to the survival of youngsters (Dickman 1989). In another food supplementation experiment, the feeders had different sizes and were placed on the ground and at 1.5 m, which served not only the small marsupial but also the terrestrial rodent *Rattus* spp. (Banks & Dickman 2000). Despite the increase in the antechinus body size, its survival rate was not affected by food supplementation (Banks & Dickman 2000). Moreover, the number of antechinuses in areas with food supplementation declined, because individuals would avoid areas with greater interspecific competition due to the high density of the larger rodents (Banks & Dickman 2000).

The characteristic seasonality of the Cerrado climate, mainly through rainfall, directly influences the availability of resources, both fruits (Batalha & Martins 2004) and arthropods (Pinheiro et al. 2002). Differences between forest savannah formations and typical savannahs, such as litter production (Valenti et al. 2008), soil fertility and floristic composition (Oliveira-Filho et al. 2002), may also lead to differences in resource availability between these phytophysiognomies. While a population of the gracile mouse opossum (the target species in this study) was described as semelparous in cerrado *sensu stricto* (typical savannah) area in the state of Minas Gerais (Lopes & Leiner 2015), another population was described as partially semelparous in a “cerradão” (savannah woodland) area in São Paulo (Martins et al. 2006a). It is possible that this difference in semelparity expression between populations may be a

reflection of habitat characteristics in which these populations are inserted, with a more intense expression in the more seasonal habitat, which reflects in the resource availability of fruits and arthropods (Pinheiro et al. 2002, Batalha & Martins 2004).

Resource availability is an important factor in terms of the species diet variation, since studies on the diets of didelphid marsupials from the Atlantic Forest and the Cerrado reported seasonal variations on food consumption related to opportunistic foraging, with this marsupials eating more frequently the items that were more available (Martins et al. 2006d, Leiner & Silva 2007b, Ceotto et al. 2009, Lessa & Geise 2014). However, not only the environment determines the diet variation and its consequence to the populations, but also how individuals interact with this changing environment. Studies on the gracile mouse opossum suggested consumption preference shifts between seasons related to energetic-nutritional requirements associated with reproduction effort of each sex (Martins et al. 2006d, Camargo et al. 2014a). In the population from a "cerradão" area in São Paulo, the dietary niche width differed between sexes in the dry season but not in the wet season (Martins et al. 2006c). The dietary niche of males was wider in the dry season than in the wet season (Martins et al. 2006c), represented by a decrease in variation among males (between-individual variation) and an increase in variation of each male (within individual variation; Martins et al. 2008). The dietary niche of females was narrower in the dry season than in the wet season (Martins et al. 2006c), though variation among females did not change in relation to the wet season.

On the other hand, in "cerradão" patches in central Brazil, a different pattern of dietary preference emerged for this species. The dietary niche width was wider in the wet season than in the dry season for both sexes (Camargo et al. 2014b). While variation among males did not change between seasons, the change in female niche width was a result of an increase in variation among females and a decrease in variation of each female (Camargo et al. 2014b). This pattern represented the individual specialization of females in the wet season, with older, reproductive females eating more arthropods than young, non-reproductive females from the newest generation (Camargo et al. 2014a, 2014b). That result was opposite to the pattern of male specialization in the dry season found in the population from São Paulo and might reflect different strategies between populations.

Therefore, environmental factors and individual traits are related to the occurrence of a variety of life-history strategies and consequently population dynamics. For this reason, comparisons of demographic and reproductive patterns among populations coping with different resource availabilities in different ways may contribute to the understanding of the adoption of semelparity by different marsupial lineages.

Objective and predictions

The overall objective of this chapter was to describe the demography and the dynamics of populations of the gracile mouse opossum *Gracilinanus agilis* in "cerradão" (savannah woodland) patches, and to evaluate the effects of food supplementation on the demographic and reproductive patterns of the studied populations. We predicted that the population parameters of *G. agilis* would be in accordance with a semelparity (or partial-semelparity) syndrome. Population abundances would decline in the end of the reproductive season, primarily because of a decline in male survival, as described in previous studies (Martins et al. 2006a, Lopes & Leiner 2015). Female survival would also decrease but not in the same intensity as male survival since females would still be nursing their offspring after the male mortality. The populations would have seasonal age structures as a consequence of seasonal reproduction, with higher recruitment rates in the wet season, the period of higher resource availability. The food supplementation experiment would increase abundances due to higher survival, and consequently individual longevity, and higher recruitment, because of better-supported offspring and extended reproductive season. Consequently, age structure would be more stable throughout the year in the food-supplemented populations than in the control populations, which would maintain marked seasonal age structures.

Methods

Age and reproductive status determination

We classified individuals into age classes based on the dental eruption of the last premolar and the last functional superior molar (Tyndale-Biscoe & MacKenzie 1976, Tribe 1990, Macedo et al. 2006). The original classification proposed by Tyndale-Biscoe and MacKenzie (1976) is composed of seven age classes: the first three classes represent the young, weaned individuals with the deciduous premolar tooth, the fourth class represents the subadults, which are usually sexually mature, the fifth class represents the adults, with complete dentition pattern, and the sixth and seventh classes represent the old individuals with cusp wear.

We delimited the reproductive seasons based on the proportion of reproductively active females. The observed signs of reproduction were swollen, lactating or regressed teats. Litter size was assumed for each female, in most cases by the number of teats with milk, since the

females of this species do not carry their offspring. The prime teat formula for *G. agilis* is 6-1-6 = 13, but the functional teat count can be less (Hershkovitz 1992).

Unlike other small mammals such as rodents, opossum males have their testicles in a descending position their entire lives, so it is not clear when they mature and if they are reproductively active throughout their adult life. However, males show indirect signs of reproduction that have been observed in other didelphid marsupials, such as developed throat gland (e.g. *Gracilinanus microtarsus*, Martins 2004; *Marmosops incanus*, Macedo 2007; *Monodelphis domestica*, Harder et al. 2008; for more examples, Hershkovitz 1992) and scrotal sac pigmentation (Nogueira 2012). Another indication of male reproduction may be testis size. Lopes and Leiner (2015) mentioned that the mean scrotal width of *G. agilis* increased from the non-reproductive period to the reproductive period. Therefore, we evaluated the scrotal width increase with time and compared with the presence of the throat gland and body size increase in males.

We applied circular statistics to test the seasonality in age structure and in the reproductive period of the studied populations using the Rayleigh Uniformity Test, whose null hypothesis is uniform distribution of data around the circle (Fisher 1993). The circle (360º) corresponds to the year, and it is divided into 12 equal parts of 30º each. We used the Mardia-Watson Wheeler Test, which compares circular distributions (Fisher 1993), to test if the age structure and the reproductive periods for the food-supplemented populations differed from the control populations. For these analyses we used the "circular" package (Agostinelli & Lund 2017) in R, version 3.4.2 (R Core Team 2017).

We used linear and linear mixed-effects models to assess the effect of food supplementation on the reproductive effort of females and males represented by the litter size and scrotal width, respectively. We used regression diagnostic tools to investigate if the assumptions of linear regression were met (Altman & Krzywinski 2016a). The assumption of linearity was checked with the residuals vs fitted values plot; the assumption of normality, that is, if the residuals are normally distributed, was checked with the Q-Q plot; and the assumption of constance variance (homoscedasticy) was checked with the scale-location plot. Possible outliers, high-leverage and/or influential points could be found using the residuals vs leverage and the cook's distances plots (Altman & Krzywinski 2016b). Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points. We decided for a transformation of the response variables or the use of link functions by comparing the fit of the global models to the data. The investigated models were: linear; linear with the response variable transformed to natural logarithm; generalized linear using gamma family and

log link function; and generalized linear using gamma family and its canonical link function, the inverse function.

Besides the food supplementation effect (Suppl), characterized by difference between the control grids (FAL and JB1) and the supplemented grids (JB2 and JB4), we included in the models the following main variables: variation among the sampled months (M), age classes (Age: adult and old individuals), generation, grid (variation among the four grids), reproductive season (Rep; only in the case of males), and interactions between variables when possible. To avoid running a large set of candidate models, we did model selection in three steps. First, we used the global model to compare the inclusion of the random intercept effect identification of the animals (1 | ID) because we had repeated measures on the same individuals over the months. Second, we compared among models with only one fixed effect and with no effect to investigate which one would be the most important for the variation in the response variable. In addition, in this step we selected which variables would be present in the next model selection depending on their ranks: M, Age or Rep different forms of time variation, and Suppl or Grid, different forms of spatial variation. Third, we built a set of models in which all included the fixed effect selected previously (and the random effect if it was the case).

Model selection for the body mass of male *Gracilinanus agilis* varied from the ones for the variation in reproductive effort of females and males. Body mass was modeled as a function of head-body length (HB), scrotal width (SW), difference between two groups of males divided by scrotal testis size, interactions among variables (two- and three-way interactions), and the random effect identity.

We compared the candidate models based on the principle of parsimony through the Akaike's information criterion (AIC; Burnham & Anderson 2002). This index is a relative measure of how much information a model loses in relation to reality; the lower its value, the less information is lost and therefore the better is the model. We ranked the models according to their AICc values, which are a modified version the AIC with a correction for small samples sizes. We obtained the ΔAICc values as the difference between the AICc of each model and the lowest AICc, and also the Akaike weights (w), which reflect the evidence of how well each model fits the data, proportional to the other candidate models (Burnham & Anderson, 2002). We used model averaged estimates to calculate predicted values of the response variables. Analyses were run using lme4 (Bates et al. 2015) and MuMIn (Barton 2018) packages in R, version 3.4.2 (R Core Team 2017).

Population parameters estimation

We calculated monthly population sizes using MNA (Minimum Number Alive, Krebs 1966) as an abundance index and compared the fluctuations among the studied areas before and during the food supplementation experiment. MNA is a counting method still widely used in small mammal studies, since they generally have small sample sizes (< 50 individuals) and therefore are more difficult to be subjected to probabilistic models (Pacheco et al. 2013).

We estimated monthly survival (φ), recapture (p) and recruitment rates (*f*), as well as population size at each capture session (N_i), using probabilistic models implemented in program MARK, version 9.0 (White & Burnham 1999). The population parameters are estimated through the maximum likelihood approach. The likelihood of a model to the data is the result of the product of all probabilities of the observed capture histories and has the multinomial distribution (Cooch & White 2018). We used the Cormark-Jolly-Seber model (CJS; Cormack 1964, Jolly 1965, Seber 1965) as the starting point of our model selection, modelling the parameters φ and p to the capture history data of the entire study period, from July 2009 to December 2016. The parameter φ is named apparent survival because permanent emigration out of the study area cannot be distinguished from mortality in CMR statistical modelling (Lebreton et al. 1992). We used the model including the interaction between sex and the full variation over time as the global model, and the parametric bootstrap procedure with 1000 simulations to assess the goodness-of-fit of the global model. We considered the model fitted the data when the observed deviance was inside the core of distribution of the simulated deviances (Johnson & Omland 2004). Otherwise, we corrected the lack of fit using the variance inflation factor (ĉ). This procedure is not recommended for $\hat{c} > 3$, which would indicate the model structure was completely inadequate (Lebreton et al. 1992).

For each of the four areas, we built a candidate model set considering φ and p to be a function of sex, time, climatic season (dry and wet), food supplementation experiment, interactions between sex and time, between sex and climatic season, and between sex and experiment, and no effect. We then used the best models from this set to build a candidate set separated for cohorts 2015 and 2016. This approach prevented the overlap between generations and therefore allowed to properly examine the effect of reproduction on the demographic parameters. We restricted our analysis to the cohorts 2015 and 2016 to assess whether the parameters differed between the food supplemented areas (JB2 and JB4) and the control areas (FAL and JB1) because these were the only cohorts that could have been influenced by the experiment since the beginning of their life cycle.

Then, we used the Jolly-Seber (JS) model with Pradel-recruitment formulation (Pradel 1996). Unlike the CJS model, which refers only to the marked individuals, the JS model assumes that marked and unmarked individuals have the same survival and capture probabilities, and this assumption allows the estimation of more population parameters than just φ and p, such as abundance and recruitment (Schwarz & Arnason 2018).

The Pradel-recruitment formulation is a variation of the Pradel's temporal symmetry models, which are based on the concept of the seniority parameter (γ) (Pradel 1996). If the standard analysis of the capture history allows estimating the probability of an individual leave the population (1 – φ), the analysis of the time-reversed capture history allows estimating the transitions going backwards in time and thus the probability of an individual entering the population. The seniority parameter represents the probability that an individual captured at time i was present in the population at time i – 1. Since all individuals alive at i + 1 are either survivors or new recruits from i, the relationship between the seniority (γ) and the recruitment (*f*) parameter is:

$$\gamma_{i+1} = \frac{\varphi_i}{f_i + \varphi_i} \quad \therefore \quad f_i = \frac{\varphi_i(1 - \gamma_{i+1})}{\gamma_{i+1}},$$

where f_i is the number of recruits *per capita* present in the population between occasions i and i +1 (Williams et al. 2002). The likelihood expression was later modified to address for recruitment as well as growth rate directly, since they are both related to γ.

We used only the variation in φ and p found in the best models from the cohort-CJS model selection to restrict our candidate model set of the Pradel models. We modeled *f* with full-time variation, with the climatic season effect or reproductive season effect, and with additive and multiplicative effects of sex.

Finally, we used the Jolly-Seber (JS) model with POPAN formulation (Schwarz & Arnason 1996) to obtain the derived estimates of population size (N_i). This formulation allows an open population model to estimate abundance because it is based on the premise of a super-population (N), which is theoretically a source of individuals for the studied population (Schwarz & Arnason 2018). In the POPAN parametrization, besides φ, p and N, we modeled the entrance parameter *b* (also referred to as pent), which represents the probability that an individual from the super-population enter in a specific time interval, and it is restricted to sum to 1 (Schwarz & Arnason 2018). The parameter *b* is not the same as *f* from the Pradel model, but there is a relationship between them:

$$f_i = N * \frac{b_i}{N_i}.$$

For this reason, we used the variation of f in the best models from the Pradel model selection to constrain b in the POPAN models. The super-population parameter may be one single value or different between sexes.

We used AICc to compare the candidate models and select the best models for inference (Burnham & Anderson, 2002). We model-averaged the best models to obtain estimates and confidence intervals of the population parameters to account for model selection uncertainty.

Results

Age and reproductive status determination

We used 1490 captures from the beginning of the experiment in 2014 to 2016 to evaluate the age by dental formula. We detected a pattern of dental eruption in *G. agilis* different from that proposed by Tyndale-Biscoe and MacKenzie (1976) for *Didelphis* and that proposed by Tribe (1990) for *Marmosops incanus* (Table 1). We found an intermediate eruption pattern between the two models, in which the subadult class, considered sexually mature, is represented by two possible dental formulas. There is a preponderance of class 5 in the population from March to October, and the presence of the senile class is small throughout the year except in February (Figure 1). Classes 2 and 3 begin to appear in November and December, and gradually decrease from January to April. Class 1 was never captured during the study period.

All age classes had a seasonal pattern except for the senile class, which showed a distribution not significantly different from a uniform distribution (Table 2, Figure 2). There was a difference in the average month between areas only for classes 4b and 6-7. The average month of class 4b in the control areas was December, whereas in the food-supplemented areas was January due to the presence of subadults still in March. Meanwhile, the senile class average changed from December in the control areas to March in the food-supplemented areas.

Table 1. Classification of age classes proposed for neotropical marsupials based on the dental eruption pattern of the premolars (P) and molars (M), and the intermediate pattern found in *Gracilinanus agilis*. In bold, two dental formulas could be classified as subadult class. d = the deciduous premolar tooth. N = number of records obtained from 2014 to 2016.

Class		*Didelphis*	*Marmosops incanus*	*Gracilinanus agilis*	N
1	juvenile	dP^3M^1	dP^3M^1	dP^3M^1	0
2	juvenile	dP^3M^2	dP^3M^2	dP^3M^2	78
3	juvenile	dP^3M^3	dP^3M^3	dP^3M^3	158
4	subadult	P^3M^3	dP^3M^4	**4a: P^3M^3**	29
				4b: dP^3M^4	29
5	adult	P^3M^4	P^3M^4	P^3M^4	1115
6	senile	M^{1-2} cusp wear	M^{1-2} cusp wear	M^{1-4} cusp wear	81
7	senile	M^{3-4} cusp wear	M^{3-4} cusp wear		

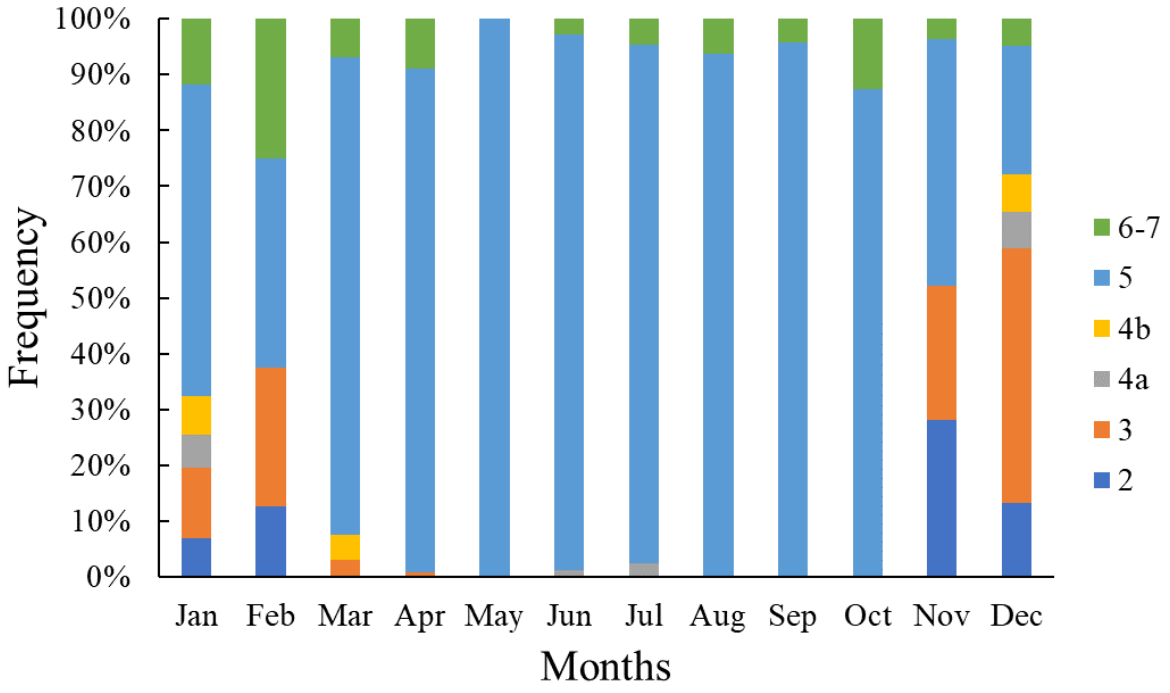
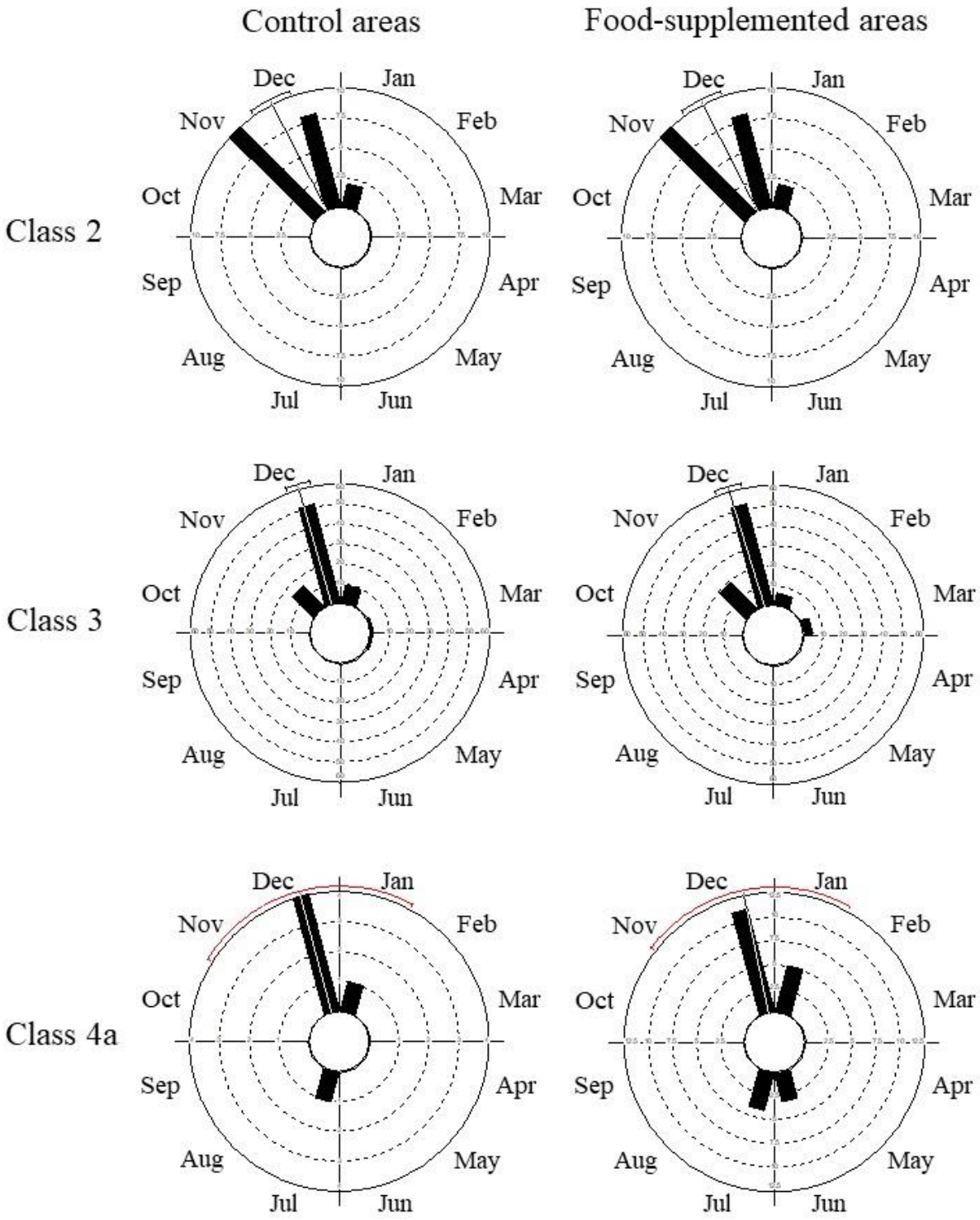


Figure 1. Relative frequencies of the age classes of *Gracilinanus agilis* in four patches of "cerradão" from 2014 to 2016. The age classes 2 and 3 are the young individuals, the age classes 4a and 4b are the potentially matured subadults, the age class 5 represents the adults, and the age classes 6 and 7 (together) are the seniles.

Table 2. Results of the Rayleigh uniformity test for each age group of *Gracilinanus agilis* for two control areas and two food-supplemented areas. Classes 2 and 3 represent the juveniles, classes 4a and 4b are potentially mature subadults, class 5 are adults and class 6-7 are the seniles.

Age class	Control areas	Food-supplemented areas
2	$Z = 18.12$, $p < 0.001$	$Z = 52.42$, $p < 0.001$
3	$Z = 67.54$, $p < 0.001$	$Z = 68.60$, $p < 0.001$
4a	$Z = 2.73$, $p = 0.059$	$Z = 3.51$, $p = 0.028$
4b	$Z = 10.81$, $p < 0.001$	$Z = 11.20$, $p < 0.001$
5	$Z = 49.90$, $p < 0.001$	$Z = 50.71$, $p < 0.001$
6-7	$Z = 1.67$, $p = 0.190$	$Z = 2.23$, $p = 0.108$


Control areas
Food-supplemented areas
Class 2
Class 3
Class 4a
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

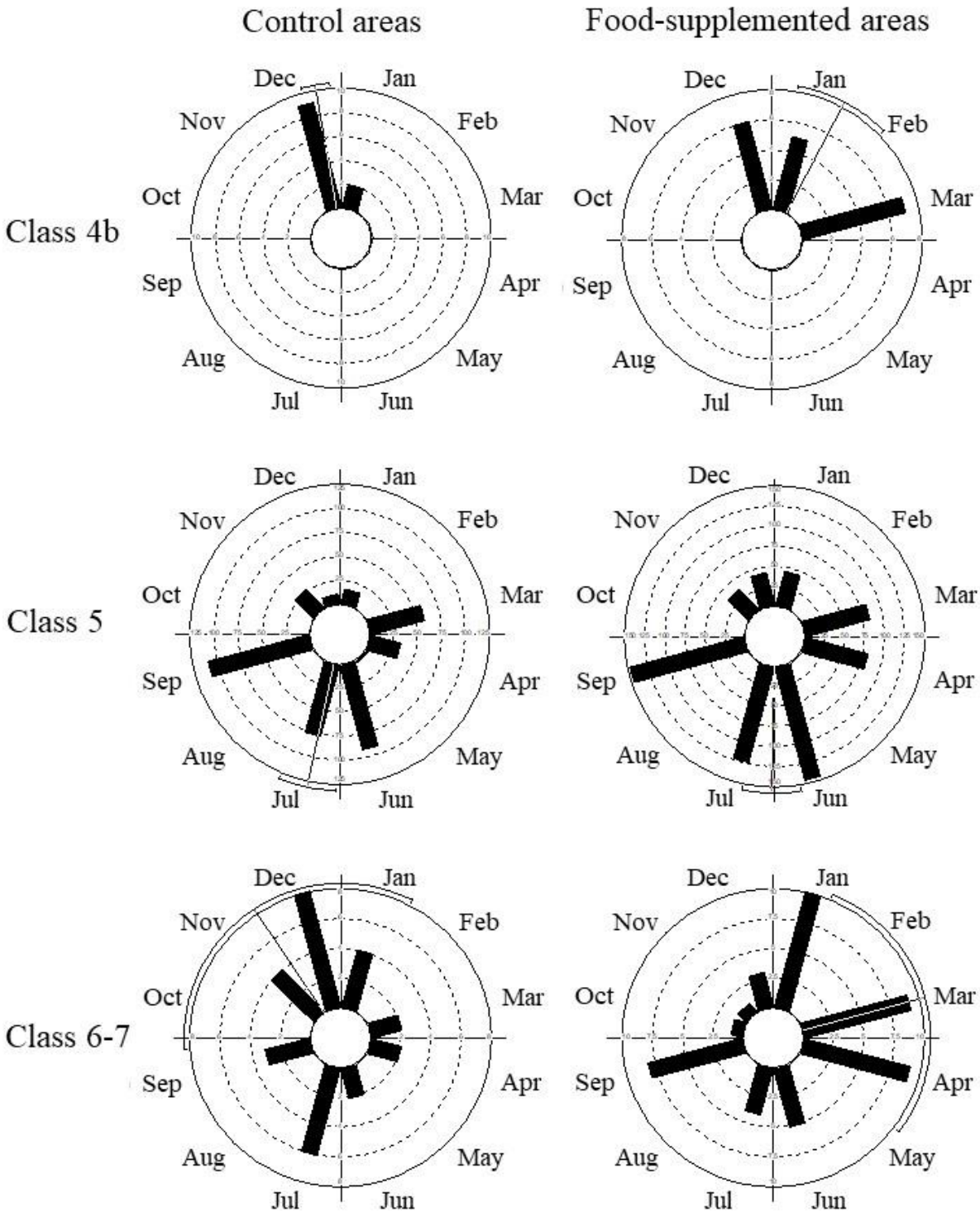


Figure 2. Results for seasonality in age classes of *Gracilinanus agilis* for two control areas and two food-supplemented areas. The bars represent the number of individuals from each age class. Classes 2 and 3 represent the juveniles, classes 4a and 4b are potentially mature subadults, class 5 are adults and class 6-7 are the seniles.

A clear seasonal pattern in reproduction was found in all areas ($Z = 21.14$, $p < 0.01$, Figure 3). Reproductive females were captured between August and March, with peaks in September and December. There was no difference in the reproductive season between control and food-supplemented areas before or during the supplementation experiment.

We had a total of 180 records of litter size (mostly indirect) in the four areas. We obtained 6 records of litter during the period between 2009 and 2016, in cases which the females gave birth inside the trap. The number of infants varied from 7 to 13. One female gave birth twice, in September of 2014 and 2015, and had 13 and 7 infants, respectively. The number of teats (swollen or lactating) varied from 2 to 13.

We considered the global model fit to the data (Appendix 1). The model including the random variable identity of the females had a relatively close performance to the model without the random variable (Table 3), but its estimated effect was zero. The model representing variation along the months (M) was the first-ranked model in the first selection of fixed effects. The model representing the difference between control and supplemented areas and the one of difference among grids had almost identical performances. We opted for the variation among grids because the model indicated only one supplemented area (JB4) had a value higher than the controls.

We had only four models in the final set, as we could not build models with interactions between M and other variables. The best model represented variation over the months and among generations, and the second-best model also included differences among grids. The litter size was the highest in the first September, decreased in November/December and February/March, and then had another peak in the second September, though not as high as the first (Figure 4). Differences among generations and among grids were not shown graphically because model-averaged coefficients were small and had confidence intervals overlapping zero (Appendix 2).

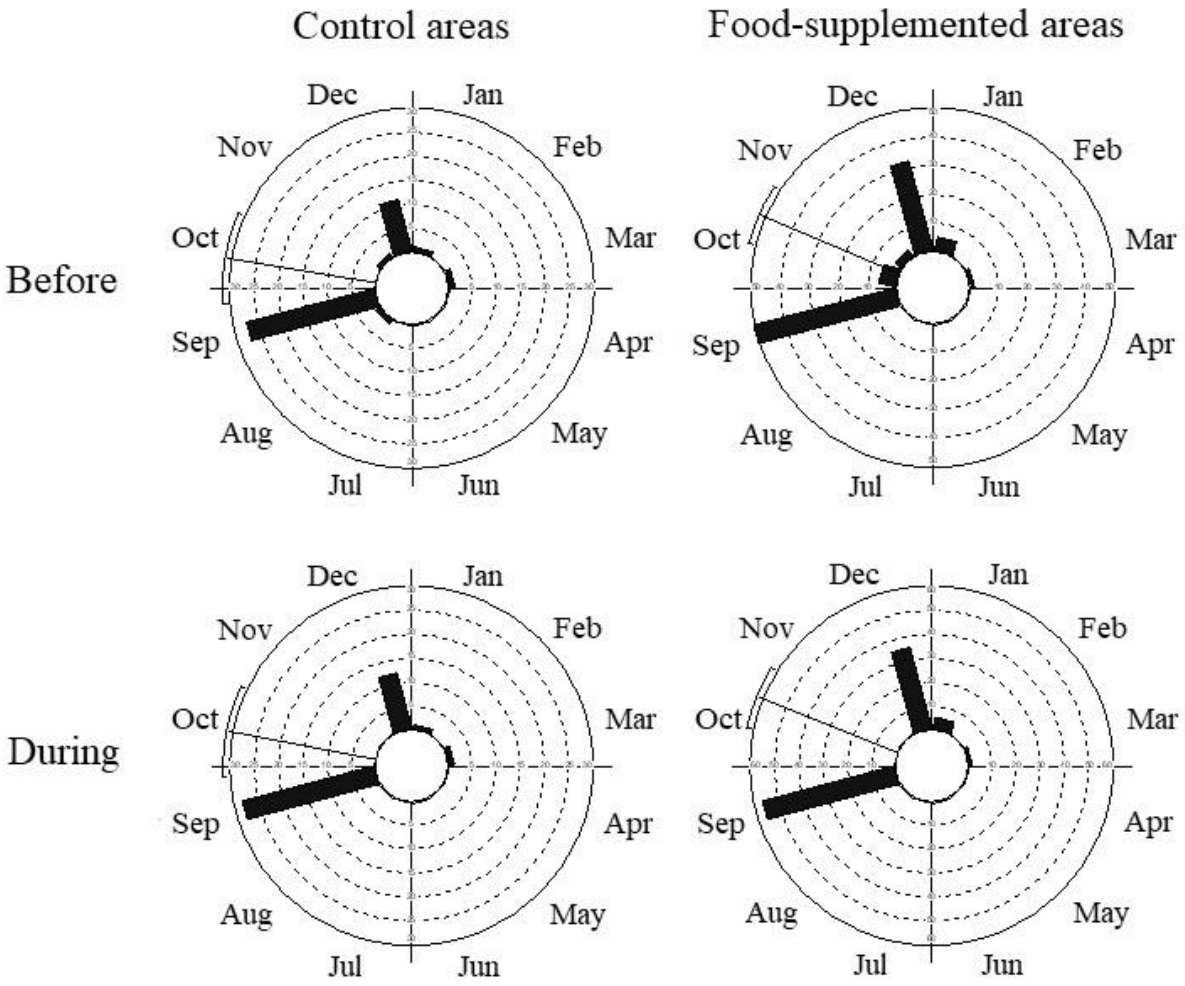


Figure 3. Results for seasonality in reproduction of *Gracilinanus agilis* for two control areas and two food-supplemented areas. The bars represent the number of reproductive females in each month.

Table 3. Model selection for the litter size of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), age class (Age), generation (Gen), grid, food supplementation experiment (Suppl), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models.

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
M + Gen + Grid	9	828.81	0.00	0.76	-404.87
M + Gen + Grid + (1 | ID)	10	831.06	2.25	0.25	-404.87
Fixed effects 1					
M[a]	4	832.21	0.00	1.00	-411.99
Age[a]	2	846.19	13.99	0.00	-421.06
Gen	3	848.47	16.26	0.00	-421.17
.	1	854.91	22.70	0.00	-426.44
Suppl[b]	2	856.92	24.71	0.00	-426.43
Grid[b]	4	857.05	24.85	0.00	-424.41
Fixed effects 2					
M + Gen	6	825.64	0.00	0.80	-406.57
M + Gen + Grid	9	828.81	3.18	0.16	-404.87
M	4	832.21	6.57	0.03	-411.99
M + Grid	7	835.28	9.64	0.01	-410.32

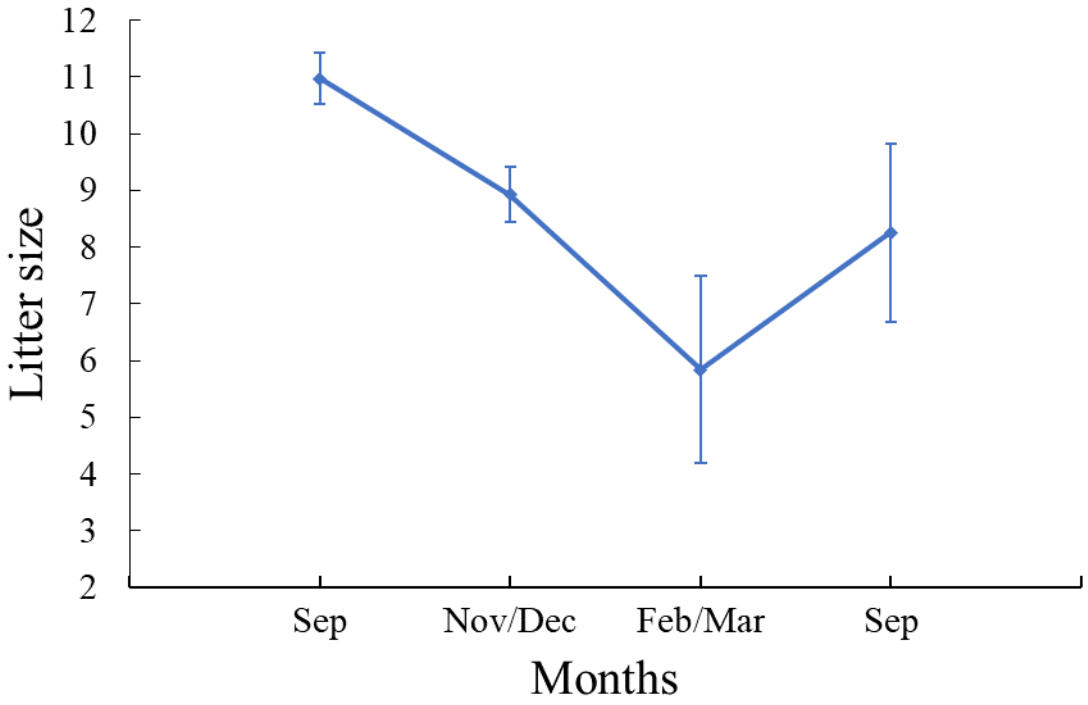
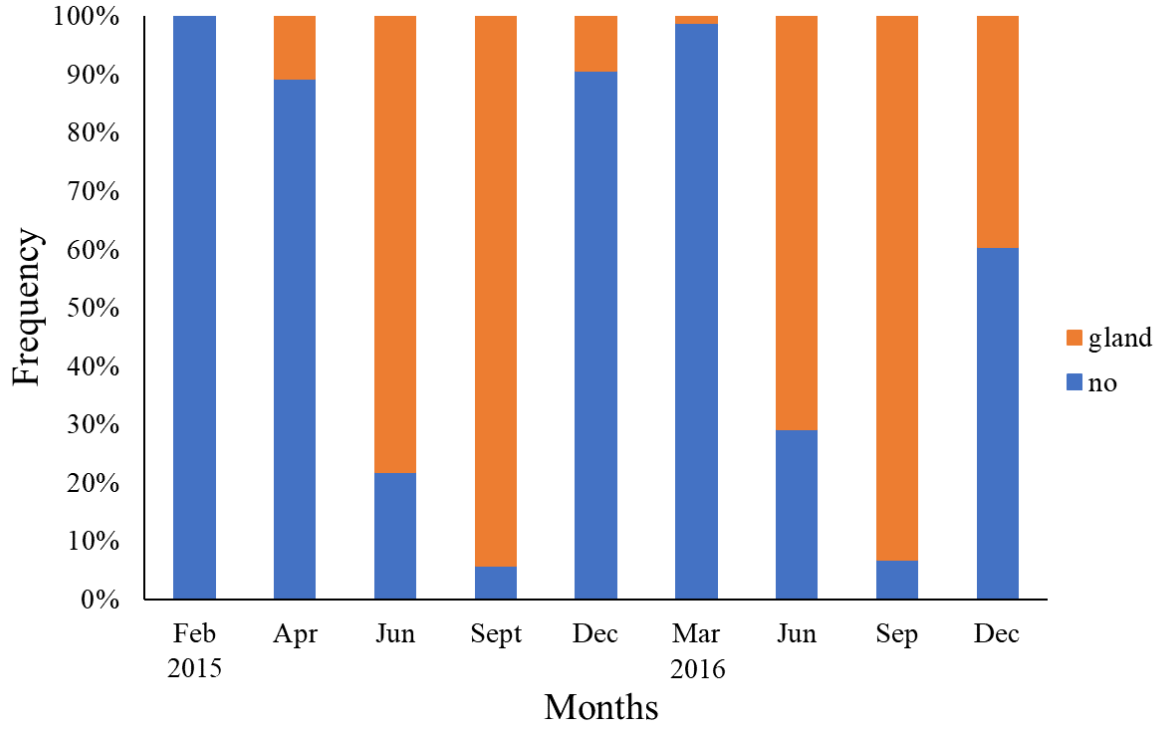


Figure 4. Estimates and 95 % confidence intervals from the model averaging of the litter size of *Gracilinanus agilis* over the months adapted to the life cycle of the females.

The male indirect reproductive trait is the presence of the throat gland, and its frequency in the populations were higher in June and September (Figure 5a). It does not coincide neither with the appearance of subadults (classes 4a and 4b) nor with the increase in adult (class 5) frequency in February/March (Figure 5b). However, it coincides with the sudden increase of scrotal width from April to June (Figure 6a). In contrast, the presence of the throat gland does not coincide with changes in male body size. The head-body length of males increased gradually from February to September and then stabilized in December for both generations 2015 and 2016 (Figure 6b). The body mass growth showed a similar pattern, but not so gradual, as the head-body length (Figure 6c). Body mass of males seemed to grow more rapidly from June to September, after the increase of the scrotal width.

a)



b)

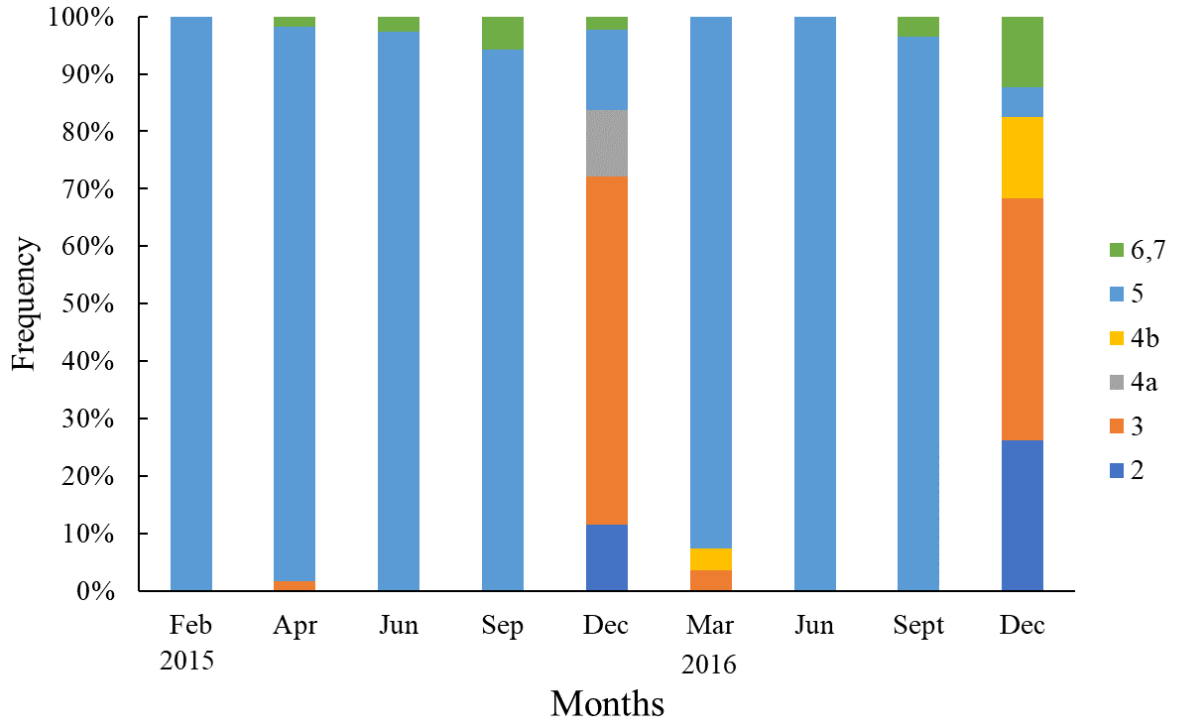
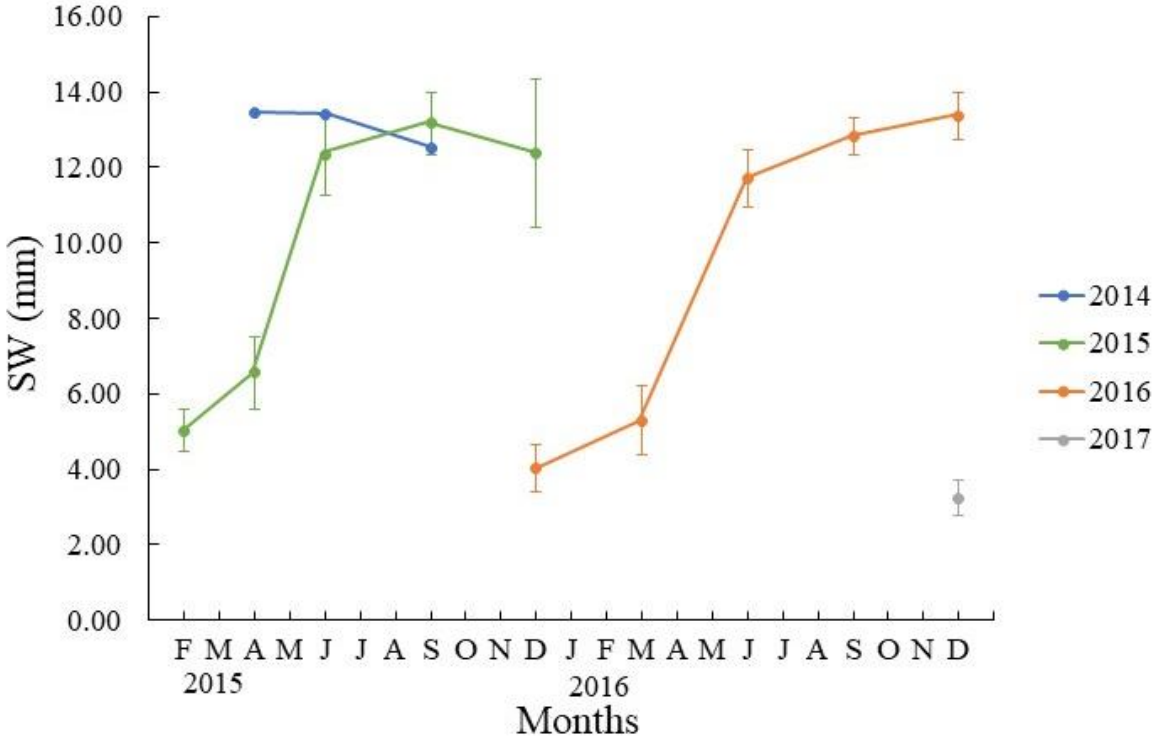
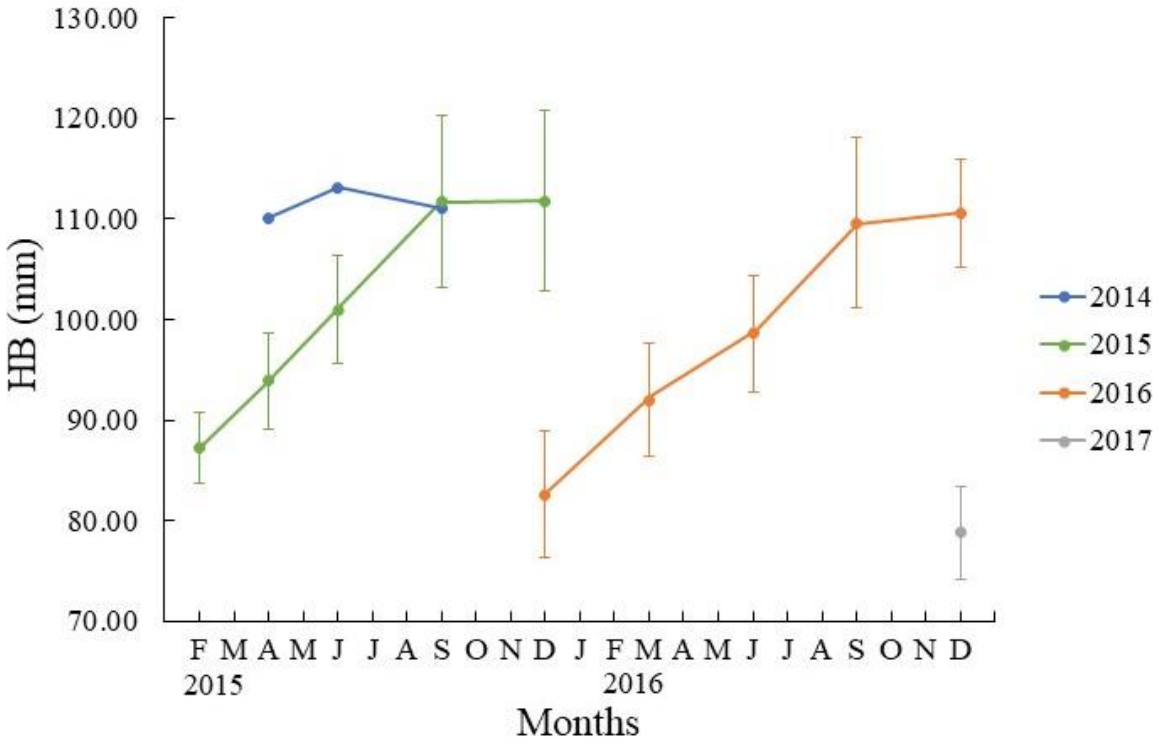


Figure 5. Relative frequencies of a) presence/absence of the throat gland and b) age classes in males of *Gracilinanus agilis* in four patches of "cerradão" during the years of 2015 and 2016.

a)


16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
SW (mm)
F M A M J J A S O N D J F M A M J J A S O N D
2015
2016
Months
2014
2015
2016
2017

b)


130.00
120.00
110.00
100.00
90.00
80.00
70.00
HB (mm)
F M A M J J A S O N D J F M A M J J A S O N D
2015
2016
Months
2014
2015
2016
2017

c)

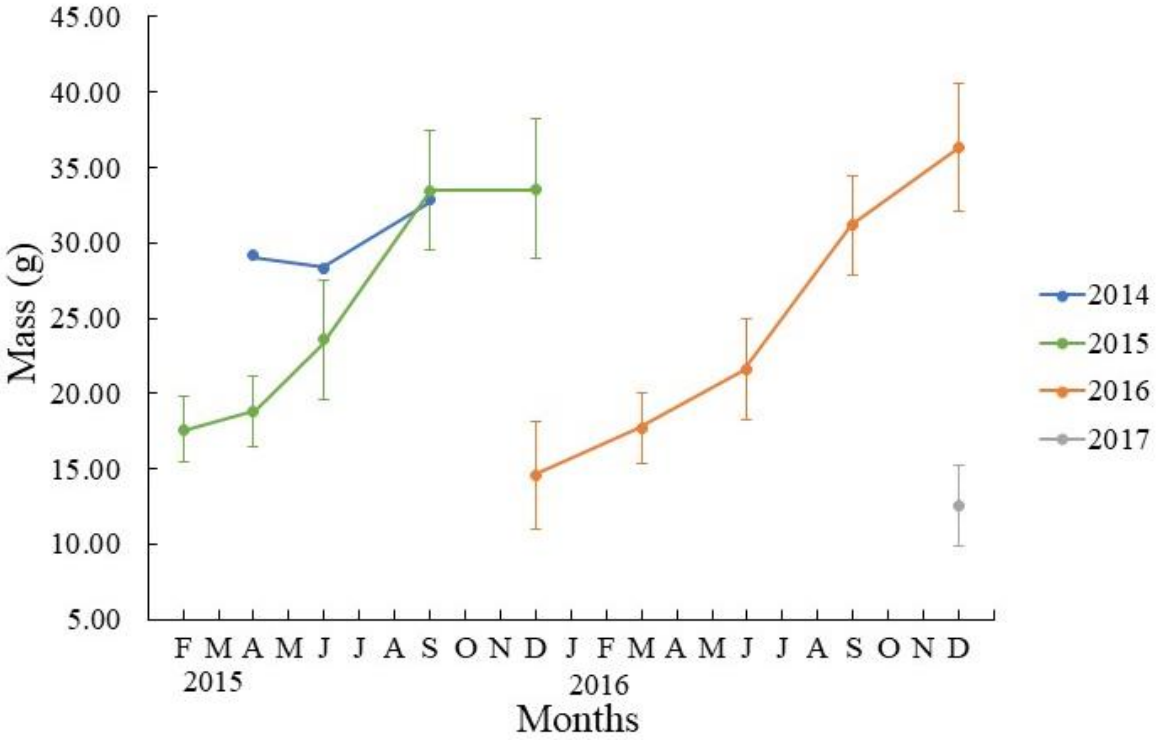


Figure 6. Temporal variation in means (± SE) of a) scrotal width (SW), b) head-body length (HB) and c) body mass and of males of *Gracilinanus agilis* from generations 2014, 2015, 2016 and 2017 present during the years of 2015 and 2016.

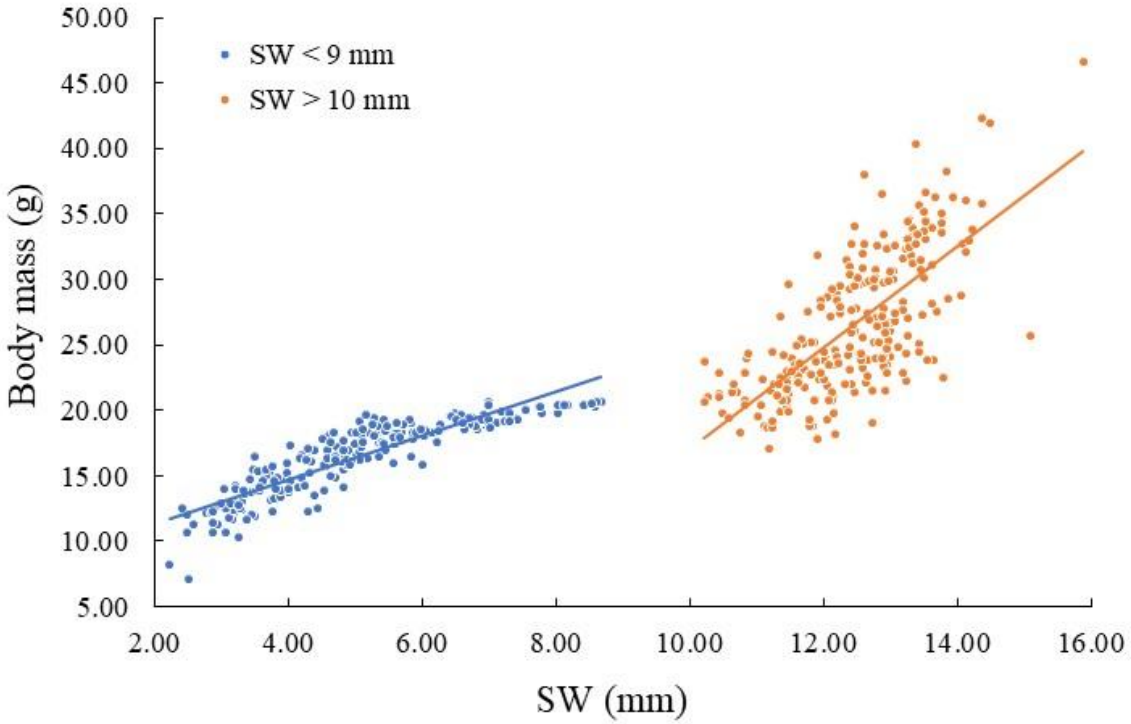
We used a total of 491 records of scrotal width from February 2015 to December 2016 to model the relationship between male body mass and scrotal width. The global model we used had the mass as a function of head-body length (HB), scrotal width (SW), and groups of males with SW < 9 mm and of males with SW > 10 mm (Group), as well as interactions among those variables. We divided SW data into two groups since its distribution was bimodal. Moreover, we discarded two records of SW between 9 mm and 10 mm to avoid placing them in the wrong group. The fit of the global model to the data was not improved by log-transforming the response variable or using a non-Gaussian family (Appendix 3). We removed two data points identified as possible outliers after we confirmed they were probable errors in measure looking at the history of the individuals.

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 4). The global model had clearly the best performance in model selection, with Akaike weight of 1. The relationships between the morphometric measures changed between the groups of SW (Figure 7, Appendix 4). The rates of increase of body mass in relation to SW and HB are higher for the group of males with SW > 10 mm than for the group with SW < 9 mm.

Table 4. Model selection for the body mass of *Gracilinanus agilis* as a function of head-body length (HB), scrotal width (SW), and groups of males with SW < 9 mm and of males with SW > 10 mm, and the random effect the identity variable (ID). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The signs + and * indicate additive and multiplicative effects between variables, respectively.

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
HB*SW*Group	9	2443.80	0.00	1.00	-1212.71
HB*SW*Group + (1 | ID)	10	2474.22	30.42	0.00	-1226.88
Fixed effects					
HB*SW*Group	9	2443.80	0.00	1.00	-1212.71
HB*SW + Group	6	2468.78	24.98	0.00	-1228.30
HB*Group + SW	8	2469.90	26.10	0.00	-1228.86
HB*Group + HB*SW + Group*SW	6	2470.74	26.94	0.00	-1227.22
HB*SW	5	2500.36	56.56	0.00	-1245.12
HB*Group	6	2511.02	67.23	0.00	-1250.45
HB + Group*SW	5	2528.08	84.28	0.00	-1257.95
HB + Group	4	2589.65	145.85	0.00	-1290.78
HB + SW	4	2593.22	149.42	0.00	-1292.57
HB	3	2628.04	184.24	0.00	-1311.00

a)



b)

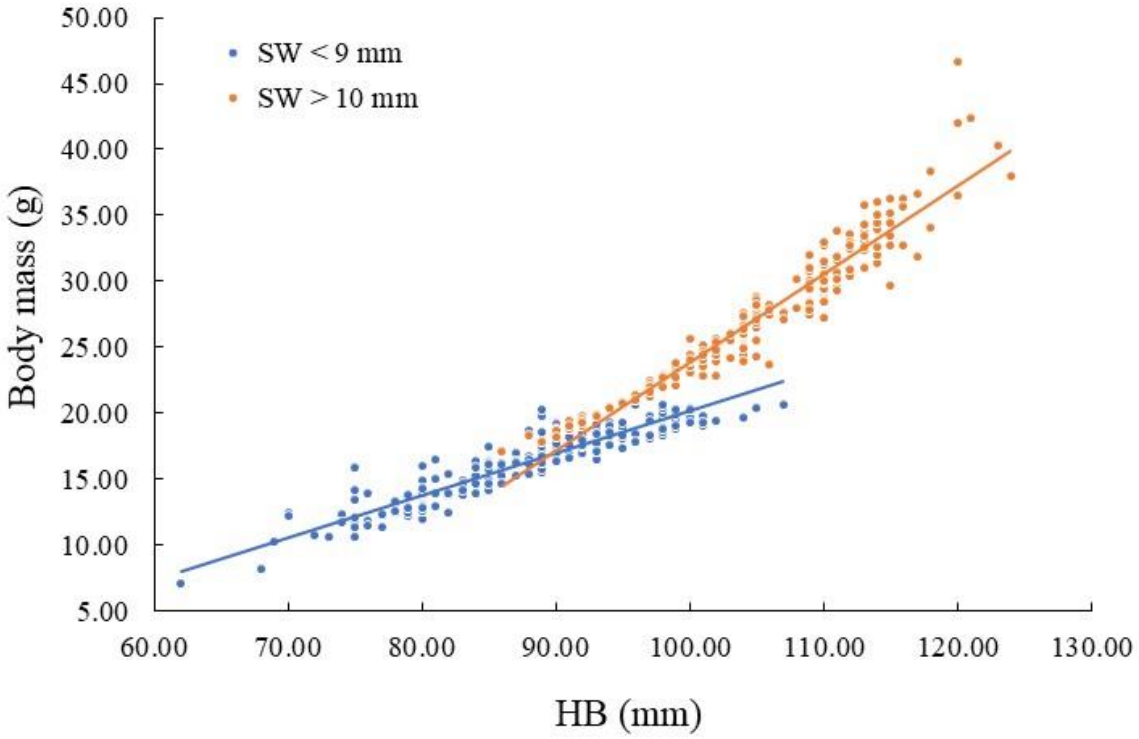


Figure 7. Predicted estimates of body mass of males of *Gracilinanus agilis* from the best model as a function of the scrotal width (a) and body size (b), between the groups SE < 9 mm (blue) and SE > 10 mm (orange).

We used a total of 253 records of scrotal width from the second group (SW > 10 mm) for testing the effect of food supplementation because the difference between the groups could mask other effects and we were interested in the response from the mature males. The fit of the global model was not improved by log-transforming the response variable or using a non-Gaussian family (Appendix 5). We did not remove any data point identified as possible outliers since we did not find any suggestion they were errors instead of biological variation.

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 5). The models representing the reproductive season (Rep) and variation along the months (M) were the best models in the rank and had close values of AICc. We chose to continue model selection with the variable M because the model indicated a difference between September and December, and these months would be together in the reproductive season. We chose the variable food supplementation (Suppl) over the variable grid based on the model ranks.

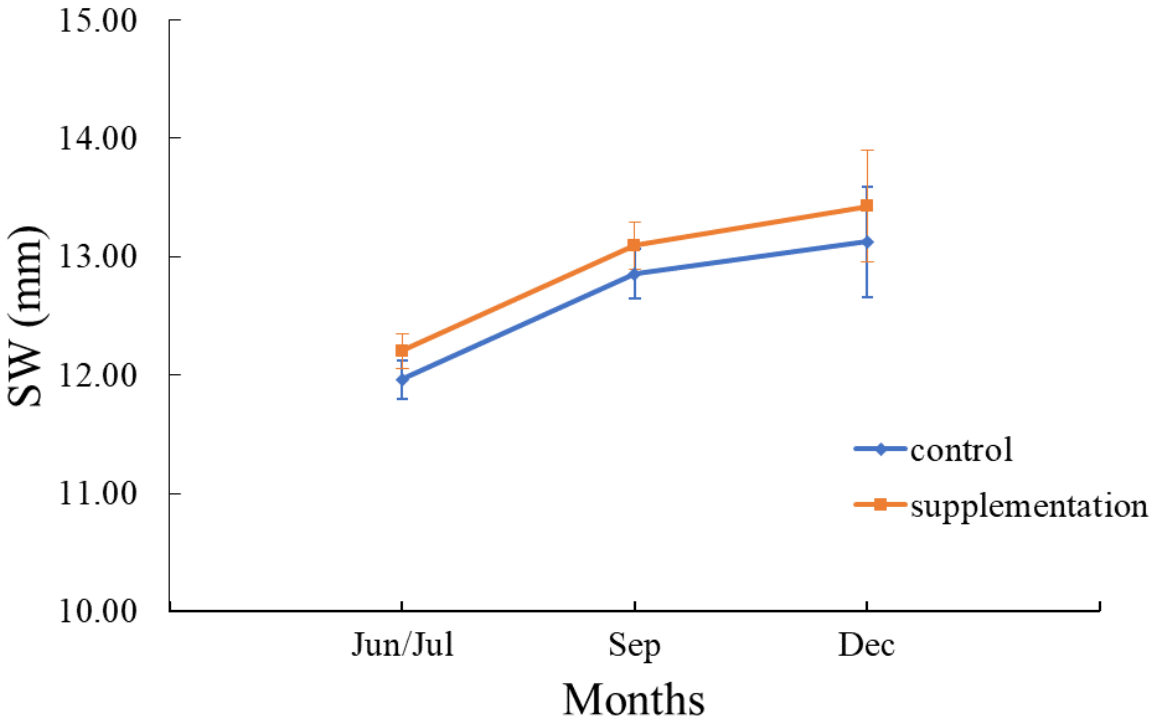
We selected 6 out of 13 models of the third set to describe the variation in scrotal width, and they had together a cumulative weight of 0.92. The variables month and generation were represented in all chosen models, and the effect of food supplementation was present in all but one. The scrotal width increased from June/July to December, and mature males from supplemented areas had larger scrotal testes than the ones from the control areas at every capture session (Figure 8a, Appendix 6). Males from generation 2015 had larger scrotal testes than males from generation 2016 in June/July, but this difference decreased in September and in December the groups had no difference anymore (Figure 8b).

Table 5. Model selection for the scrotal width of mature males of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), generation (Gen), age class (Age), reproductive season (Rep), grid, food supplementation experiment (Suppl), the interactions between between month and generation (M*Gen), month and grid (M*Grid), generation and grid (Gen*Grid), month and experiment (M*Suppl), generation and experiment (Gen*Suppl), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models.

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
M + Gen + Grid + M*Gen + M*Grid + Gen*Grid	19	610.81	0.00	1.00	-284.77
M + Gen + Grid + M*Gen + M*Grid + Gen*Grid + (1 | ID)	20	633.91	23.11	0.00	-295.15
Fixed effects 1					
Rep[a]	3	633.24	0.00	0.61	-313.57
M[a]	4	634.15	0.92	0.39	-313.00
Gen	3	675.09	41.86	0.00	-334.50
Suppl[b]	3	703.53	70.30	0.00	-348.72
Age[a]	3	705.92	72.69	0.00	-349.91
Grid[b]	5	707.41	74.18	0.00	-348.58
.	2	708.18	74.94	0.00	-352.07
Fixed effects 2					
M + Gen + Suppl + M*Gen	8	595.04	0.00	0.46	-289.23
M + Gen + Suppl + M*Gen + Gen*Suppl	9	597.17	2.12	0.16	-289.21
M + Gen + Suppl	6	597.88	2.84	0.11	-292.77
M + Gen + Suppl + M*Gen + M*Suppl	10	597.92	2.88	0.11	-288.51

M + Gen + M*Gen	7	599.81	4.77	0.04	-292.68
M + Gen + Suppl + Gen*Suppl	7	599.99	4.95	0.04	-292.77
M + Gen + Suppl + M*Gen + M*Suppl + Gen*Suppl	11	600.10	5.06	0.04	-288.50
M + Gen + Suppl + M*Suppl	8	600.82	5.77	0.03	-292.11
M + Gen	5	602.95	7.91	0.01	-296.35
M + Gen + Suppl + M*Suppl + Gen*Suppl	9	602.97	7.92	0.01	-292.11
M + Suppl	5	626.86	31.82	0.00	-308.31
M + Suppl + M*Suppl	7	630.17	35.12	0.00	-307.86
M	4	634.15	39.11	0.00	-313.00

a)



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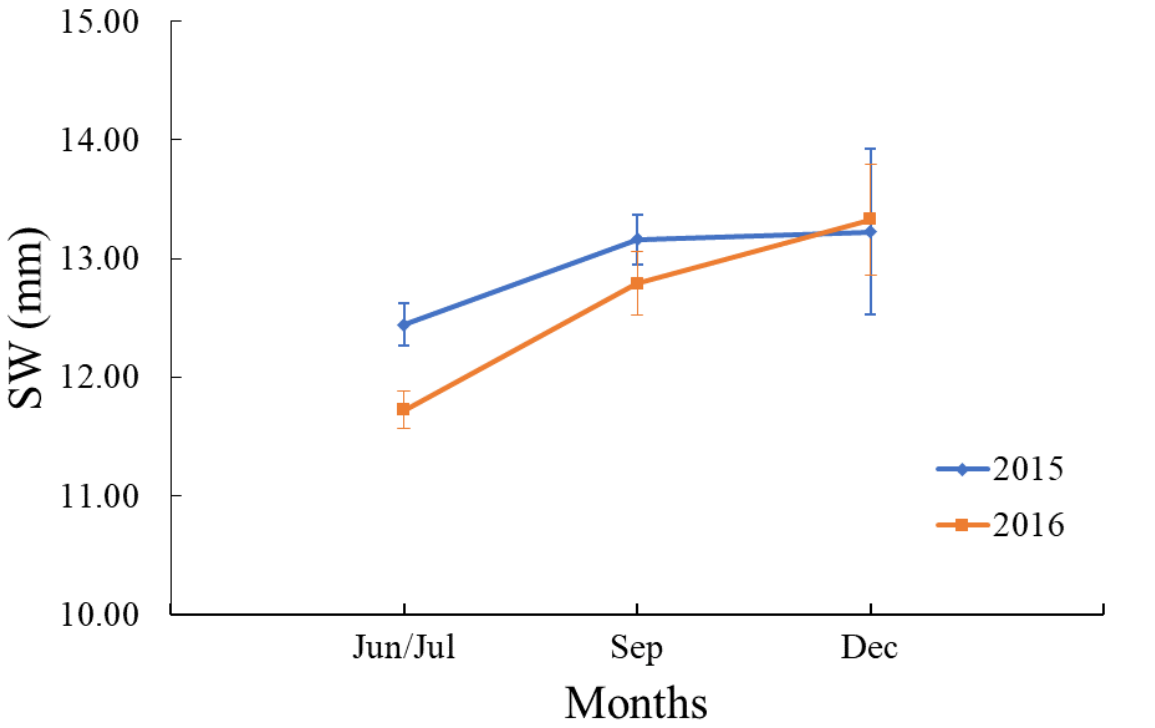


Figure 8. Estimates and 95 % confidence intervals from the model averaging of the scrotal width (SW) of mature males of *Gracilinanus agilis* over the months adapted to the life cycle a) for control and food-supplemented areas and b) for generations 2015 and 2016.

Population parameters estimation

The population sizes calculated by MNA (Minimum number alive) showed seasonal fluctuations with peaks between April and June and falls between September and October, at the end of the dry season (Figure 9). Moreover, there is evidence of a population increase in the food-supplemented areas. Before the beginning of the experiment, the mean population sizes were 22.2 ± 7.7 (FAL), 24.4 ± 8.7 (JB1), 24.1 ± 12.9 (JB2) and 13.9 ± 8.4 (JB4). After that, the means were 16.9 ± 7.9 (FAL) and 32.0 ± 8.9 (JB1) in the control areas and 40.5 ± 12.0 (JB2) and 40.8 ± 10.5 (JB4) in the food supplemented areas.

Bootstrap simulations for the models of survival and recapture probabilities of the entire study period resulted in most of the deviances greater than the observed deviances, and in variance inflation factors (ĉ) less than 1 (FAL: 0.49, JB1: 0.37, JB2: 0.66, JB4: 0.99). Therefore, we did not adjust the models (ĉ = 1).

Sex difference and time variation were present in survival probabilities of all selected models from all areas (Table 6). Neither the climatic seasons nor the food supplementation experiment could explain the variation in survival better than time. Sex difference was found in recapture probabilities of most selected models. Both control areas FAL and JB1 had the climatic season effect on the recapture probabilities of their best models. The food supplemented areas had different results: JB2 had full-time variation effect on recapture probabilities, whereas JB4 had time constant, food supplementation and climatic season effects on recapture probabilities of the best-ranked models.

The model-averaged survival probabilities were variable between the areas but had in common peaks in the dry seasons, as well as higher rates for females than for males (Figure 10). JB4 had poor survival estimates in the beginning of the sampling because of the small number of animals caught and long intervals between the first sessions. The recapture probabilities were high during the entire study (> 0.70) and higher for males than for females, except for JB2 (Figure 11). JB2 had an extensive fluctuation on recapture probabilities, especially during 2012 and 2013, when we had only 2 capture sessions each year, and almost identical estimates for females and males.

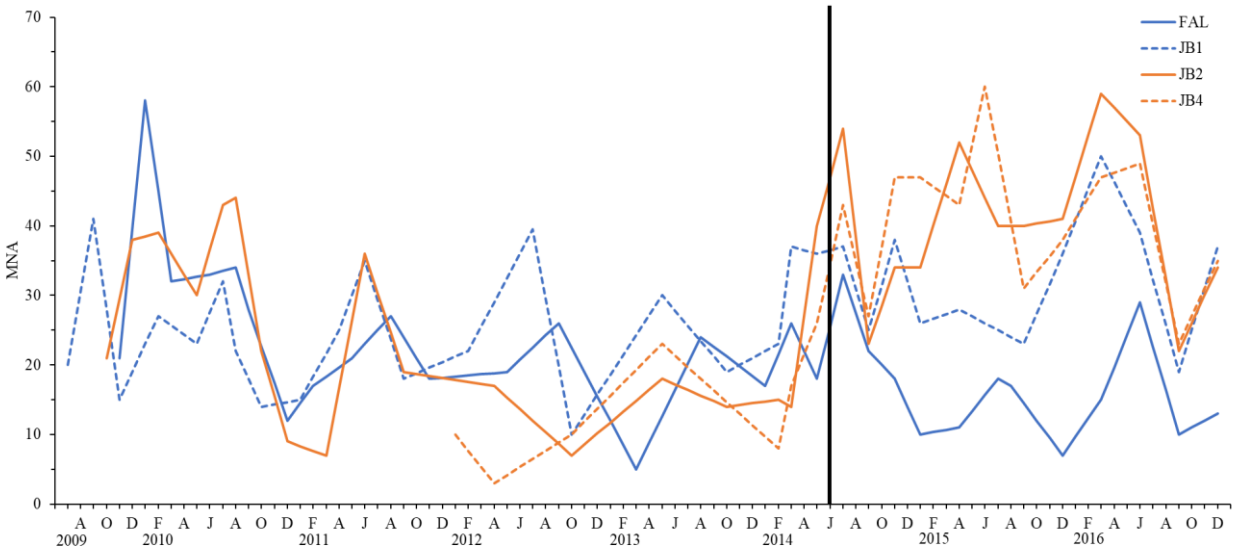


Figure 9. Population sizes (MNA) of *Gracilinanus agilis* in four in four patches of "cerradão", two with food supplementation experiment (in orange – JB2 and JB4) and two controls (in blue – FAL and JB1) from July 2009 to December 2016. The vertical bar indicates when the food supplementation started.

Table 6. Model selection for the capture histories of *Gracilinanus agilis* for each of the four patches of "cerradão", two with food supplementation experiment and two controls. Models may have apparent survival (φ) and recapture (p) probabilities varying as a function of sex, time (t), climatic season (seas: dry and wet), food supplementation experiment (suppl), interaction between factors (*) or no effect (.). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, L is the model likelihood and Dev is the deviance. Only the first models whose weights sum at least 0.90 are represented here. The complete list is in the supplemented information (Appendix 7).

Models	**K**	**AICc**	**ΔAICc**	**w**	**-2logL**	**Dev**
FAL (control)						
φ(sex+t) p(sex*seas)	34	854.81	0.00	0.58	782.41	260.77
φ(sex+t) p(sex)	32	857.23	2.42	0.17	789.34	267.70
φ(sex+t) p(.)	31	858.02	3.21	0.12	792.37	270.73
φ(sex+t) p(sex+seas)	33	858.97	4.16	0.07	788.83	267.19
JB1 (control)						
φ(sex+t) p(sex)	33	1132.72	0.00	0.53	1063.66	313.70
φ(sex+t) p(sex+seas)	34	1133.89	1.16	0.29	1062.64	312.68
φ(sex+t) p(sex*seas)	35	1136.05	3.32	0.10	1062.60	312.64
JB2 (experiment)						
φ(sex+t) p(t)	58	1310.89	0.00	0.73	1185.84	350.50
φ(sex+t) p(sex+t)	59	1312.85	1.96	0.27	1185.47	350.14
JB4 (experiment)						
φ(sex*t) p(sex)	38	974.70	0.00	0.45	898.70	313.50
φ(sex*t) p(sex+suppl)	39	976.17	1.47	0.21	898.17	312.97
φ(sex*t) p(sex+seas)	39	976.70	2.00	0.16	898.70	313.50
φ(sex*t) p(sex*suppl)	40	978.17	3.47	0.08	898.17	312.97

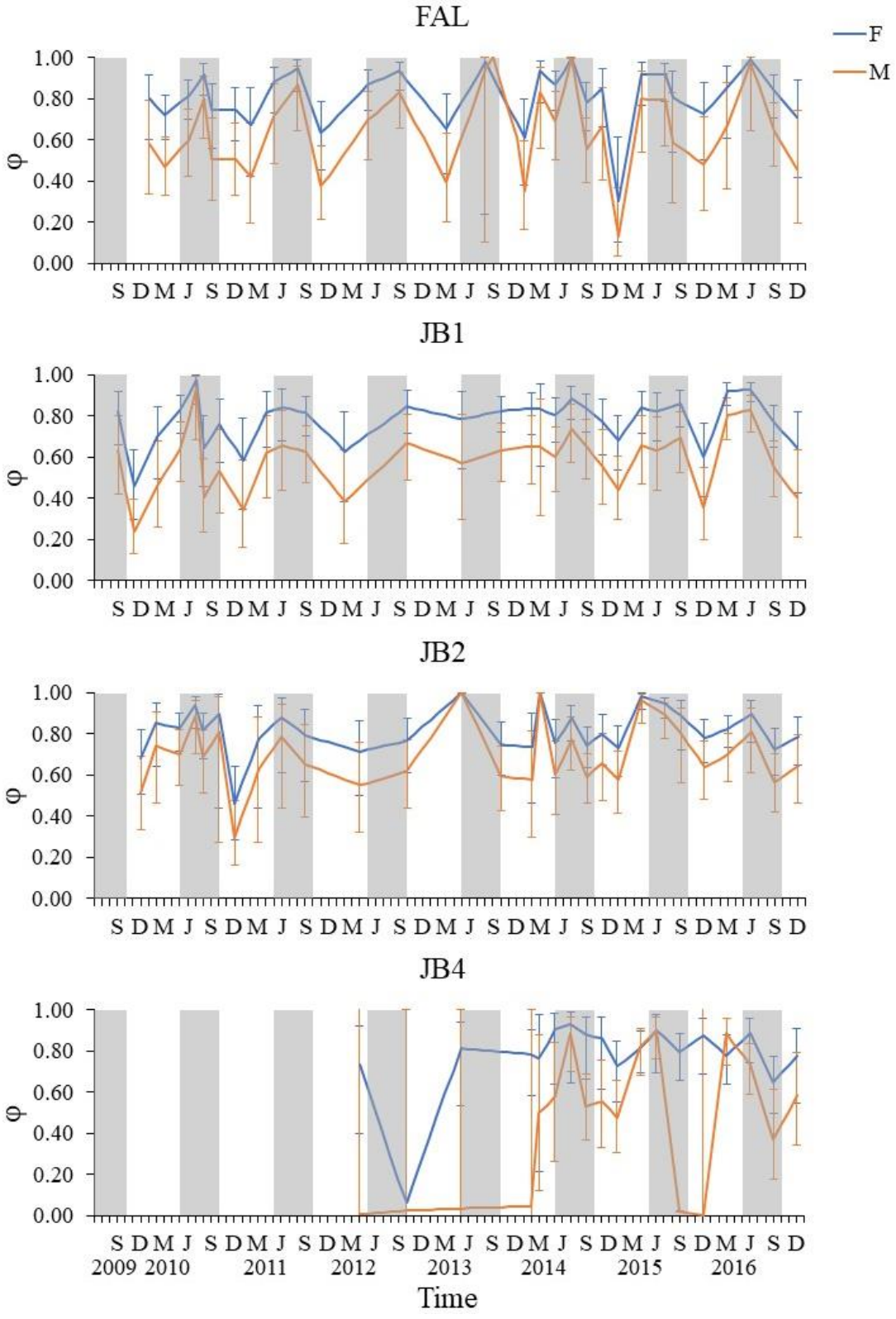


Figure 10. Model-averaged estimates and 95 % confidence intervals of the monthly apparent survival probabilities (φ) of females (blue lines) and males (orange lines) of *Gracilinanus agilis* in four in four patches of "cerradão" from July 2009 to December 2016. FAL and JB1 are the control areas and JB2 and JB4 are the food supplemented areas. Shading bars represent dry seasons.

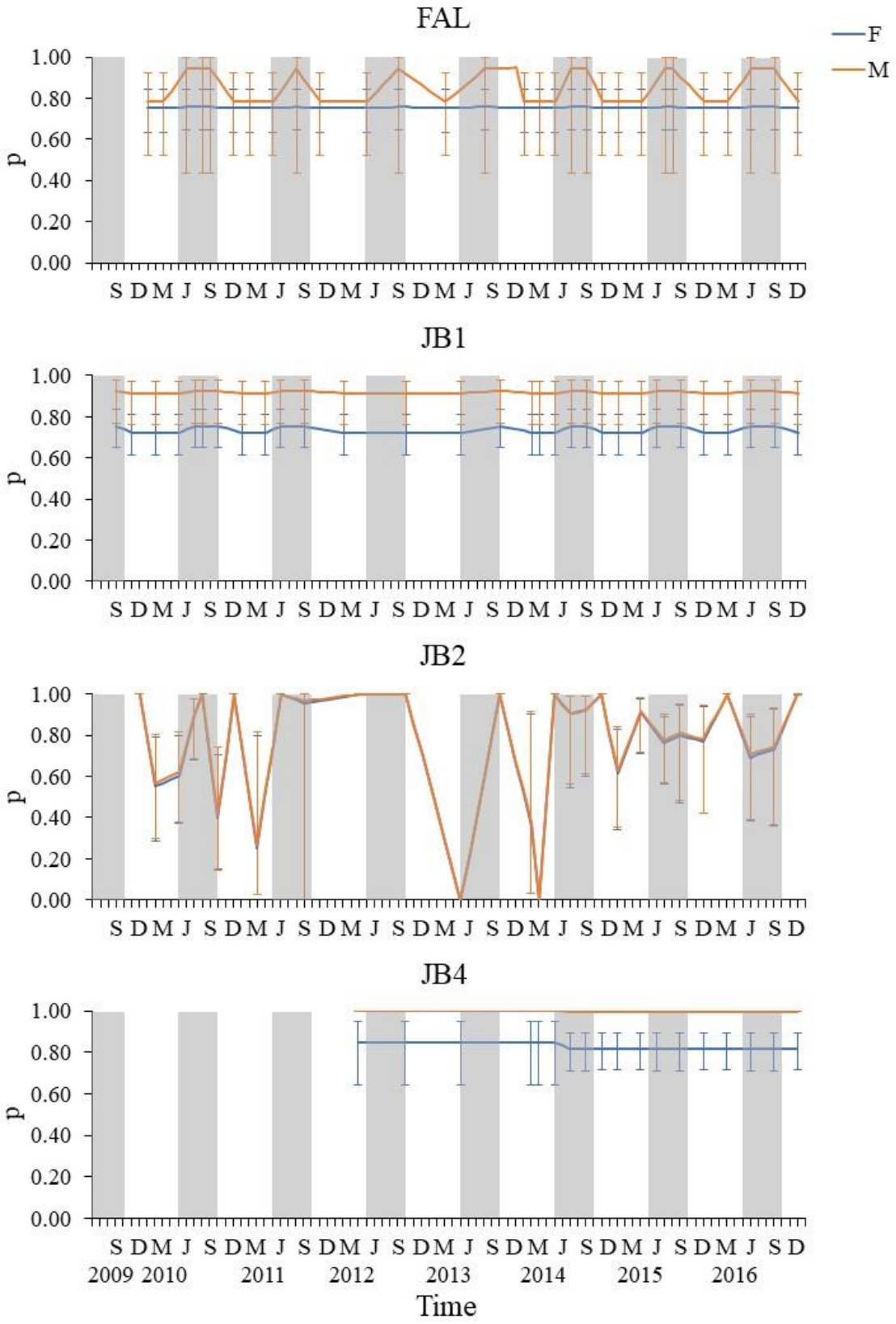


Figure 11. Model-averaged estimates and 95 % confidence intervals of the monthly recapture probabilities (p) of females (blue lines) and males (orange lines) of *Gracilinanus agilis* in four in four patches of "cerradão" from July 2009 to December 2016. FAL and JB1 are the control areas and JB2 and JB4 are the food supplemented areas. Shading bars represent dry seasons.

Results of model selection for cohorts 2015 and 2016 had differences between sexes in apparent survival probabilities in best-ranked models (Table 7 and Appendices 8 to 11). For cohort 2015 of FAL and JB1, full-time variation in apparent survival was replaced by variation in reproductive seasons, except for cohort 2016 of FAL, in which the selected models had constant survival. Many chosen models had constant recapture probabilities, which was different from the previous model selection but similar to the previous averaged estimates.

For JB1, JB2 and JB4, females had higher survival estimates than males and both decreased with reproduction, except for cohort 2015 of JB4, in which model selection could not detect a strong difference between sexes or with time (Table 7). Monthly survival estimates for females from cohort 2015 of FAL had very large confidence intervals since we had only four recaptures during this period (Figure 12a). In 2015, survival estimates for males were high before the reproductive season and declined continually during it. In 2016, survival was estimated constant and equal between sexes.

The recapture probabilities were in general high, were equal (or close) between sexes in most cases, and had a small fluctuation, except for cohort 2016 of FAL and cohort 2015 of JB4, cases of constant survival (Figure 12b). In both cases the estimates were high in the pre-reproductive seasons and decreased with reproduction.

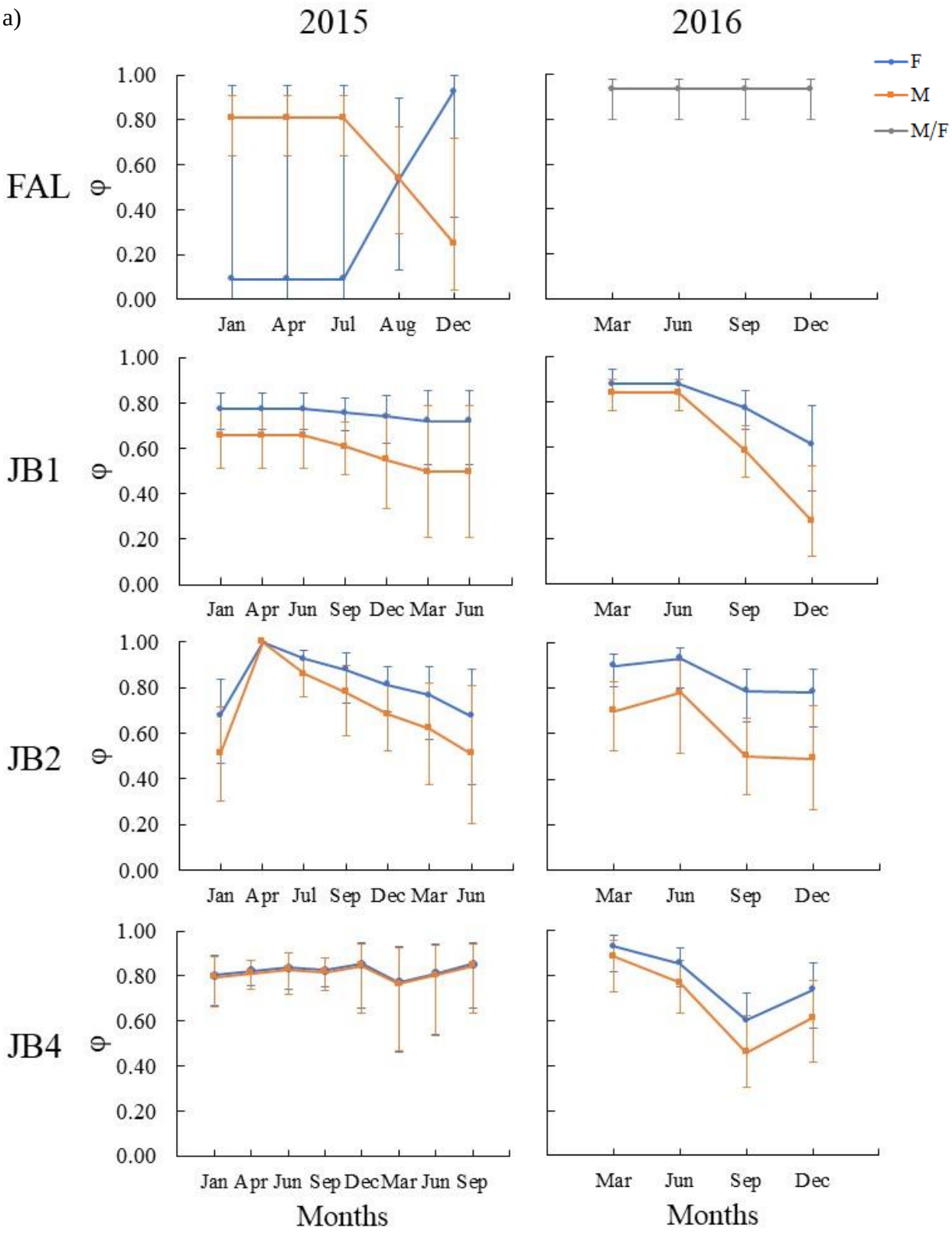
The recruitment estimates of males were equal or higher than of females, except for the cohort 2015 of FAL (Figure 12c). Recruitment was in general high before the reproductive season. The cohort 2015 of JB2 had an increase in September and cohorts 2016 of FAL and JB1 had small increases in December.

The estimated population sizes had an overall decrease with the reproductive season, following the pattern of survival, recapture and/or recruitment probabilities (Figure 12d). Cohorts 2016 had higher population sizes than cohorts 2015, except for JB4. Whereas FAL and JB1 had an increase in males, JB2 and, to a lesser extent, JB4 had an increase in females.

Table 7. Selected models for the capture histories of the cohorts 2015 and 2016 of *Gracilinanus agilis* for each of the four patches of "cerradão", two with food supplementation experiment and two controls. Apparent survival (φ) probabilities, recapture (p) probabilities and probabilities of entrance (pent) may vary as a function of sex, time (t), climatic season (seas: dry and wet), reproductive season (pre-reproductive, reproductive and post-reproductive), interaction between factors (*) or no effect (.). Super-population sizes (N) can only vary between sexes or stay constant. The complete lists of the candidate models sets for FAL, JB1, JB2 and JB4 are is in the supplementary information (Appendices 8, 9, 10 and 11, respectively).

	Cohort 2015	**Cohort 2016**
FAL	φ(sex*rep) p(.) pent(sex*rep) N(.)	φ(.) p(rep) pent(t) N(.) φ(.) p(rep) pent(t) N(sex)
JB1	φ(sex) p(.) pent(sex+rep) N(.) φ(sex+rep) p(.) pent(sex+rep) N(.) φ(sex) p(seas) pent(sex+rep) N(.)	φ(sex*rep) p(.) pent(seas) N(.) φ(sex*rep) p(.) pent(sex*seas) N(.) φ(sex*rep) p(.) pent(seas) N(sex) φ(sex*rep) p(sex) pent(seas) N(.) φ(sex*rep) p(.) pent(sex*seas) N(sex) φ(sex*rep) p(rep) pent(sex*seas) N(.)
JB2	φ(sex+t) p(.) pent(t) N(.)	φ(sex+t) p(sex+t) pent(sex+rep) N(sex) φ(sex+rep) p(sex+t) pent(sex+rep) N(sex) φ(sex+rep) p(sex+t) pent(sex+rep) N(.) φ(sex+t) p(sex+t) pent(sex+rep) N(.) φ(sex+rep) p(sex+t) pent(sex+t) N(sex) φ(sex+rep) p(sex+t) pent(sex+t) N(.)
JB4	φ(.) p(sex*rep) pent(sex*rep) N(.) φ(.) p(sex*rep) pent(sex+rep) N(.) φ(sex) p(sex*rep) pent(sex+rep) N(.) φ(t) p(sex*rep) pent(sex*rep) N(.) φ(.) p(sex*rep) pent(sex*rep) N(sex)	φ(sex+t) p(.) pent(rep) N(.) φ(sex+t) p(rep) pent(rep) N(.) φ(sex+t) p(sex) pent(sex+rep) N(.) φ(sex+t) p(.) pent(sex+rep) N(.)

a)


2015
2016
F
M
M/F
FAL
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JB2
JB4
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1.00
0.80
0.60
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Jan Apr Jul Aug Dec
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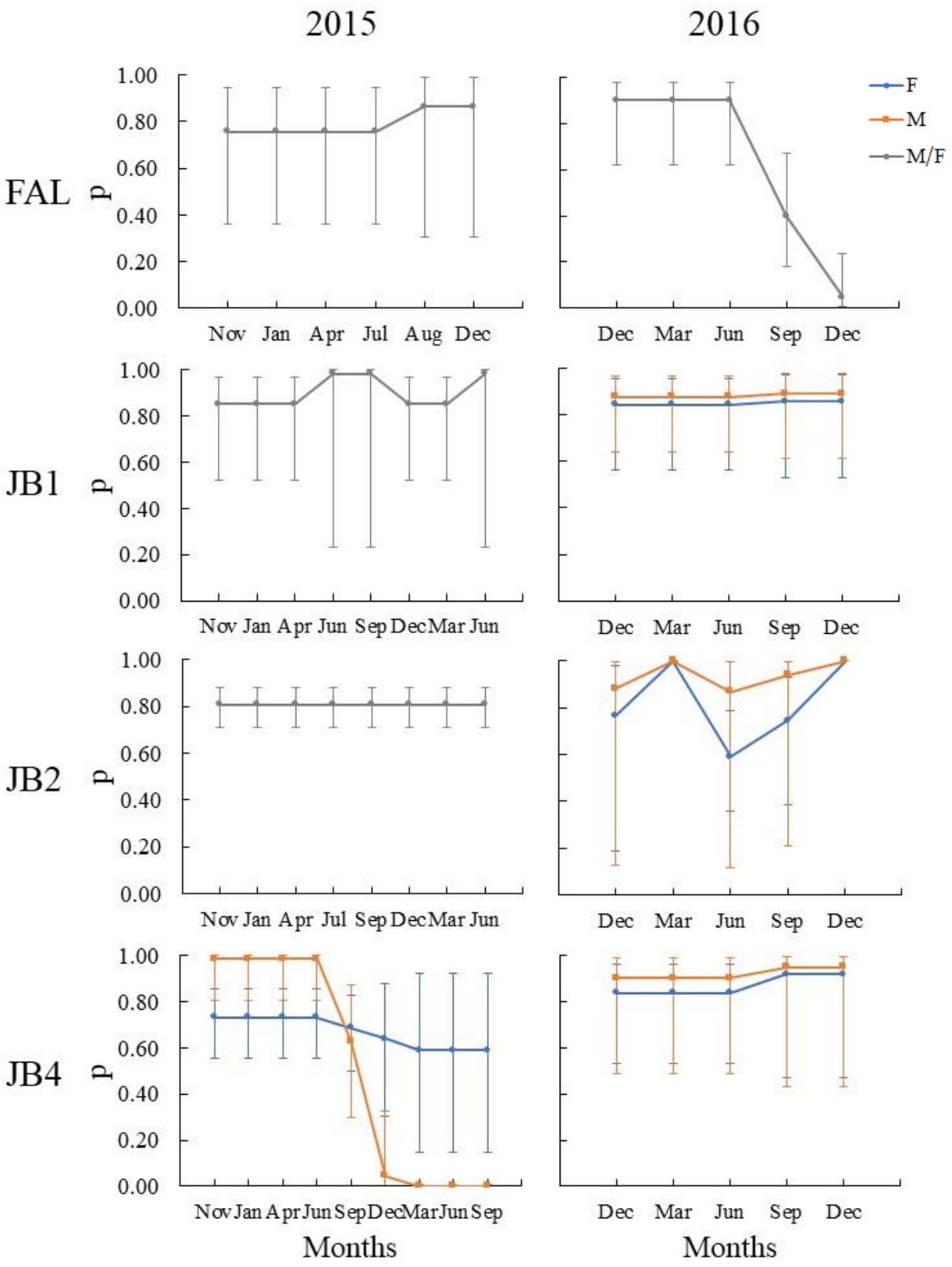
Jan Apr Jun Sep Dec Mar Jun Sep
Months
Months


2015
2016
FAL
JB1
JB2
JB4
p
1.00
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F
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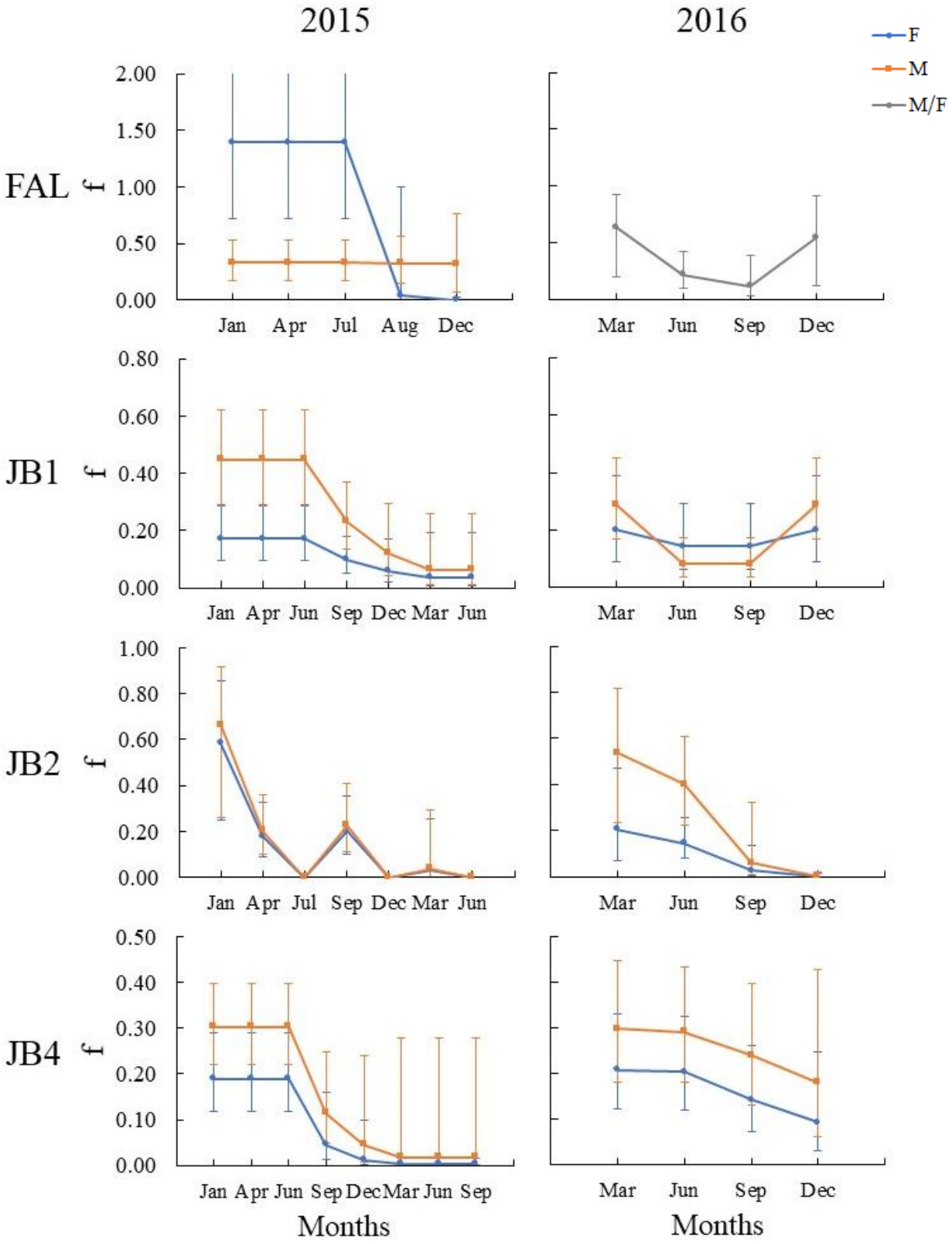
Nov Jan Apr Jun Sep Dec Mar Jun
Nov Jan Apr Jul Sep Dec Mar Jun
Nov Jan Apr Jun Sep Dec Mar Jun Sep
Months

b)

c)


2015
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Months

d)

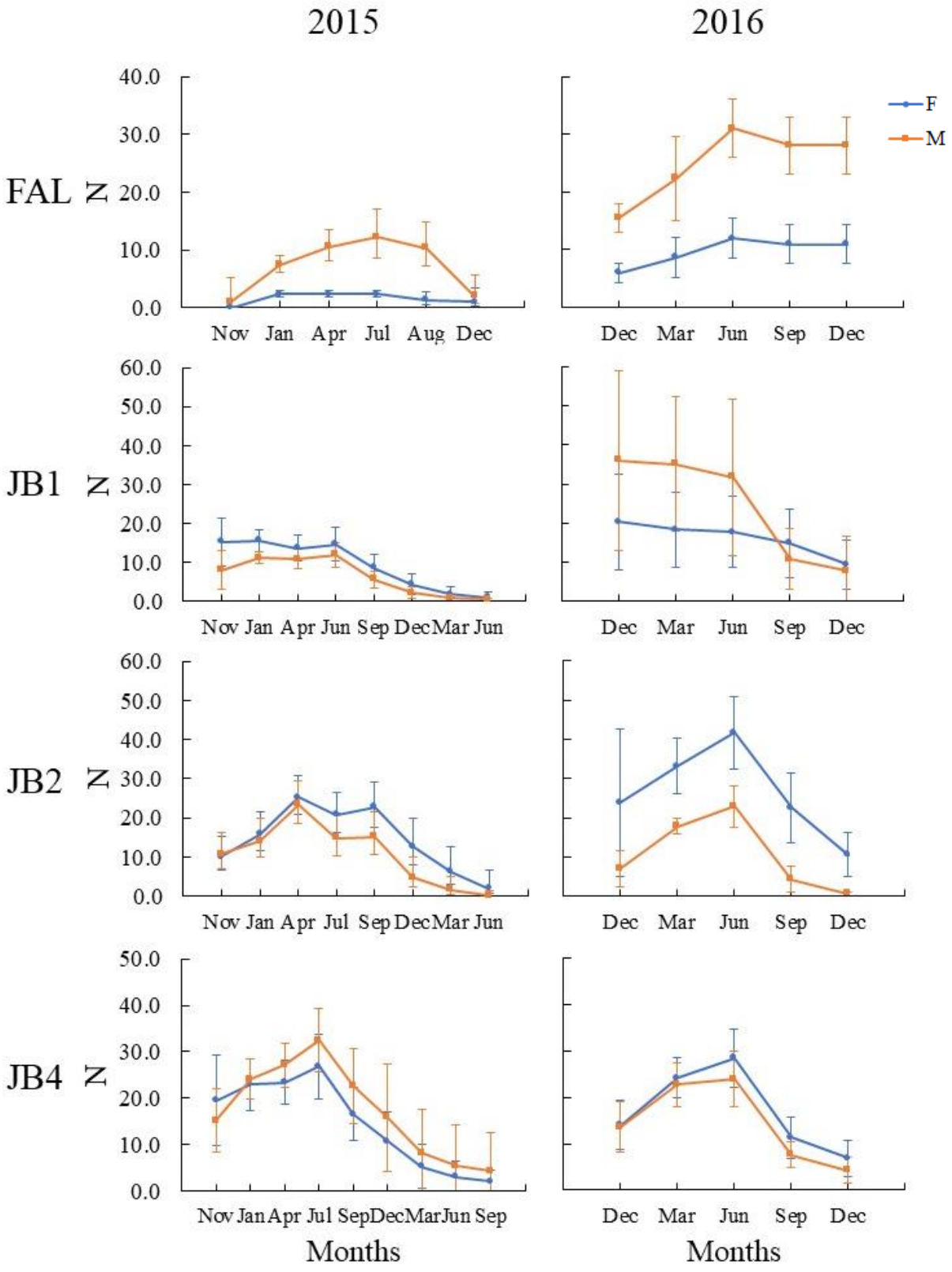

Figure 12. Model-averaged estimates and 95 % confidence intervals of a) the monthly apparent survival probabilities (φ), b) the monthly recapture probabilities (p), c) the monthly recruitment probabilities (*f*), and d) the population sizes (N) of females (blue lines) and males (orange lines)

of *Gracilinanus agilis* from the cohorts 2015 and 2016 in four in four patches of “cerradão” from July 2009 to December 2016. FAL and JB1 are the control areas and JB2 and JB4 are the food supplemented areas. Gray lines represent estimates for sexes together.

Discussion

Our results were consistent with the predictions of the semelparous strategy for *G. agilis*. The studied populations had seasonality in age structure, reproduction and population parameters. Food supplementation had minor effects on reproductive effort in both females and males, and did not seem to change the population pattern.

The reproduction of *G. agilis* was markedly seasonal, and reproductive females were found from August to March, with higher proportions in September and December. The same pattern was observed in previous studies (Martins et al. 2006b, Lopes & Leiner 2015), but a more restricted reproductive period occurred in another population, with signs of pregnancy only in September and signs of lactation only in November (Puida & Paglia 2015). The food supplementation experiment seemed to have no effect on the seasonality of reproduction.

Our prediction of seasonal age structure was considerably supported, since all classes but the last one showed a seasonal pattern. The classes represented by the young individuals and subadults were concentrated in November, December and January, coinciding with the end of the reproductive season. However, we unexpectedly found a few subadults (P^3M^3) also in June and July, a period just before the beginning of reproduction, in both control and supplemented areas. Since we do not have any evidence for lower classes in June, May or April, it implies that this low proportion of subadults was probably caused by misidentification of the fourth molar in the field. We found adults with complete dentition throughout the year, but more concentrated from June to September.

The effect of food supplementation on the age structure was partially supported. The control populations had subadults (class 4b) mostly in January, whereas the food-supplemented populations had the same class from December until March, pattern which might indicate females were nursing late litters in those areas. A few juveniles of *G. agilis* were also reported in April/May in other study (Lopes & Leiner 2015), so that could be a natural variation. Besides, other classes did not show the same pattern to strengthen this hypothesis. Another difference found was regarding the senile class. Although the senile individuals appeared year-round in both control and food-supplemented areas, the shift in the average month from December in the control areas to March in the food-supplemented areas suggests an expanded longevity as an effect of food supplementation. Despite a few females being caught in two reproductive seasons in control and supplemented areas throughout the entire study (FAL: 4; JB1: 3; JB2: 4; JB4: 1), only one female from a control area was reproductively active in the second season, whereas all females from the supplemented areas and during the experiment (2014 - 2016) were

reproductive during the two seasons. Indeed, we captured the only male surviving two seasons in JB2, with the throat gland evident in both occasions, though not in a good state in the last one, since it had a fracture in the tail and intense fur loss.

We have reason to believe that the classification based on tooth eruption pattern is not a reliable indication of sexual maturation for the gracile mouse opossum. In didelphids in general, individuals from classes 4 and 5 are considered mature and potentially reproductive (Tyndale-Biscoe & MacKenzie 1976, Tribe 1990, Macedo et al. 2006). However, the replacement of age classes was not gradual but rather relatively fast. So, the adults found in the beginning of the year were still apparently young, considering other features such as, body size, mass, fur, and behaviour. In addition, the scrotal width, which possibly reflects testosterone production, leaped up from a mean lower than 8 mm to higher than 12 mm between April and June, implying that male maturity occurred after individuals turned to class 5. No subadult male or female showed signs of reproduction in the present study, in contrast with the findings of Lopes and Leiner (2015) for this same species using a similar age classification.

The reproductive effort of females, measured as the litter size, was not affected by the food supplementation experiment, varying only among the months. Litter size was the largest in September, when most females were reproductive, and reduced as the proportion of reproductive females also reduced in November/December and later in February/March. Although there is no exact information available about the gracile mouse opossum gestation period and time of weaning, we presume they are around two and eight weeks respectively, in line with another small didelphid, the short-tailed opossum *Monodelphis domestica* (Macrini 2004). If it takes females almost three months after mating to wean their young, it is unlikely that they were able to have two successful litters from September to December or from December to March. So, the females in December were probably nursing the same litter they were in September, and the reduced number of functional teats in December would represent more accurately how many new individuals the females would contribute to the population. Alternatively, females could reproduce a few months later, either because they had lost their first litter or simply because they were the last to enter oestrus, but with a cost of a reduced litter. The reason for this cost might be that they would find males in a suboptimal condition to mate. These hypotheses could also explain the difference in litter size between December and March, with a more intense cost of mating in the very end of reproductive period. Moreover, a few females could have had two successful litters from September to March, and this strategy was probably used only by the ones that entered oestrus early in the season. Since lactation represents most of the marsupial female energy expenditure (Tyndale-Biscoe 2005), it is

reasonable to assume that the females would have less energy to invest in the second litter than in the first. However, we also found a few cases of old females reproducing again in a second reproductive season, and their mean litter size was higher than in February/March of the first reproductive season. These females were not reproductive more than once in the season before. Therefore, it seems to be more advantageous for old females to have a second litter in the second season, mating with males from the new generation, than in the end of the first season, mating with the degenerating males. Although the modeling did not detect a relevant effect of food supplementation population parameters, as mentioned before, most old reproductive females found in the second season were from supplemented areas.

The reproductive effort of males, measured as the scrotal width, was affected by the food supplementation experiment. Matured males from food-supplemented areas had larger testis than the ones from control areas, which suggests higher investment in reproduction among fed males. Therefore, instead of reducing the stress of the reproductive season, the increased food availability had the potential to increase competition among males for mates. However, the difference between generations was greater than the difference between control and supplemented areas. Mature males of generation 2016 had smaller testis than the ones of generation 2015 before and in the beginning of the reproductive season.

The evident throat gland is an indirect sign of male reproductive activity found in many didelphids (Hershkovitz 1992). Despite not fully understood, the male throat gland is inferred to be under the influence of androgens (Fadem & Cole 1985), like the paracloacal glands (Helder 2012). The increase in frequency of the throat gland indeed coincided with the increase in the scrotal testis size in our study. In *Monodelphis domestica*, females can be induced into oestrus when they nuzzle scentmarks from the throat gland (Harder & Jackson 2010). However, it takes females of *G. agilis* practically two months to respond to male stimuli, since they became reproductive only in September. Therefore, scentmarking is likely to play an important role in female maturation in the gracile opossum, but it does not trigger the timing of reproduction. The changing photoperiod is probably the reproductive cue, as observed in other seasonal-breeding marsupials (Cerqueira 2005, McAllan et al. 2006, Naylor et al. 2008, Barros et al. 2015).

Although there was an indication that the food supplementation experiment affected population abundances, we did not find a consistent effect of the experiment on survival or recapture probabilities. Considering cohorts separately, we showed that the population parameters were mainly influenced by reproductive season and sex instead of climatic season. This result is consistent with the previous finding that demographic parameters of a *G. agilis*

population from the Cerrado was mainly influenced by its life history than by variation in primary productivity, which reflected local rainfall (Puida & Paglia 2015).

In general, monthly survival rates were higher for females than for males and declined with reproduction. Our results were contrary to the study of Martins et al. (2006b), which showed constant survival estimates for females between reproduction periods in every cohort. Puida and Paglia (2015) had also somehow different results, since survival estimates were equal between sexes in most cohorts. Lopes and Leiner (2015) did not estimate population parameters by cohorts, and the overall pattern of survival was similar to what we found for the entire study.

The recruitment rates were higher for males than females, and both declined with reproduction. Male abundances were mostly higher than female abundances in control populations, in accordance with male biased sex ratios found in previous studies (Aragona & Marinho-Filho 2009, Andreazzi et al. 2011, Puida & Paglia 2015). However, supplemented populations showed a reverse pattern, with female abundances more similar or higher than male abundances. This suggests food supplementation could have favored females more than males, though not detected neither in survival nor in recruitment parameters.

It is reasonable to expect that seasonality of food resources was not identical among the habitats where the studies on *G. agilis* populations were conducted, even being in the same biome, or even the same phytophysiognomy. Variations in seasonality could be a result of latitudinal differences (Fisher et al. 2013) or climate interannual variation, such as the El Niño/La Niña (ENSO) effects (Marcuzzo & Romero 2013). Our study area was closest to the equador line comparing with the previous population studies on *G. agilis* in the Cerrado, which implies the lowest seasonality among them. Furthermore, our food supplementation experiment occurred during the 2015-2016 El Niño event, which was the strongest event since 1997-1998. The ENSO effects on the central-west region of Brazil are complex, but changes are related to extreme rainfall events in the wet season (Grimm & Tedeschi 2009, Marcuzzo & Romero 2013). So, this climatic phenomenon could have had an impact on primary productivity, providing more food resources for small mammal populations in those years. Despite that, we found seasonality in the population parameters similarly to the other studies, even in food-supplemented areas. Comparisons between *G. agilis* populations from distinct Cerrado sites (located about 660 km apart) indicated that climatic differences caused differences in daily activity patterns of this species only during non-reproductive periods. In the reproductive period, in both areas, *G. agilis* individuals showed similar, temperature-independent activity during the night (Vieira et al. 2017).

Even though evidence supports the semelparity syndrome for the didelphid *G. agilis*, we found differences with the semelparous dasyurids in some respects. Dasyurids have been classified into six strategies based on five life-history traits: the frequency of oestrus, the duration and the timing of male reproductive effort, the seasonality of reproduction and the age at maturity (Lee et al. 1982, Lee & Cockburn 1985). The gracile mouse opossum could not be placed into the strategy I, which correlates with the semelparous strategy. Dasyurids employing the first strategy show a monoestrous pattern, a mating period (estimated as two weeks) shorter than gestation (about 28 days), and the male die-off within 10 days after the start of mating. In contrast, *G. agilis* females are at least facultative polyoestrous, since each female can produce two litters in one reproductive season, or even participate in two seasons. This trait would place the species into the strategy II or III, but the species with these strategies show a smaller litter size, live in less predictable habitats, and males and females live to reproduce in a second year. Furthermore, the extended reproductive season and the age at maturity (8-11 months) of *G. agilis* could place it in the strategy V, though most females produce two or more litters and there is no post-mating male mortality among species employing this strategy. We conclude that the life-history strategy of *G. agilis* supports the argument that life history must be seen as continuous rather than categorical, notably for groups that show high plasticity such as the marsupials.

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CHAPTER 2: Semelparity and the physiological response of *Gracilinanus agilis* (Didelphimorphia, Didelphidae) to food supplementation

Introduction

Marsupials occupy a great diversity of habitats and present a wide range of life-history patterns accordingly. The American and Australasian marsupials share a common ancestor with placental mammals in the Jurassic (ca. 160 million years ago [Ma] Luo et al. 2011), but the origins of marsupial living clades are relatively recent, only around 45 Ma (Meredith et al. 2011, Sánchez-Villagra 2013, Jansa et al. 2014). Phylogenetic and paleontological studies showed that most diversification of marsupials occurred within moist-forest environments, and that adaptations to open and dry habitats evolved independently several times (Travouillon et al. 2009, Jansa et al. 2014, Mitchell et al. 2014). Among American marsupials, dry-forest adaptations occurred during or after the late Miocene, around 10 Ma, consistent with the expansion of drier and more open habitats (Jansa et al. 2014). A similar pattern was found among Australasian marsupials, though evidence indicates that adaptation did not evolve only towards aridity, but also in the reverse direction, which denotes an unexpectedly plasticity from marsupial lineages (Mitchell et al. 2014).

An extreme life-history strategy called semelparity, in which individuals have only one reproductive episode during their lifetime (Cole 1954), has been recorded among mammals only in males of two marsupial families: Dasyuridae in Oceania (Braithwaite & Lee 1979, Boonstra 2005, Holleley et al. 2006) and Didelphidae in the Americas (Pine et al. 1985, Lorini et al. 1994, Martins et al. 2006a, Leiner et al. 2008, Lopes & Leiner 2015). This strategy has probably evolved independently several times in these marsupial families (Krajewski et al. 2000), even in genera from the same tribe (*Antechinus* and *Phascogale*; Westerman et al. 2016). There is a general consensus that semelparity is associated with strongly seasonal and predictable habitats, and food resource abundance would coincide with marsupial late lactation (Braithwaite & Lee 1979).

The physiological changes underlying semelparity is well exemplified with a group of Australasian dasyurid marsupials, in which males show die-off, that is, the synchronized mortality in a short period (*Antechinus adustus*, *A. agilis*, *A. bellus*, *A. flavipes*, *A. godmani*, *A. leo*, *A. minimus*, *A. stuartii*, *A. subtropicus*, *A. swainsonii*, *Dasykaluta rosamondae*, *Parantechinus apicalis*, *Phascogale calura* – Fisher et al. 2013). The high free circulating

cortisol is responsible for gastrointestinal ulcerations, immune and inflammatory suppression, increase in parasitism, changes in haematological parameters and general debilitaded condition (Lee & Cockburn 1985, Bradley 2003, Naylor et al. 2008). The increase in cortisol levels is directedly related to changes in feedback mechanisms of the hypothalamic-pituitary-adrenal (HPA) axis (Lee & Cockburn 1985, Bradley 2003, Naylor et al. 2008).

The HPA axis is a part of the neuroendocrine system that controls reactions to stress and regulates several body processes, such as digestion, immune system and energy storage (Figure 1). This axis is evolutionarily conserved in vertebrates (Denver 2009) and, together with the limbic system in the brain, constitute the stress axis, essencial for the adaptive success (Boonstra 2005). The stress axis allows, for instance, the classical fight-or-flight reaction in response to a stressor, such as a predator attack, mobilizing energy for its immediate use (Sapolsky et al. 2000, Vedder 2008). Also known as the acute stress reaction, this response involves a release of catecholamines (epinephrine and norepinephrine) by the adrenal medulla, as well as a release of the functional inhibition of hippocampus on the HPA axis, which initiates a cascade of physiological responses, so the individual can cope with the stressor and return to homeostasis. The HPA axis activation starts when the hypothalamus releases arginine vasopressin (AVP, vasopressin in mammals and vasotocin in other vertebrate groups) and corticotropin-releasing hormone (CRH); both hormones stimulate the pituitary gland to release the adrenocorticotropic hormone (ACTH), which in turn stimulates the adrenal cortex to secrete glucocorticoids (GC) (Vedder 2008). Whereas chatecolamines act within seconds, the effects of GCs last from a few minutes to hours in the organism (Sapolsky et al. 2000).

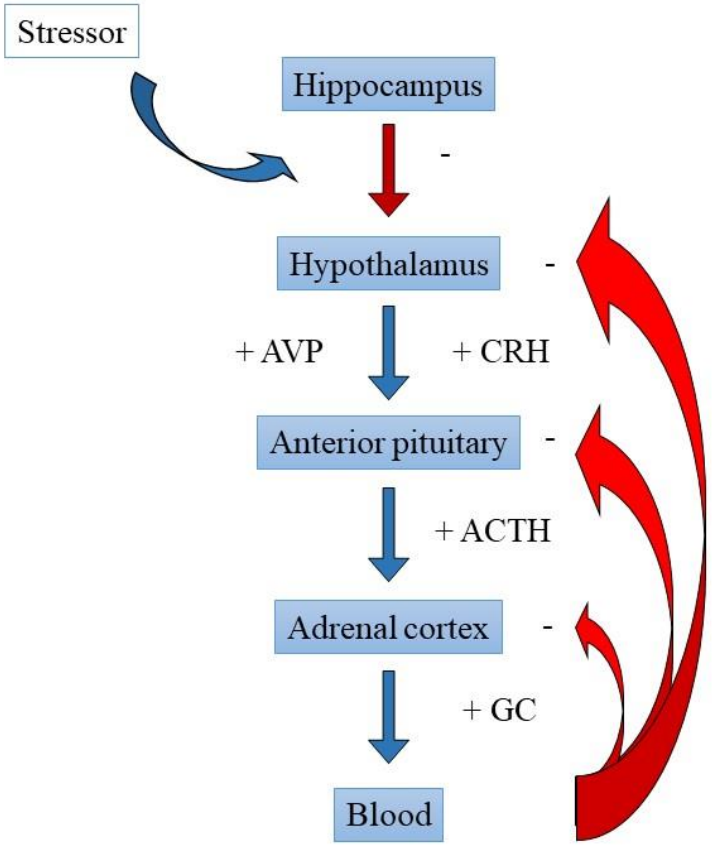


Figure 1. Model of the hypothalamic-pituitary-adrenal (HPA) axis function in the presence of a stressor. CRH: corticotropin-releasing hormone; AVP: arginine vasopressin; ACTH: adrenocorticotropic hormone; GC: glucocorticoids (cortisol/corticosterone).

GCs are steroid hormones that are important in the regulation of several physiological processes. Cortisol (found in fish and most mammals) and corticosterone (found in reptiles, birds and some rodents) are the primary GCs for vertebrates and both play the same roles (Romero et al. 2007). However, about 90 % of the circulation GCs in the blood are bound to the corticosteroid-binding globulin (CBG; transcortin) in most species (Desantis et al. 2013). There is strong evidence to support that only the remain fraction is biologically active, being available to diffuse across plasma membranes and bind receptors (Rosner 1990). CBG is a protein synthesized by the liver, binds to GCs with high affinity but low capacity, in contrast to albumin, the most abundant plasma protein, and may have more roles than the buffering reservoir of GC, such as GC delivery to inflammation sites and other target tissues (Rosner 1990, Hammond 1995, Moisan et al. 2014).

In a reaction to acute stress, the increase in the GC concentration itself mediates negative feedback on the HPA axis, acting on the hypothalamus, pituitary and adrenal glands (Figure 1; Sapolsky et al. 2000, Romero 2004). A loss of the feedback efficiency results in a prolongued GC release, which can be detrimental to the organism survival (Romero et al. 2007). On the other hand, the chronic activation of the HPA axis may be adaptive to some life history strategies. The strategy named 'adaptive stress response' leads to energy mobilization to support the reproductive effort in a short reproductive period, and can maximize fitness despite the decrease in survival (Boonstra & Boag 1992, Boonstra 2005). The alternative strategy is the 'homeostasis stress response', in which the reproductive effort is spread over a longer reproductive period, maintaining the HPA axis feedback during this period (Boonstra & Boag 1992, Boonstra 2005). The 'adaptive stress response' strategy is proposed for semelparous species, and the 'homeostasis stress response' is proposed for species with more than one reproductive cycle over the course of its lifetime (iteroparous species), though a continuum of life histories between these extremes is reflected by a continuum of physiological adaptations (Boonstra 2005).

The stress metrics are quantifiable physiological measures that describe the HPA axis and the cascade effects of the high GC concentration (Johnstone et al. 2012b). Among the commonly used metrics are the concentrations of GC (and sometimes CBG and testosterone; Delehanty & Boonstra 2009), leukocyte profile (neutrophil/lymphocyte ratio, neutrophil, lymphocyte and eosinophils concentrations; Davis et al. 2008), immune function (leukocyte responsiveness; McLaren et al. 2003), regenerative anaemia (haemoglobin concentration, haematocrit (the volume percentage of red blood cells), red blood cell distribution width; Johnstone et al. 2011, 2012a), and plasma glucose increase (e.g. Boonstra et al. 1998, Fletcher & Boonstra 2006). Each metric has its advantages and disadvantages in methodological issues, and the use of several indicators is a recommended procedure to avoid problems in interpretations (Johnstone et al. 2012b, Breuner et al. 2013).

Hormone concentrations are the most used metrics, with the plasma GC concentration being the most direct measure for the detection of the HPA axis activation and therefore the detection of stress. However, several issues need to be considered, which make this metric less direct. It is important to distinguish the difference between measuring total or free GC in plasma, since only free GC is biologically active (Rosner 1990). In the case of the semelparous dasyurids, endocrine profiles indicates that the increase in free plasma cortisol is not only due to the increase in the production, which already starts before the reproductive period, but also

due to the decrease in the CBG levels, induced by the increase of testosterone (Lee & Cockburn 1985, Bradley 2003, Naylor et al. 2008).

Another issue to be considered when using GC concentration as a stress metric is that blood concentrations represent three components of the state of an organism (Sheriff et al. 2011): 1- endogenous, circadian, and seasonal cycles; 2- immediate experience of acute stress, such as a predator attack or trapping; and 3- experience of chronic stressors, such as the search for sexual partner, food availability, and habitat quality. To evaluate the effect of chronic stressors, it is necessary to remove or control the effects of the other components. Blood collection of individuals at the same time of day and year is a simple method that reduces the variation of the circadian and seasonal cycles of the samples. However, removing or evaluating the effect of trapping is not a simple task in the study of free-living animals, but there are some ways to deal with this issue.

The first option to deal with the stress response to capture is the “capture challenge protocol”, which consists of obtaining baseline values from the blood collection in less than 5 minutes of capture, and comparing them with one or more values corresponding to different times of collection (e.g. 10, 20, 30, 60 min) in order to capture GC changes due to capture stress (e.g. Delehanty & Boonstra 2009). However, this protocol is often not possible to be done, either because the animals are nocturnal, making logistics difficult, or because the presence of the researcher close to the traps decreases the catchability of these animals.

The second option is the "hormonal challenge protocol", which consists of the use of dexamethasone, a suppressor of the GC production, to obtain base values. Resistance to dexamethasone and hence, high baseline values may indicate that the animal undergoes chronic stress (e.g. Delehanty & Boonstra 2009). The ACTH hormone is then injected to stimulate GC production again by testing the adrenal gland response.

The third option is to evaluate the capture stress by means of "nominal base values", that is, collections after hours of confinement in the trap, relating these values to the record of the time the animal was kept inside traps (obtained by timers coupled to the traps). Even without the "true base value", it is possible to detect seasonal changes or effects of experiments (Boonstra et al. 1998, Place & Kenagy 2000).

The fourth option is the sample collection of different substrates, such as faeces, saliva and hairs, for the determination of GCs. These collections are less invasive and easier to obtain multiple samples from a small individual (< 50 g) when compared to blood collections (Sheriff et al. 2011). Furthermore, these substrates present a high correlation between GC or their metabolites and blood GC concentration, without the rapid increase (3 - 5 min) in response to

stress (saliva: 20-30 min, Kirschbaum & Hellhammer 1989; faeces: 4 - 24 h, Good et al. 2003, Palme et al. 2005; hair: weeks or months; Sheriff et al. 2011).

The other stress metrics used, as they are results of the cascade effect of increased GC production, have the advantage of being more resistant to the stress influence, not rapidly reflecting the hormonal increase in response to acute stress (leukocyte profile: 1- 2 h; Dhabhar et al. 1995, Davis et al. 2008; erythrocyte profile: around 8 h; Fletcher & Boonstra 2006). Nevertheless, this response may still occur faster than the period individuals stay trapped in small mammal studies.

Objective and predictions

The overall objective of this chapter was to examine the stress response of a neotropical marsupial, the gracile mouse opossum (*Gracilinanus agilis*) associated with the functioning of the HPA axis and the semelparity syndrome, and to relate with resource availability through a food supplementation experiment. The neutrophil/lymphocyte ratio (N/L) was used as an indicator of inflammatory process and medium-term stress measure, since high concentrations of stress hormones increase the concentration of neutrophils and reduce lymphocytes (Dhabhar et al. 1995, Davis et al. 2008). Body condition and haemoglobin concentration were used as indicators of general health and related to the reproductive effort of the individuals. Plasma glucose levels were considered a measure of energy mobilization, since increased production of GC by stress induction stimulates gluconeogenesis, inhibits insulin activity, decreases glucose entry in peripheral tissues, and promotes the breakdown of proteins and lipids for the production of substrates for gluconeogenesis (Sapolsky et al. 2000). Hormone patterns were investigated using faecal cortisol metabolites, total plasma cortisol, CBG concentration and free cortisol as the fraction CBG-unbound.

We predicted that the physiological parameters of *G. agilis* would show an adaptive stress response as expected for the semelparity syndrome. The signs of failure of the HPA axis would be the increased neutrophil/lymphocyte ratio, glucose and cortisol concentration, and the reduced body condition and haemoglobin concentration. These signs would last from the start of reproduction until the disappearance of the individuals in the populations, and males would be more affected than females. Furthermore, if the environment influences this life-history constraint, the physiological parameters would be less affected in individuals of the food-supplemented areas than in individuals of the control areas, as the additional resource

availability would reduce the stress of the reproductive season and thus the semelparity syndrome.

Methods

Sample collections

We took blood samples in every capture session from April 2015 to December 2016. For logistical reasons we were not able to collect all samples from each individual at the four grids. We therefore chose two grids that had been more abundant during the long-term population monitoring, JB1 (control) and JB2 (experiment), to make an attempt to collect samples from near all captured individuals. We also collected blood samples from six females and six males in the other two grids (FAL – control; JB4 – experiment) at each session.

A precondition for blood collection was the record of the time spent by the individuals inside trap prior to blood sampling. This time information is fundamental to evaluate the stress response to capture (Sheriff et al. 2011, Johnstone et al. 2012b), statistically controlling this effect as a covariable. Thus, we did not take blood samples of individuals captured in traps on the ground (which did not have timers) or in traps with non-functional timers.

In addition to recording how long individuals were retained in traps, we recorded how long we handled the animals before we could take the blood samples. We managed to take the blood samples for the hormone measurements within 5 minutes from disturbing the animals in the trap until the end of the bleeding, and only after the other procedures were done. Blood samples were obtained from the facial vein by using a 30-gauge needle (8 mm x 0.3 mm) without anesthesia (Figure 2). This technique does not cause significant adverse effects on the wellbeing of the animals (Hoff 2000, Golde et al. 2005, Francisco et al. 2015). Blood drops were collected in previously heparinized Eppendorf® tubes. The quantity of blood was no more than 1.5 % of the animal body mass (Sikes & The Animal Care and Use Committee of the American Society of Mammalogists 2016). This percentage corresponded to a volume between 150 µL and 600 µL (body masses varied from around 10 g to 40 g). Samples were kept on ice and were centrifuged for 15 min at 15000 g. The separated plasma was stored at -80 ºC until analysis and shipped to the University of Toronto on dry ice.

Figure 2. Blood collection technique from the facial vein of *Gracilinanus agilis*. a) Blood dropping into the tube. b) The individual soon after the bleeding with no sign of injury.

Immediately after the blood collection for the hormone measurement, we measured glucose levels (Gl; ± 1 mg/dL) with a FreeStyle Optium glucometer (Abbott Diabetes Care Inc.) using 0.6 µL of fresh blood. We also measured haemoglobin concentration (Hb; ± 0.1 g/dL) on a 5-µL sample with a Hemo Vet photometer (Veterinary Haemoglobin Analyser; EKF Diagnostics). When the bleeding from the facial vein ceased, we obtained blood from the tail vein for Hb. For the peripheral blood smears, we used about 5 µL of fresh blood, most of the time from the tail vein. The slides were created as described by Lewis et al. (2006), in duplicates, left to air dry and then fixed in methanol by immersion for 3 min. Each individual was submitted to only one blood collection at each capture session. The general procedures detailed in the general Material and Methods were done only after the blood collection.

Faecal samples were collected concurrently with the other procedures because the individuals usually defecated during handling. Since this method is non-invasive, we collected samples upon each capture of *G. agilis*, recording the time of collection. We did not collect samples inside traps because faecal cortisol metabolite (FCM) concentrations could vary according to the circadian rhythm and interpretation of the results could be difficult if we homogenized faeces of different times (Boonstra 2005). Furthermore, the exposition of faeces to external bacteria could lead to further metabolization of the FCMs (Möstl et al. 1999, Lexen et al. 2008). We registered the occurrences of contamination by urine for further investigation. Samples were kept on ice during transportation, stored at -80 ºC until analysis and shipped to the University of Toronto on dry ice.

For the biological validation of the FCMs, we had three additional capture sessions in JB4 in February and March 2017, after the population study had ended and when most of the

individuals would be non-reproductive. We checked the traps several times from sunset to sunrise, recording the ones that were closed, the time of the night and the time running in the timers. We used red lights and minimized the noise to avoid disturbing the animals in the grid. We assigned the traps to the following groups of time: 0 h (< 20 min), 3 h, 6 h, 9 h, 12 h, 15 h and 18 h and waited for the countdown to end to collect the faecal samples. We only opened the traps to confirm its occupancy and species identification at the moment of the sample collection. In the morning, we baited the traps and checked their timers for the next night. Each session consisted of three nights and we kept the individuals in cages during the sessions so that we would not have recaptures, avoiding the influence of the stress response by repeated handling (Good et al. 2003, Johnstone et al. 2012a).

Laboratory analyses

The blood smears were stained with 10 % Giemsa's solution for 20 min and examined under 1000 x magnification. The leukocytes were classified as neutrophils, lymphocytes, eosinophils, basophils, and monocytes, according to their nuclear and cytoplasmic characteristics (Figure 3). Lysed leukocytes were not considered in the counts. Two experimenters made the differential leukocyte counts based on 100 cells per slide.

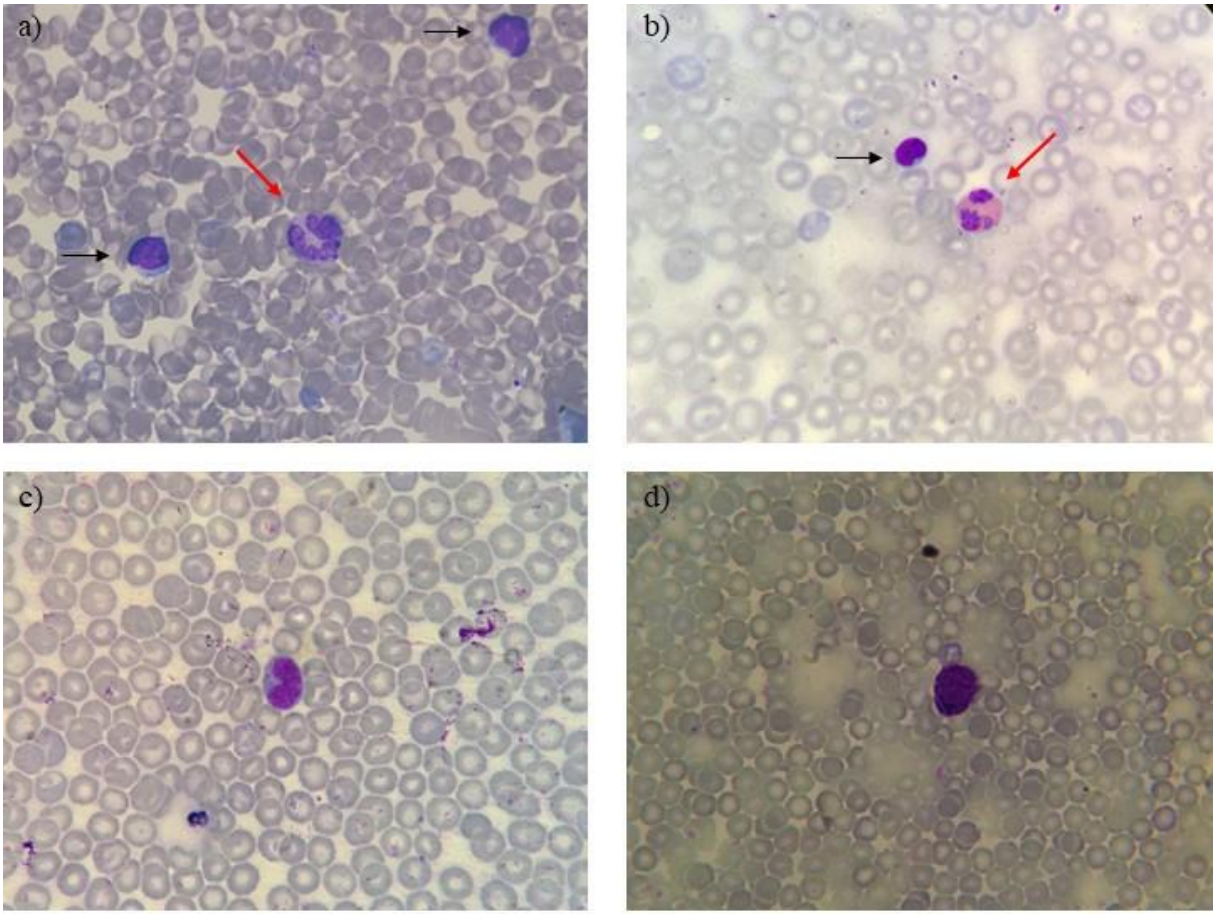


Figure 3. Leukocytes in peripheral blood smears of the marsupial *Gracilinanus agilis* under 1000 x magnification. a) red arrow: neutrophil, black arrows: lymphocytes; b) red arrow: eosinophil, black arrow: lymphocyte; c) monocyte; d) basophil.

The hormone assays were performed in the laboratory of Dr. Rudy Boonstra, at the Centre for the Neurobiology of Stress, University of Toronto Scarborough, Canada. The principle of the immunoassays is the equilibrium of the antigen-antibody binding following the Law of Mass Action (Ekins 1974, Abraham et al. 1977):

$$Ag + Ab \leftrightarrow Ag.Ab$$

The distribution between the bound and the unbound phases is related to the amount of antigen (Ag) in the presence of a limited amount of antibody (Ab). When we have labelled and unlabelled forms of Ag 'competing' for the binding sites of the Ab, the quantity of the two types of Ag binding is proportional to its concentration at the equilibrium. The unlabeled Ag is the hormone of interest and the labelled Ag is the tracer, whose concentration is known. While in

the radioimmunoassay (RIA) the label is a radioactive isotope (*e.g.* ^{125}I, ^{3}H) and the measure is the radioactive counts per minute (cpm), in the enzimeimmunoassay (EIA) the label is an enzyme (*e.g.* biotin) and the measure is optical density (od) levels produced by a colorimetric reaction. However, the unkown hormone concentrations can only be determined based on a standard curve made from known concentrations.

The preparation of the faecal samples for the EIA consisted of four steps: lyophilizing, homogenizing, weighing and extracting. The samples were freeze-dried for 14-16 h using a lyophilizer (LabConco, MO, USA), then frozen in liquid nitrogen and homogenized by crushing with a mortar and pestle. We weighed 50 ± 5 mg of faeces per sample and extracted the faeces by adding 1 mL of 80 % methanol and voxtexing for 30 min at 1450 rpm using a multi-vortexer (IKA VXR Basic Vibrax) (Palme 2005, Palme et al. 2013). Then the extracts were centrifuged for 15 min at 2500 g, and an aliquot of the supernatant was diluted 1:10 in assay buffer.

We used the 5α-pregnane-3ß,11ß,21-triol-20-one EIA (Lab-code: 37e) (Touma et al. 2003), which is used for detection of a broad-spectrum of faecal glucocorticoid metabolites and is produced in the University of Veterinary Medicine, Vienna, Austria. Its application was successful in studies with several rodents (Touma et al. 2004, Lepschy et al. 2007, Nováková et al. 2008, Bosson et al. 2009, Dantzer et al. 2010, 2016) , and marsupials (Fanson et al. 2017). The antibody has the following cross-reactivities: 5α-pregnane-3ß,11ß,21-triol-20-one (100%); 5α-pregnane-3ß,11ß,20ß,21-tetrol (110%); 5α-pregnane-3ß,11ß,17α,21-tetrol-20-one (45%); 5α-androstane-3ß,11ß-diol-17-one (230%); cortisol, corticosterone or metabolites differing at 5α, 3ß- and/or 11ß-ol (< 1 %); progesterone, androstenedione, and dehydroepiandrosterone or their reduced metabolites (< 1 %). The assay was validated for the species by demonstrating parallelism between the standard curve and serially dilutions of faecal extracts ($F = 1.85$, $P = 0.16$; Appendix 1). The intra-assay coefficient of variation was 11.05 %. Low and high faecal extract pools were used as quality controls to measure the interassay precision (Möstl et al. 2005), and their coefficients of variation were 9.80 % and 13.79 %, respectively (n = 23 plates). The assay steps are described in Appendix 2. We analysed faecal extracts again when the coefficient of variation of the duplicates were greater than 15 % and values were out of the standard curve range (with the latter we tried a different dilution).

Faecal cortisol metabolites were calculated using the formula:

$$ng(steroid)/g(faeces) = \frac{pg/well\ x\ ExtractVolume\ (\mu L)\ x\ DilutionFactor}{FaecalWeight\ (g)\ x\ SampleVolume\ (\mu L) x\ 1000},$$

in which pg/well = result from the plate reader; ExtractVolume = volume 80 % methanol used for extraction + faecal weight; DilutionFactor = the dilution pre EIA; FaecalWeight = weight of faeces extracted; SampleVolume = volume transferred to EIA.

We measured the total plasma cortisol using the commercially available ImmuChem^{TM} Cortisol-^{125}I RIA kit (MP Biomedicals; assay steps in Appendix 2). The minimum detection limit of the kit is 1.7 ng/mL and the mean recovery of ^{125}I-cortisol added to plasma was 102.4% (range = 91-117 %). The antibody shows the following cross-reactivities: 11-desoxycortisol – 12.5 %; corticosterone – 5.5 %; 17a-hydroxyprogesterone – 1 %; all other steroids < 1 %. Serially diluted pool plasma of *G. agilis* was parallel to the standard curve with no difference in slopes ($F = 1.494$, $P = 0.25$; Appendix 3). The inter-assay coefficient of variations for the low and high quality controls were 0.33 % and 3.45 %, respectively (n = 3 assays).

We used the maximum corticosteroid-binding capacity (MCBC) to determine plasma corticosteroid-binding globulin (CBG) using dextran-coated charcoal (DCC) to separate the bound from the unbound cortisol (Delehanty et al. 2015; assay steps in Appendix 2). This assay determines the specific bounding (SB) of the CBG indirectly by subtracting the values of the total binding (TB) and the non-specific binding (NSB). The NSB would represent the binding of other plasma proteins, specially albumin, the most abundant one (Peters 1985). Unlike the CBG, that has high affinity and low capacity for glucocorticoids, albumin has low affinity and high capacity. Thereby, it is expected that the CBG saturates before albumin. The TB is obtained by saturating the CBG with labelled hormone so that the other plasma proteins can also bind to the labelled hormone. The NSB is obtained by adding not only labbelled hormone, but also an amount of unlabelled hormone way beyond the CBG binding capacity, so that only the other plasma proteins can bind to the labbelled hormone.

The DCC adsorbs free hormone, but not the CBG-bound hormone, but the removal continually disturbs the equilibrium, so there is a loss of the amount of bound hormone directly related to the time of DCC exposure (Delehanty et al. 2015). Doing the separation quickly and at low temperatures reduces this effect, but it might not be sufficient. For this reason, the results of the MCBC assay were adjusted by a loss-to-charcoal factor. This factor was calculated from the curve of the charcoal adjustment protocol. All the runs were done using the same batch of DCC, so only one adjustment factor was calculated (0.72). We ran the MCBC assays with 1/54, 1/60 and 1/75 plasma dilutions. The inter-assay coefficient of variation was 15.30 % (n = 11 assays).

Free plasma cortisol was calculated using a formula based on the Law of Mass Action (Barsano & Baumann 1989):

$$H_f = \frac{-(MCBC - H_t + 1/K_a) \pm \sqrt{(MCBC - H_t + 1/K_a)^2 - 4(-H_t/K_a)}}{2},$$

in which H_f = free hormone, H_t = total hormone, and K_a = $1/K_d$; K_d = equilibrium dissociation constant for CBG. K_d is species-specific and is estimated from the equilibrium saturation binding curve. This essay involved incubating a fixed amount of plasma in varying concentrations of ^{3}H-cortisol, from < 1 nM to about 15 or 20 nM. Then we used the non-linear regression to fit the equation:

$$y = B_{max} * \left(\frac{x}{x + K_d}\right),$$

in which y = SB, x = free hormone; free hormone = [1 - (TB/total counts)] * starting concentration, B_{max} = maximum binding capacity (of the pooled plasma, different from the MCBC), K_d = equilibrium dissociation constant. When this assay is run at 4 °C, the curve gives information compatible with the MCBC assay, and when it is run at 37 °C, it gives the K_d of the species close to what would be found *in vivo*. A low K_d indicates a strong affinity of the CBG for glucocorticoids, while a high K_d indicates a weak affinity.

Data analyses

To access body condition of the individuals, we used the morphometric measures from their first capture in each capture session. We calculated the final body mass subtracting the mass of the ear-tags (0.5 g) when the animals were already marked. We used the scaled mass index (SMI) (Peig & Green 2009, 2010), which is the predicted body mass of an individual standardized to the mean body size, given by the equation:

$$SMI = M_i \left[\frac{L_0}{L_i}\right]^{b_{SMA}},$$

where M_i and L_i are respectively the body mass and the head-body length of the individual i; b_{SMA} is the scaling exponent of the power function and can be estimated from the equation $b_{SMA} = b_{OLS}/r$, b_{OLS} being the angular coefficient from the regression on ln M and ln

L, and r being the correlation coefficient; L_0 is the mean L or any arbitrary value for the population (Peig & Green 2009, 2010).

We chose this index because it has the advantage of being independent from the size of the animals, in opposition to other condition indexes calculated from the mass and size ratio, and because it can be compared among populations, different from the indexes calculated from regression residuals (Labocha et al. 2014). We tested for between-sex differences in the linear on ln M and ln L, as *G. agilis* is sexually dimorphic in size (Costa et al. 2003), before deciding for the calculation of SMI based on all individuals together or separated by sex.

The following tests were done to the physiological variables to test possible variations in the data that were not the focus of the study but, if not removed or accounted for in the model selections, could cause biased results. The tests were done using a bootstrap procedure (Ong 2014) with 5000 iterations.

For the neutrophil/lymphocyte ratio, the correlation between the readers was tested using data from duplicate smears of the same capture events, each smear counted by each reader. Since the conditions for preparing the blood smears in the field were not the same as they would be in a lab, we tested the homogeneity of the smears by the correlation the correlation between duplicate readings of the same smears. The quality of the slides was also tested comparing two groups, one classified as compacted, and more susceptible of misidentification of leukocytes, and the other classified as non-compacted.

When samples had been prepared with blood from two different methods, from facial and tail veins, we tested for differences between them. That was the case for the neutrophil/lymphocyte ratio, haemoglobin concentration and glucose. In the same way, we tested for differences between physiological data from captures and from recaptures. Only for data from the biological validation we tested for differences between generations. The reason for this was that our primary goal was to capture young, non-reproductive individuals, but we eventually captured some individuals from the previously generation that were still alive.

Quality of the samples was tested in several ways. In faecal samples, presence of urine in the sample was registered and concentrations were tested between the groups with and without the contamination. In biological validation specifically, difference between samples from diarrhea and samples from normal defecation was tested. Cases of diarrhea could underestimate the concentration since the gut passage time was drastically reduced. In blood samples, the index of quality was the colour of the plasma. Dark-coloured plasma could reflect a lower quality of the sample, and consequently a degradation of the studied hormones, than light-coloured plasma.

We used linear and linear mixed-effects models to assess effects on the studied physiological variables neutrophil/lymphocyte ratio (N/L), body condition (SMI), haemoglobin concentration (Hb), glucose (Gl) faecal cortisol metabolites (FCM), total cortisol (CORT), maximum binding capacity (MCBC), and free cortisol (FREE).

We used regression diagnostic tools to investigate if the assumptions of linear regression were met (Altman & Krzywinski 2016a). The assumption of linearity was checked with the residuals vs fitted values plot; the assumption of normality, that is, if the residuals are normally distributed, was checked with the Q-Q plot; and the assumption of constance variance (homoscedasticy) was checked with the scale-location plot. Possible outliers, high-leverage and/or influential points could be found using the residuals vs leverage and the cook's distances plots (Altman & Krzywinski 2016b). Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points. We decided for a transformation of the response variables or the use of link functions by comparing the fit of the global models to the data. The investigated models were: linear; linear with the response variable transformed to natural logarithm; generalized linear using gamma family and log link function; and generalized linear using gamma family and its canonical link function, the inverse function.

The effects investigated in the models were the following:

- Sex: difference between females and males.

- Rep: reproductive status, difference between two classes, reproductive and non-reproductive individuals. Females were reproductive when lactating or had swollen teats; males were considered reproductive when the size of their scrotal testis was > 10 mm. Details in the first chapter.

- M: month adapted to the life cycle of the individuals. Populations of *G. agilis* were seasonal, with discrete generations, with overlap in the end and beginning of the years. In the years 2015 and 2016, we captured individuals from the generations of 2014, 2015, 2016 and 2017. To give more biological meaning to the intra-annual variation, we represented time variation according to the maximum duration of the generations. Therefore, it begins in December, when the juveniles start appearing in the traps, until the second September lived by a few senile individuals. For example, young individuals caught in December 2015 would be represented in December (generation 2016), while the old individuals caught in the session would be in the second December (generation 2015).

- Age: age classes, difference among 4 classes: 3 (juveniles), 4 (subadults), 5 (adults) and 6-7 (seniles). Details in Chapter 1. Since the populations of *G. agilis* were age-structured, this variable could reflect a simpler version of time variation.

- Seas: reproductive season, difference among three classes: pre-reproductive, reproductive and post-reproductive seasons. The pre-reproductive season was from December to June/July, the reproductive season was in September and the second December, and the post-reproductive season was from the second January to the second September. Details in Chapter 1. This variable was a simpler version of time variation.

- Suppl: food supplementation experiment, difference between the control grids (FAL and JB1) and the supplemented grids (JB2 and JB4).

- Grid: variation among the four grids, independently of the food supplementation experiment.

- Time: time inside trap (in min). Covariate to evaluate the possible effect of the capture in the physiological variables.

- T.Blood: time of blood collection (in sec). Covariate to evaluate the possible effect of the handling when collecting blood samples. It was used in CORT, MCBC and FREE.

- Blood: origin of blood sample. N/L, Hb and Gl were obtained with different methods of blood collection, from the facial vein or the tail vein. This variable was used when we found a difference using bootstrap and we had a relatively balanced number of samples from each one.

- Colour: colour of plasma sample. Difference between two classes of samples: dark-coloured plasma could reflect a lower quality of the sample, and consequently in degradation of the studied hormones, than light-coloured plasma.

- Interaction terms: Sex*Rep, Sex*Age, Sex*Seas, Sex*Suppl and Sex*Grid. We chose only a few possible interactions to reduce the number of candidate models. We were interested in the responses between sexes to the biological variables to the experiment. However, we did not use the interaction between sex and month (M) because it would add too many parameters to the models.

To avoid running an extremely large set of candidate models, we did model selection in three steps. First, we used the global model to compare the inclusion of the random intercept effect identification of the animals (1 | ID) because we had repeated measures on the same individuals over the months. Second, we compared among models with only one fixed effect and with no effect (null model) to investigate which one would be the most important for the variation in the response variable. In addition, in this step we selected which variables would

be present in the next model selection depending on their ranks: M, Age or Seas, different forms of time variation, and Suppl or Grid, different forms of spatial variation. Third, we built a set of models in which all included the fixed effect selected previously (and the random effect if it was the case). Models differed in the presence or absence of the remaining variables and possible interactions. For this reason, each model selection had a different number of candidates in the final step.

Model selection for the biological validation of the faecal samples varied from the others. The effects in each model were: time inside trap divided in 7 groups (from 00 h to 18 h at intervals of 3 hours; Group), sex, time of capture standardized in minutes after sunset (Time.cap), and no effect (.). Since we had a wide range in time of faecal samples collection in the biological validation, from early evening to afternoon, and the time of capture was represented by groups instead of continuous data, we could test for possible variation in FCM from the circadian rhythm (Time.cap). We did not use any interaction term because of the limited sample size.

We evaluated the plausibility of the candidate models based on the Akaike's information criterion corrected for small samples (AICc; Burnham & Anderson 2002). We used for comparisons the AICc difference between models and the one with the lowest value (ΔAICc), and Akaike weight (wi), which reflect the relative evidence of fit of a model to the data, proportional to the candidate set of models (Burnham & Anderson 2002). We used model averaged estimates to calculate predicted values of the response variables and ploted them against the variables from the best models. Analyses were run using lme4 (Bates et al. 2015) and MuMIn (Barton 2018) packages in R, version 3.4.2 (R Core Team 2017).

Results

We registered 1087 captures of 314 individuals of *G. agilis*, 135 females and 179 males, during the population study. We obtained the records of time in trap for 782 captures for the studied species. We collected 1517 faecal samples and 665 plasma samples during the study.

Neutrophil/lymphocyte ratio

The correlation between duplicate readings from the same blood smears was high for both readers (reader 1: 0.94, 95 % CI 0.89 to 0.97, N = 624; reader 2: 0.90, 95 % CI 0.82 to

0.94, N = 216), which assured the homogeneity of the smears. A high correlation between duplicate smears from the same capture event (0.85, 95 % CI 0.80 to 0.89, N = 1100) demonstrated the readings were also equivalent between the readers.

The mean difference in values of N/L ratio between the compacted and the non-compacted blood smears was not equal to zero (-0.24, 95 % CI -0.34 to -0.15). While the mean for the compacted smears was 0.41 (95 % CI 0.34 to 0.50, N = 103), the mean for the non-compacted smears was 0.66 (95 % CI 0.60 to 0.71, N = 517). Therefore, we did not use data from compacted smears in the models.

We did not find a difference between the groups of blood smears prepared with blood from two different veins (0.08, 95 % CI -0.02 to 0.18). The mean for smears from the tail vein was 0.66 (95 % CI 0.59 to 0.74, N = 272) and the mean for the smears from the facial vein was 0.58 (95 % CI 0.52 to 0.65, N = 341). The result was similar after we excluded values from the compacted smears (difference: 0.02, 95 % CI -0.08 to 0.13; mean of tail: 0.67, 95 % CI 0.60 to 0.75, N = 243; mean of facial: 0.65, 95 % CI 0.58 to 0.73, N = 268).

Similarly, there was no difference between values from captures and recaptures (0.02, 95 % CI -0.09 to 0.12). The mean of N/L ratio was 0.62 (95 % CI 0.57 to 0.68, N = 506) for captures and 0.60 (95 % CI 0.52 to 0.70, N = 114) for recaptures. Means increased after the exclusion of the compacted smears, but the confidence interval of the difference between groups remained overlapping with zero (difference: 0.01, 95 % CI -0.11 to 0.14; mean of captures: 0.66, 95 % CI 0.60 to 0.72, N = 429; mean of recaptures: 0.65, 95 % CI 0.55 to 0.76, N = 88).

The fit of the global model to the data was best when the response variable was transformed to the natural logarithm (Appendix 4). Six data points were identified as possible outliers, high-leverage and/or influential points, but none changed the pattern of the results when removed. Only two were removed from the analysis due to the possibility of error in measure.

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 1). The first selection of fixed effects resulted in two top-ranked models with similar values of ΔAICc describing variation over time: one over the months (M), and the other specifically among pre, reproductive and post reproductive periods (Seas). For this reason, we used both time variables in the second model selection of fixed effects, although not together in the models. We chose the variable food supplementation (Suppl) over the variable grid based on the model ranks.

Among 88 competing models, the first 11 models summed weight of evidence 0.90 and were model averaged (Table 1, Appendix 5). All chosen models had the variables reproductive

season (Seas) instead of month, and the reproductive status (Rep), as well as the covariate time inside trap (Time). The variable sex was included in 9 models and had the relative importance of 0.63, and of the variable food supplementation was in 6 models, with a relative importance of 0.36.

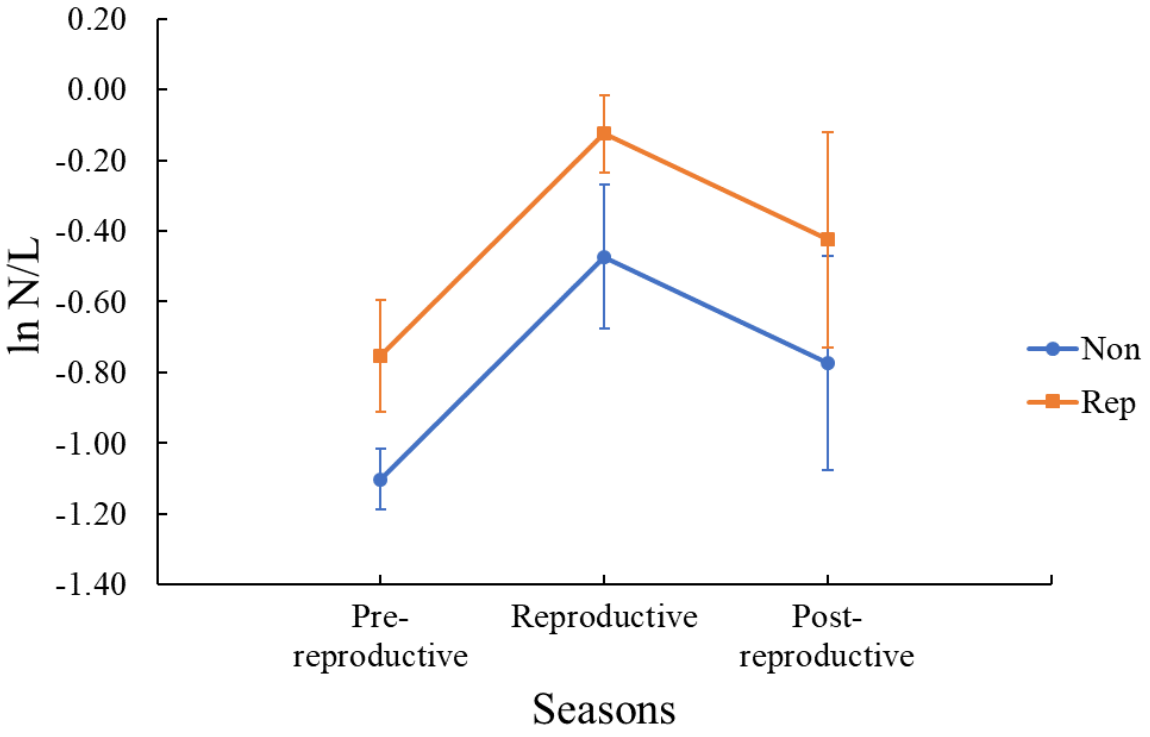
The neutrophil/lymphocyte ratio was highest during the reproductive season and higher among reproductive individuals than among non-reproductive individuals (Figure 4a). Confidence intervals did not overlap between the groups in the pre- and reproductive seasons but overlapped in the post-reproductive season. On the other hand, the difference between sexes was small since confidence intervals were highly overlapped in all three periods (Figure 4b). The coefficient for time in the trap was positive but small, and confidence interval overlapped with zero (Appendix 6). Differences between control and supplemented areas were not shown graphically because the coefficient was also small.

Table 1. Model selection for the log-transformed neutrophil/lymphocyte ratio of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and reproductive season (Sex*Seas), sex and grid (Sex*Grid), sex and experiment (Sex*Suppl), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 5).

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid	19	959.93	0.00	1.00	-460.13
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid + (1 | ID)	20	1013.69	53.76	0.00	-485.92
Fixed effects 1					
M[a]	9	1061.24	0.00	0.82	-521.44
Seas[a]	4	1064.22	2.98	0.18	-528.07
Rep	3	1095.71	34.47	0.00	-544.83
Time	3	1102.80	41.56	0.00	-548.37
Age[a]	5	1204.61	143.37	0.00	-597.25
.	2	1213.88	152.64	0.00	-604.93
Suppl[b]	3	1215.20	153.96	0.00	-604.58
Sex	3	1215.62	154.38	0.00	-604.79
Grid[b]	5	1218.51	157.27	0.00	-604.20
Fixed effects 2					

Seas + Time + Rep	6	951.69	0.00	0.17	-469.76
Seas + Time + Sex + Rep + Sex*Seas	9	951.86	0.17	0.16	-466.74
Seas + Time + Sex + Rep + Suppl + Sex*Seas	10	952.80	1.11	0.10	-466.16
Seas + Time + Rep + Suppl	7	952.87	1.18	0.10	-469.32
Seas + Time + Sex + Rep + Sex*Seas + Sex*Rep	10	952.95	1.26	0.09	-466.24
Seas + Time + Sex + Rep	7	953.74	2.05	0.06	-469.75
Seas + Time + Sex + Rep + Sex*Rep	8	953.80	2.11	0.06	-468.75
Seas + Time + Sex + Rep + Suppl + Sex*Seas + Sex*Rep	11	953.83	2.14	0.06	-465.63
Seas + Time + Sex + Rep + Suppl + Sex*Seas + Sex*Suppl	11	954.56	2.87	0.04	-465.99
Seas + Time + Sex + Rep + Suppl + Sex*Rep	9	954.94	3.24	0.03	-468.28
Seas + Time + Sex + Rep + Suppl	8	954.94	3.25	0.03	-469.31

a)



b)

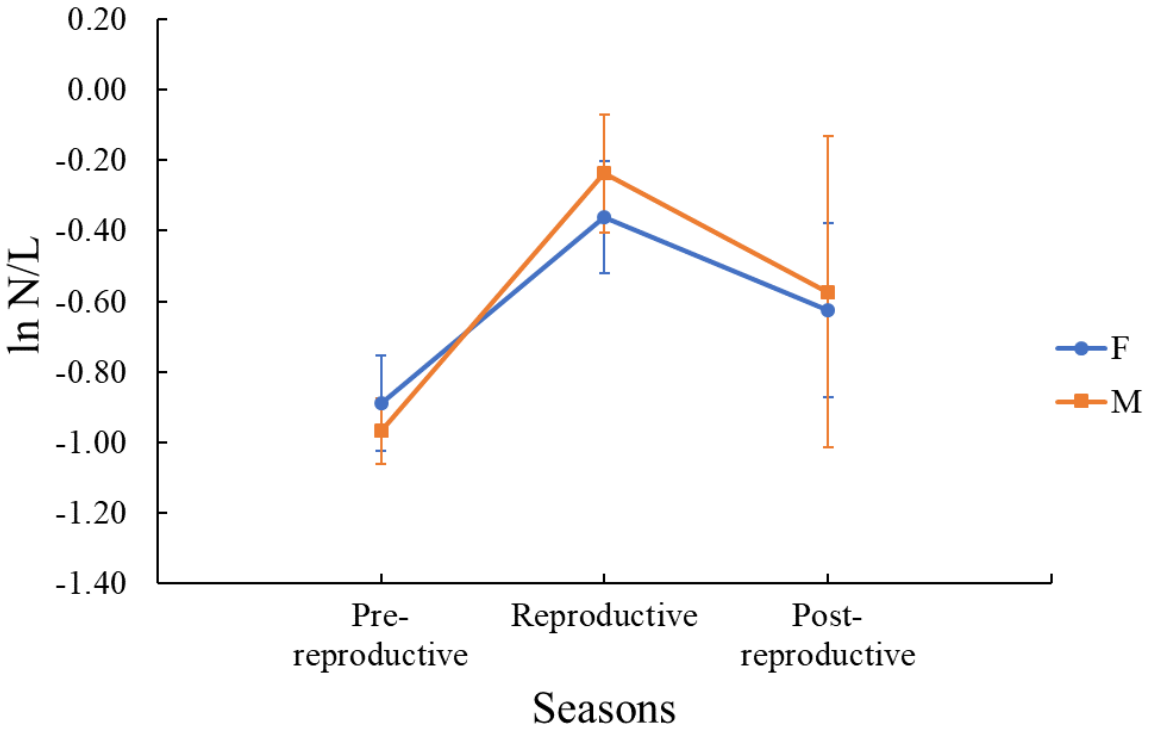


Figure 4. Estimates and 95 % confidence intervals from the model averaging of the log-transformed neutrophil/lymphocyte ratio (ln N/L) of *Gracilinanus agilis* for pre-reproductive, reproductive and post-reproductive seasons between a) non-reproductive and reproductive individuals and b) females and males.

Body condition

We obtained 1109 records of body mass (M_i) and head-body length (L_i). We removed three extreme values we considered as wrong measures (L_i = 144 mm). Model selection for M_i to L_i relationship resulted in a difference in AICc > 20 between the model including interaction with and the model without sex (Table 2). Therefore, we calculated SMI for females and males separately.

The fit of the global model to the data when the response variable was transformed to the natural logarithm was similar to when a link function was used, so we opted for the transformation (Appendix 4). Four data points were identified as possible outliers, high-leverage and/or influential points. Although the first model increased its weight in most cases of removal, the difference was not sufficient to change the pattern of the results. Nevertheless, we removed all four points because they were likely result of error in body or weight measures.

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 3). The first selection of fixed effects had as the single best model the one representing variation along the months (M). The model containing effect of the food supplementation experiment (Suppl) had a lower AICc comparing to the model for unique differences among grids (Grid).

We built 26 models based on the result of the previous selections. The first three models were the best ones among the candidates to describe the variation in body condition of the individuals, accounting together for 1.0 of weight (Table 3, Appendix 7). The three models had in common the variables sex, variation over the months, reproduction status and interaction between sex and reproduction status. The difference among them was the presence or absence of the food supplementation effect and its interaction with sex. The relative importance of food supplementation was 0.85. The covariable time inside trap did not appear among the top-ranked models.

Body condition of females and males reached its lowest value in December, increased in January, and then from June/July to September and the second December (Figure 5a). The estimates slightly decreased from the second January to the second June/July, and increased again in the second September. The mean estimate of body condition of males was higher than of females, and the difference between sexes increased when they were reproductively active (Figure 5b). Differences between control and supplemented areas were not shown graphically because the coefficient was small (Appendix 8).

Table 2. Model selection of the linear models of natural log of the body mass (M_i) against natural log head-body length (L_i) with and without the effect of sex. K is the number of parameters, AICc is the Akaike's information criterion corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, LL is the log-likelihood of the models.

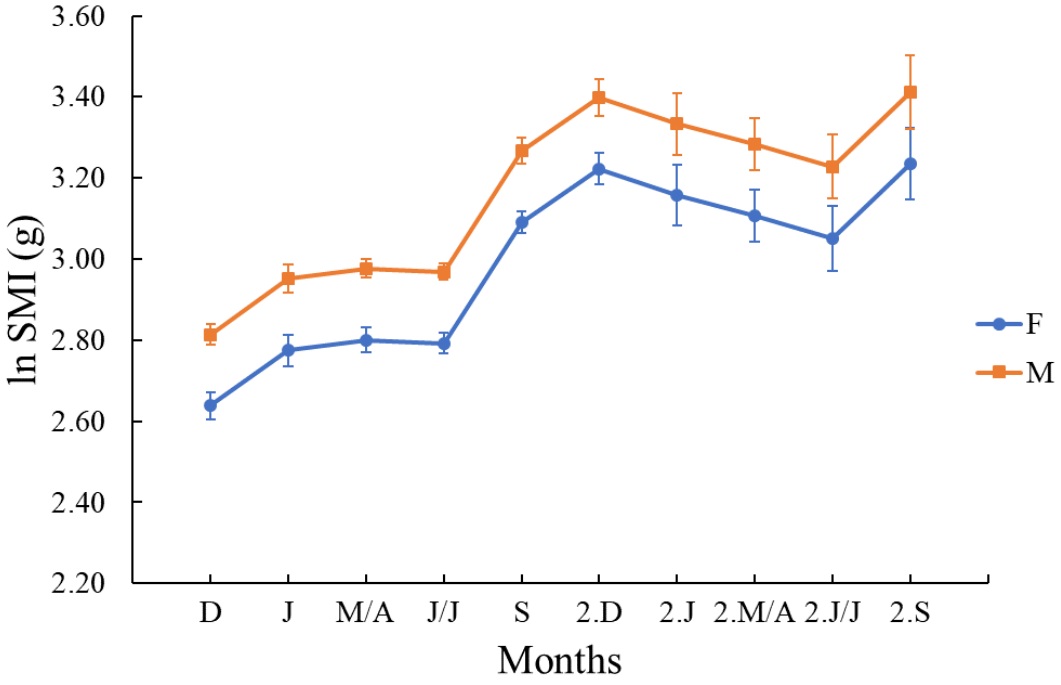
Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
$\ln M_i \sim \ln L_i * Sex$	5	-785.16	0.00	1.00	397.61
$\ln M_i \sim \ln L_i$	3	-760.83	24.33	0.00	383.43

Table 3. Model selection for the log-transformed body condition of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and grid (Sex*Grid), sex and experiment (Sex*Suppl), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 7).

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid	20	-1058.51	0.00	1.00	549.86
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid + (1 | ID)	21	-951.57	106.94	0.00	497.45
Fixed effects 1					
M[a]	11	-704.29	0.00	1.00	363.27
Rep	3	-567.04	137.26	0.00	286.53
Seas[a]	4	-487.55	216.75	0.00	247.79
Age[a]	5	-186.30	517.99	0.00	98.18
Time	3	86.45	790.74	0.00	-40.21
Sex	3	89.30	793.60	0.00	-41.64
Suppl[b]	3	159.27	863.56	0.00	-76.62
.	2	160.57	864.87	0.00	-78.28
Grid[b]	5	160.72	865.02	0.00	-75.34
Fixed effects 2					
M + Sex + Rep + Suppl + Sex*Rep	15	-1133.60	0.00	0.63	582.02

M + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	16	-1131.59	2.01	0.23	582.05
M + Sex + Rep + Sex*Rep	14	-1130.69	2.91	0.15	579.54

a)



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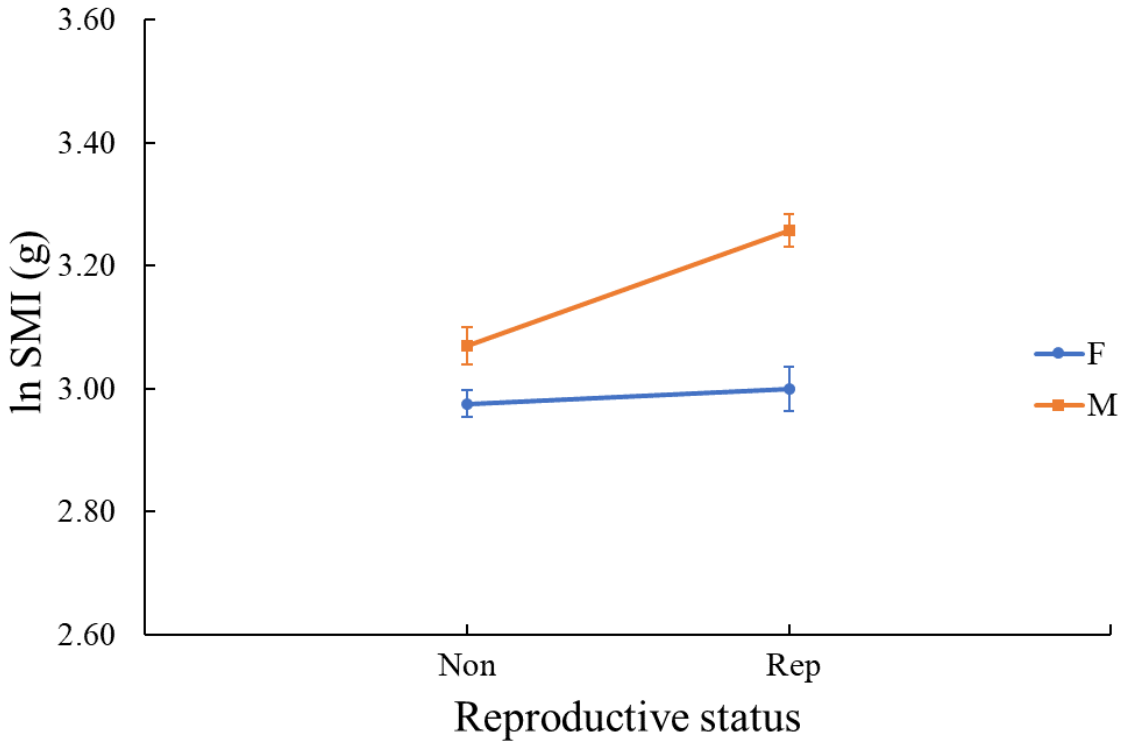


Figure 5. Estimates and 95 % confidence intervals from the model averaging of the log-transformed body condition (ln SMI) of *Gracilinanus agilis* for females and males a) over the months adapted to the life cycle of the individuals, and b) between non-reproductive and reproductive individuals. D: December; J: January; M/A: March/April; J/J: June/July; S: September; 2.: second month of the same generation.

Haemoglobin concentration

Samples from different origins of peripheral blood differed in haemoglobin concentration (Hb; -0.75, 95 % CI -1.09 to -0.43). The mean Hb for the tail vein (13.54 g/dL, 95 % CI 13.27 to 13.82, N = 164) was lower than the mean for the facial vein (14.30 g/dL, 95 % CI 14.12 to 14.48, N = 454). The mean difference of Hb between captures and recaptures also differed (0.75, 95 % CI 0.35 to 1.17), mean value from individuals first captures in the sessions (14.23 g/dL, 95 % CI 14.07 to 14.40, N = 509) was higher than from their recaptures (13.49 g/dL, 95 % CI 13.09 to 13.85, N = 109). We chose to remove data from recaptures to avoid adding more variation and complexity to the models, and to add the variable origin of blood to account for this difference instead of removing more data points.

There was no need to log-transform the response variable or to use a non-Gaussian family in the global model (Appendix 4). Five data points were identified as possible outliers, high-leverage and/or influential points, but none changed the pattern of the results when removed.

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 4). The first selection of fixed effects had as the single best model the one with the covariate time inside trap (Time). The models with variation along the months (M) and differences among grids (Grid) performed better than their simpler versions, variation among seasons (Seas) and age classes (Age), directly competing with the former, and effect of the food supplementation experiment (Suppl) competing with the latter.

We built 52 models based on the result of the previous selections. We chose the first seven of them to describe the variation in the haemoglobin concentration as they summed 0.92 of weight (Table 4, Appendix 9). The variables time inside trap, variation over the months and grid appeared in all chosen models. The relative importance of reproduction status was 0.85, of sex was 0.73, and of origin of blood was 0.71.

The variations described in the model averaging of the haemoglobin concentration were summarized in Figure 6. The mean estimate of haemoglobin concentration was the lowest in JB1, one of the control areas (Figure 6a). Hb estimates were similar from December to June/July, then had a peak in the first September and a decline in the second December (Figure 6b). After that, estimates varied with higher confidence intervals. Males had higher estimates than females, and reproductive individuals had higher estimates than non-reproductive individuals, although the uncertainty is high (Figure 6c). The estimate for the tail vein was lower

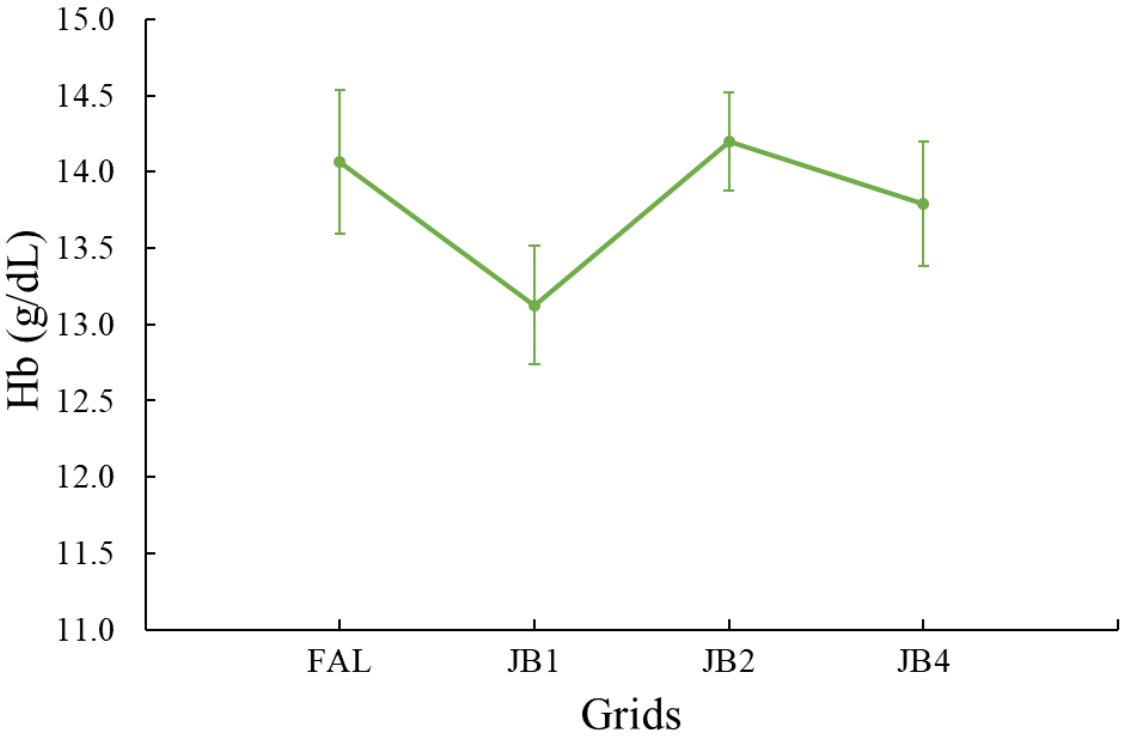
than for the facial vein, confirming the bootstraped tests done before model selection but with higher confidence intervals (Figure 6d). The coefficient for time in the trap was positive but small (Appendix 10).

Table 4. Model selection for the haemoglobin concentration of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, origin of the blood sample (Blood), time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and grid (Sex*Grid), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 9).

Models	K	AICc	ΔAICc	w	LL
Random effect					
M + Sex + Rep + Grid + Blood + Time + Sex*Rep + Sex*Grid	20	1859.47	0.00	1.00	-908.82
M + Sex + Rep + Grid + Blood + Time + Sex*Rep + Sex*Grid + (1 | ID)	21	1881.99	22.51	0.00	-918.98
Fixed effects 1					
Time	3	1995.33	0.00	1.00	-994.64
M[a]	9	2031.80	36.47	0.00	-1006.72
Rep	3	2068.37	73.04	0.00	-1031.16
Seas[a]	4	2087.17	91.84	0.00	-1039.54
Age[a]	5	2098.94	103.61	0.00	-1044.41
Grid[b]	5	2101.94	106.61	0.00	-1045.91
Blood	3	2108.22	112.89	0.00	-1051.09
Suppl[b]	3	2114.58	119.25	0.00	-1054.27
Sex	3	2115.23	119.90	0.00	-1054.59
.	2	2124.69	129.35	0.00	-1060.33
Fixed effects 2					

Time + Blood + M + Sex + Rep + Grid	16	1852.73	0.00	0.34	-909.78
Time + Blood + M + Sex + Rep + Grid + Sex*Rep	17	1854.28	1.55	0.16	-909.48
Time + Blood + M + Rep + Grid	15	1854.44	1.71	0.14	-911.71
Time + M + Sex + Rep + Grid	15	1854.90	2.17	0.11	-911.93
Time + Blood + M + Sex + Grid	15	1855.77	3.04	0.07	-912.37
Time + M + Sex + Rep + Grid + Sex*Rep	16	1856.47	3.74	0.05	-911.65
Time + M + Rep + Grid	14	1856.61	3.88	0.05	-913.85

a)


15.0
14.5
14.0
13.5
13.0
12.5
12.0
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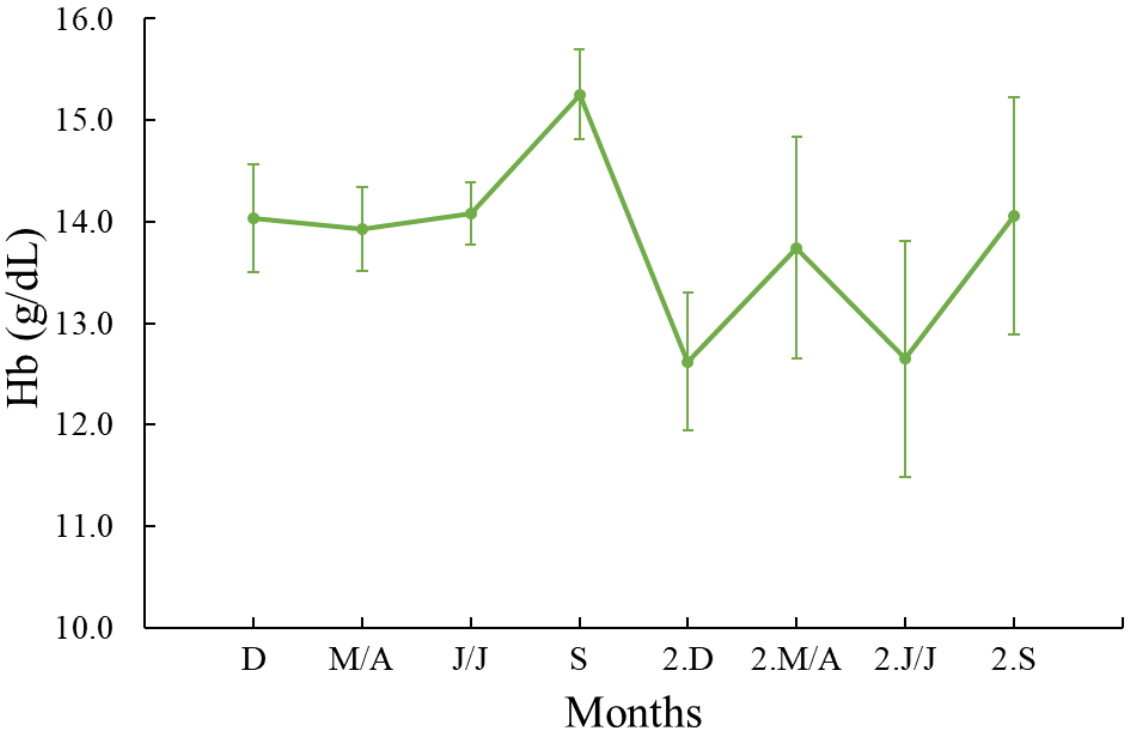
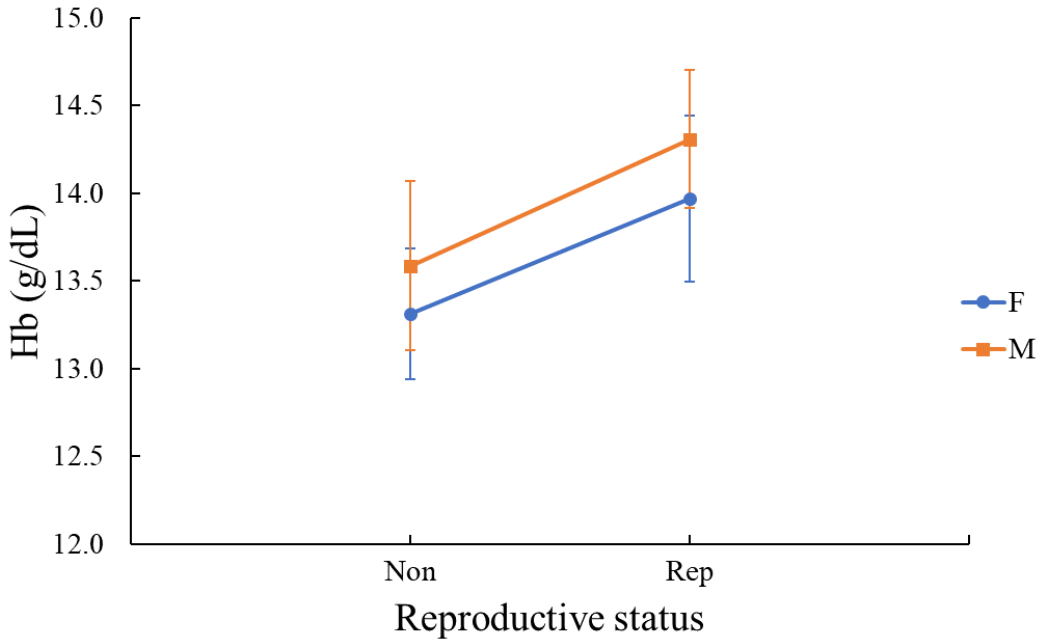
11.0
Hb (g/dL)
FAL
JB1
JB2
JB4
Grids

b)


16.0
15.0
14.0
13.0
12.0
11.0
10.0
Hb (g/dL)
D
M/A
J/J
S
2.D
2.M/A
2.J/J
2.S
Months

c)



d)

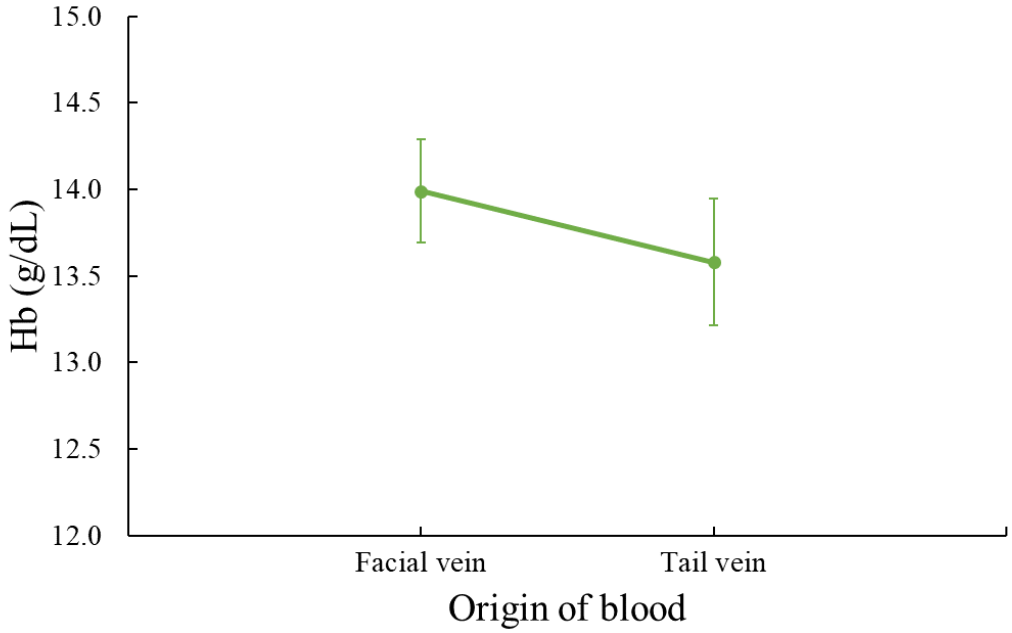


Figure 6. Estimates and 95 % confidence intervals from the model averaging of the haemoglobin concentration (Hb) of *Gracilinanus agilis*. a) mean differences among control (FAL and JB1) and supplemented (JB2 and JB4) grids; b) variation over the months adapted to the life cycle of the individuals; c) estimates of females and males with non-reproductive and reproductive status; and d) estimates for samples collected from facial and tail veins. D: December; M/A: March/April; J/J: June/July; S: September; 2.: second month of the same generation.

Glucose

Samples from different origins of peripheral blood differed in glucose concentration (32.90, 95 % CI 7.21 to 64.68). The mean glucose for the tail vein (110.50 mg/dL, 95 % CI 85.12 to 142.63, N = 8) was higher than the mean for the facial vein (77.41 mg/dL, 95 % CI 75.07 to 79.80, N = 607). We chose to remove data from tail vein samples. The confidence intervals of the mean difference of glucose between captures and recaptures overlapped with zero (-5.73, 95 % CI -12.81 to 1.02). The mean value from individuals first captures in the sessions was 76.66 mg/dL (95 % CI 74.07 to 79.41, N = 489) and from individuals recaptures was 82.44 mg/dL (95 % CI 76.66 to 89.15, N = 126). The result was similar after we excluded values from the tail vein samples (difference: -4.82, 95 % CI -11.84 to 1.51; mean of captures: 76.45 mg/dL, 95 % CI 73.81 to 79.21, N = 483; mean of recaptures: 81.37 mg/dL, 95 % CI 75.56 to 87.80, N = 124).

The fit of the global model to the data was best when the response variable was transformed to the natural logarithm (Appendix 4). Six data points were identified as possible outliers, high-leverage and/or influential points, but none changed the pattern of the results when removed. None was removed from the analysis because there was no indication of error in measure.

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 5). The model representing variation along the months (M) was the first-ranked model in the first selection of fixed effects. The model with differences among grids (Grid) had a lower AICc than the one with the food supplementation experiment (Suppl).

We chose the first three among 26 models to describe the variation in the glucose concentration and together they had a weight of evidence of 0.95 (Table 5, Appendix 11). The variables variation over the months, time inside trap, reproduction status and grid appeared in those three models. The first model was the simplest of them, and for each additional variable (sex and interaction) the increase in ΔAICc was around 2. The relative importance of sex was 0.37.

The mean estimate of glucose concentration was the highest in JB1, one of the control grids, and it was closer to JB4, a food supplemented grid, than to FAL, the second control grid (Figure 7a). Estimates fluctuated over the months and had a peak in the second June/July, but confidence intervals were higher for the three last months (Figure 7b). Reproductive individuals had higher estimates than non-reproductive individuals, but confidence intervals overlapped

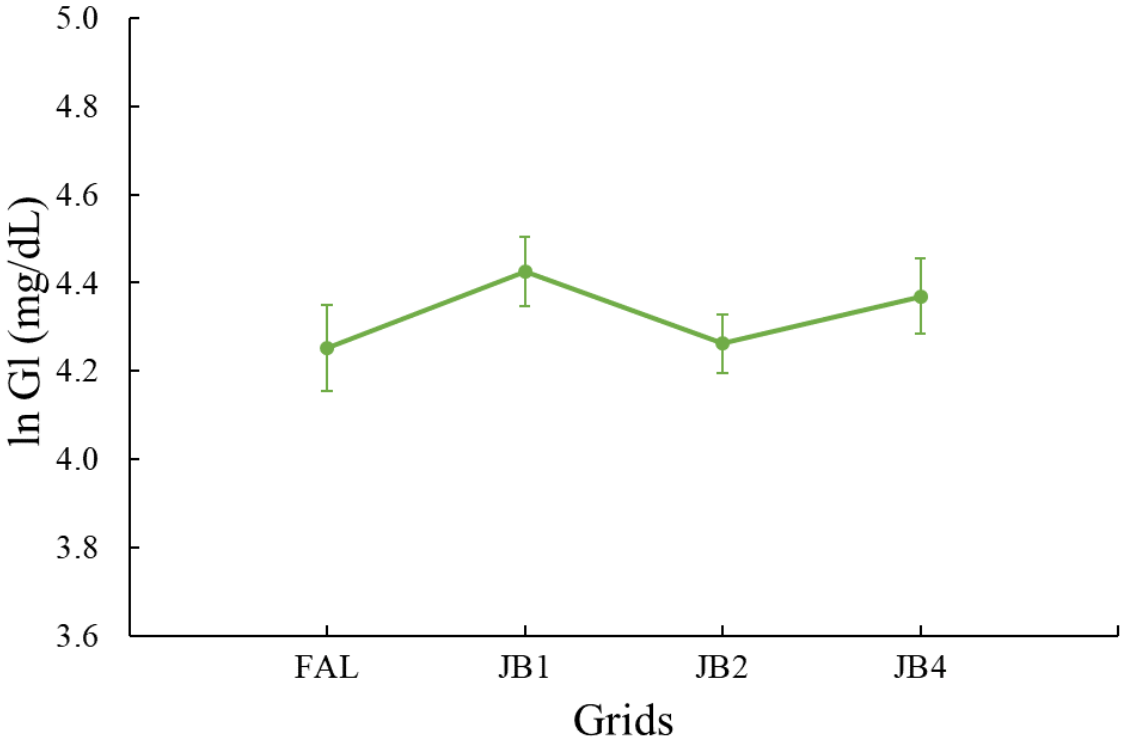
from the second December to the second September. The difference between females and males was not apparent given the small estimates for both the main effect and the interaction coefficients (Appendix 12). The coefficient for time in the trap was positive but small.

Table 5. Model selection for the glucose concentration of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and grid (Sex*Grid), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 11).

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid	18	541.16	0.00	1.00	-251.96
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid + (1 | ID)	19	613.38	72.22	0.00	-286.99
Fixed effects 1					
M[a]	9	577.66	0.00	0.51	-279.68
Rep	3	579.32	1.66	0.22	-286.64
Time	3	579.53	1.87	0.20	-286.74
Seas[a]	4	581.99	4.32	0.06	-286.96
Age[a]	5	593.60	15.94	0.00	-291.75
Grid[b]	5	599.81	22.15	0.00	-294.86
Suppl[b]	3	609.70	32.04	0.00	-301.83
.	2	610.83	33.17	0.00	-303.40
Sex	3	611.39	33.73	0.00	-302.67
Fixed effects 2					
M + Time + Rep + Grid	14	518.86	0.00	0.58	-245.05

M + Time + Sex + Rep + Grid	15	520.96	2.11	0.20	-245.05
M + Time + Sex + Rep + Grid + Sex*Rep	16	521.38	2.53	0.16	-244.20

a)



b)

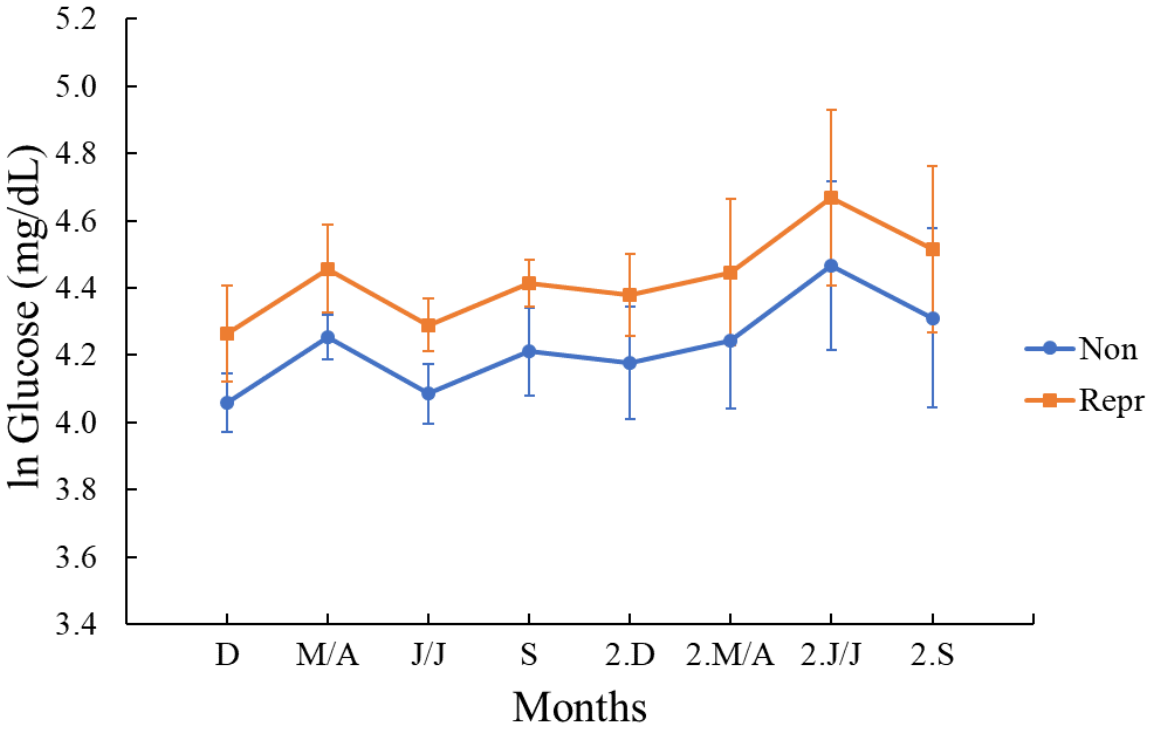


Figure 7. Estimates and 95 % confidence intervals from the model averaging of the log-transformed glucose concentration (ln Gl) of *Gracilinanus agilis*. a) mean differences among control (FAL and JB1) and supplemented (JB2 and JB4) grids; and b) variation over the months adapted to the life cycle of the individuals, grouped according to their reproductive status.

Biological validation of faecal cortisol metabolites

We collected 65 faecal samples, 31 samples from females and 34 samples from males, during the biological validation fieldwork. We did not find a difference in faecal cortisol metabolites (FCM) between first captures and recaptures (78.44, 95 % CI -87.62 to 293.07), considering here the captures of the entire life of the individuals and not inside the capture session. The mean FCM was 504.25 ng/g (faeces) (95 % CI 364.05 to 700.66, N = 29) for captures and 422.36 ng/g (faeces) (95 % CI 343.12 to 513.88, N = 32) for recaptures.

The mean difference in FCM between the faecal samples from diarrhea and the rest of samples was not equal to zero (-357.77, 95 % CI -480.16 to -250.17), even when considered only group 00 h (-206.35, 95 % CI -500.97 to -17.35). The mean of the cases of diarrhea was 123.64 ng/g (faeces) (95 % CI 74.19 to 201.07, N = 3) while the mean of normal faecal samples was 480.85 ng/g (faeces) (95 % CI 396.09 to 587.36, N = 58) and 333.16 ng/g (faeces) (95 % CI 157.54 to 610.03, N = 5) when considering only group 00 h. Therefore, we did not use data from diarrhea samples.

There was no mean difference in FCM between the cases of urine contamination in the samples (745.52, 95 % CI -22.71 to 1915.10), even when considered only samples from the groups 09 h and 12 h, the ones that had contamination (722.89, 95 % CI -56.26 to 1870.49). The mean of the cases of urine contamination was 1199.08 ng/g (faeces) (95 % CI 405.28 to 2378.874, N = 3) while the mean of normal faecal samples was 443.39 ng/g (faeces) (95 % CI 371.36 to 522.55, N = 55) and 464.65 ng/g (faeces) (95 % CI 354.19 to 593.26, N = 18) when considering only groups 09 h and 12 h.

There was no mean difference in FCM between the two generations of individuals (-96.68, 95 % CI -244.25 to 44.70), even when considered only samples from the groups 06 h, 09 h and 12 h, the ones that had old individuals (-119.51, 95 % CI -343.56 to 53.02). The mean of the group of old individuals was 393.90 ng/g (faeces) (95 % CI 300.73 to 500.87, N = 6) while the mean of the group of young individuals was 489.77 ng/g (faeces) (95 % CI 395.25 to 609.56, N = 52) and 513.30 ng/g (faeces) (95 % CI 377.58 to 708.48, N = 27) when considering only groups 06 h, 09 h and 12 h.

Since the number of samples of the biological validation is small, and the confidence intervals are large for both the results for the difference urine-contaminated vs. good samples and young vs. old individuals, model selection and model averaging were presented considering all samples (N = 58) and removing urine-contaminated and old individuals (N = 49). The fit of the global model to the data was best when the response variable was transformed to the natural

logarithm (Appendix 13). Four data points were identified as possible outliers, high-leverage and/or influential points, but only one was removed from the analysis because there was a possibility of error in measure (point 37 in the first analysis and point 31 in second analysis, both points represent the same sample).

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 6). The rank of the candidate models varied between the scenarios of including or excluding samples from urine contamination and old individuals. In the first case, the best model contained the covariate time of capture, and in the second case, the best model was without any effect. However, models were very close to each other in terms of in ΔAICc in both scenarios. The mean estimates of FCM did not vary neither between sexes nor among the groups of time inside trap since confidence intervals highly overlapped (Figure 8). The effect of time of capture was negative but small (Appendix 14).

Table 6. Results of the selection of linear models of faecal metabolites for the faecal metabolites (FCM) from the biological validation of *Gracilinanus agilis*. The random effect was the identity variable (ID) and the fixed effects were: time inside trap divided in 7 groups from 00 h to 18 h at intervals of 3 hours (Group), sex, time of capture standardized in minutes after sunset (Time.cap), and no effect (.). K is the number of parameters, AICc is the Akaike's information criterion corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models.

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
a) N = 57					
Random effect					
Group + Sex + Time.cap	10	112.46	0.00	1.00	-43.79
Group + Sex + Time.cap + (1 | ID)	11	140.36	27.90	0.00	-56.18
Fixed effects					
Time.cap	3	110.96	0.00	0.22	-52.25
Time.cap + Group	9	111.08	0.13	0.20	-44.59
Time.cap + Sex	4	111.32	0.37	0.18	-51.27
Group + Sex + Time.cap	10	112.46	1.50	0.10	-43.79
.	2	112.55	1.59	0.10	-54.16
Group	8	112.84	1.88	0.09	-46.92
Sex	3	113.16	2.20	0.07	-53.35
Group + Sex	9	114.34	3.38	0.04	-46.25
b) N = 48					
Random effect					
Group + Sex + Time.cap	10	99.72	0.00	1.00	-36.80
Group + Sex + Time.cap + (1 | ID)	11	140.36	40.64	0.00	-56.18
Fixed effects					
.	2	92.69	0.00	0.33	-44.21
Time.cap	3	93.02	0.33	0.28	-43.23

Sex	3	94.16	1.47	0.16	-43.81
Time.cap + Sex	4	94.41	1.72	0.14	-42.73
Group	8	96.91	4.22	0.04	-38.61
Time.cap + Group	9	97.12	4.43	0.04	-37.13
Group + Sex	9	99.45	6.76	0.01	-38.36
Group + Sex + Time.cap	10	99.72	7.03	0.01	-36.80

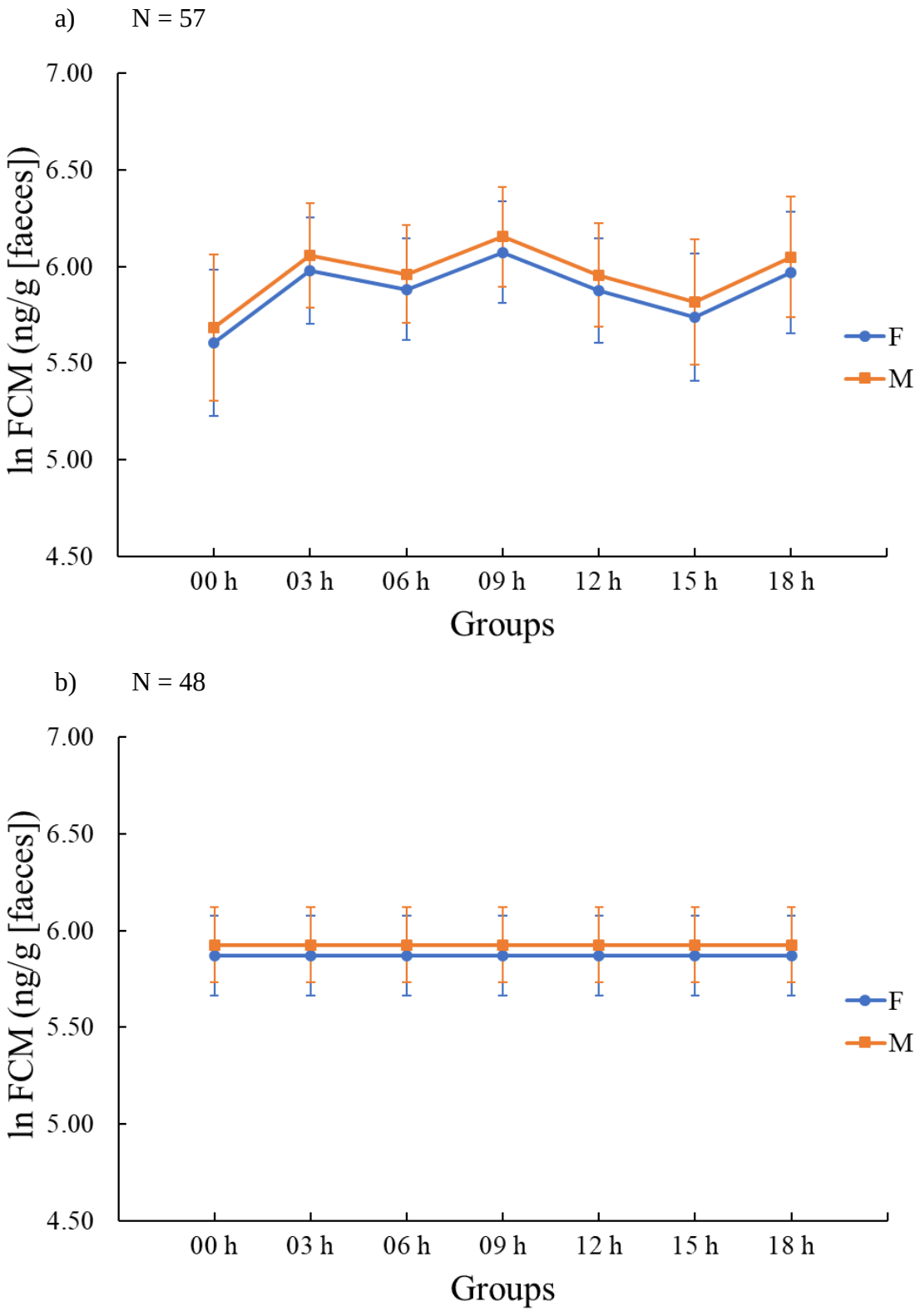


Figure 8. Estimates and 95 % confidence intervals from the model averaging of the log-transformed faecal cortisol metabolites (ln FCM) of *Gracilinanus agilis* from the biological validation. Results were presented for females and males and for each group of time inside trap, considering a) all samples (N = 57) and b) removing urine-contaminated and old individuals (N = 48).

Faecal cortisol metabolites monitoring

From a total of 1517 faecal samples, we analysed 531 samples among the ones collected in the first captures of sessions, 258 from females and 273 from males.

The correlation between duplicate faecal samples from the same capture event with and without urine contamination was high (0.99, 95 % CI 0.97 to 1.00, N = 8). However, the mean difference between contaminated and non-contaminated faecal samples was not equal to zero (-739.24, 95 % CI -1011.36 to -471.21). While the mean for the contaminated samples was 664.54 ng/g (faeces) (95 % CI 497.61 to 851.81, N = 22), the mean for the non-contaminated samples was 1402.88 ng/g (faeces) (95 % CI 1215.75 to 1633.33, N = 509). Therefore, we did not use data from urine-contaminated samples in the models.

The fit of the global model to the data was best when the response variable was transformed to the natural logarithm (Appendix 4). Five data points were identified as possible outliers, high-leverage and/or influential points, but none changed the pattern of the results when removed. We removed three points from the analysis due to the possibility of error in measure (points 141, 326 and 349).

The model including the random variable identity of the animals had a poor fit, so model selection was done only with the fixed effects (Table 7). The first selection of fixed effects had as the single best model the variation over the months (M). The model containing effect of the food supplementation experiment (Suppl) had lower AICc than the model for unique differences among grids (Grid), which ranked last.

We built 26 models based on the result of the previous selections. We chose the first seven of them to describe the variation in the faecal metabolites, which represents a cumulative weight of 0.90 (Table 7, Appendix 15). The variables variation over the months, time inside trap, and sex were in all chosen models. The relative importance of food supplementation was 0.86 and that of reproduction status was 0.47.

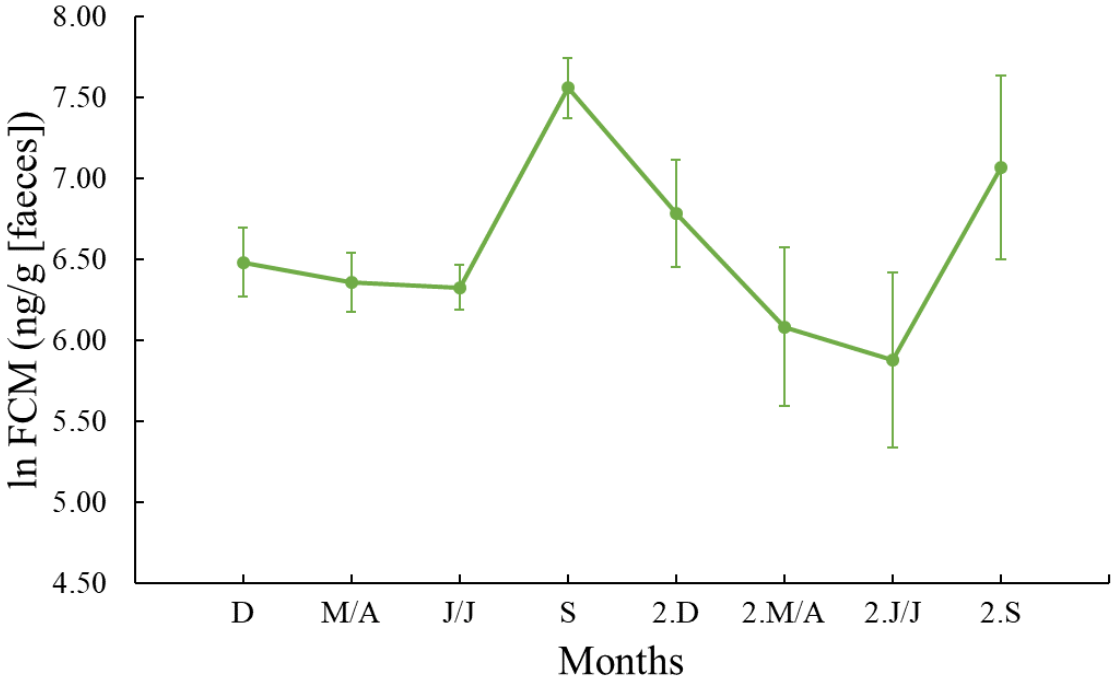
FCM estimates were similar from December to June/July, then had a peak in the first September, followed by a decline from the second December to the second June/July, and another peak in the second September (Figure 9a). Males had higher estimates than females, and supplemented areas had higher estimates than control areas, but with highly overlapped confidence intervals (Figure 9b). Differences between reproductive and non-reproductive individuals were not shown graphically because the coefficients for the main effect and the interaction were small (Appendix 16). The coefficient for time in the trap was positive but small.

Table 7. Model selection for the log-transformed faecal metabolites of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The random effect was the identity variable (ID) and the fixed effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and grid (Sex*Grid), sex and experiment (Sex*Suppl), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 15).

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Random effect					
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid	19	1198.66	0.00	1.00	-579.52
M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid + (1 | ID)	20	1253.11	54.45	0.00	-605.66
Fixed effects 1					
M[a]	9	1283.14	0.00	1.00	-632.39
Seas[a]	4	1297.26	14.12	0.00	-644.59
Time	3	1335.14	51.99	0.00	-664.54
Rep	3	1341.92	58.78	0.00	-667.94
Age[a]	5	1373.81	90.66	0.00	-681.84
Suppl[b]	3	1384.03	100.89	0.00	-688.99
Sex	3	1384.32	101.18	0.00	-689.14
.	2	1385.21	102.07	0.00	-690.59
Grid[b]	5	1387.46	104.32	0.00	-688.67
Fixed effects 2					
M + Time + Sex + Suppl	12	1192.07	0.00	0.29	-583.71

M + Time + Sex + Rep + Suppl	13	1192.67	0.60	0.21	-582.95
M + Time + Sex + Rep + Suppl + Sex*Rep	14	1193.71	1.65	0.13	-582.41
M + Time + Sex + Suppl + Sex*Suppl	13	1194.05	1.98	0.11	-583.64
M + Time + Sex + Rep + Suppl + Sex*Suppl	14	1194.67	2.60	0.08	-582.89
M + Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	15	1195.71	3.64	0.05	-582.35
M + Time + Sex	11	1196.15	4.08	0.04	-586.80

a)



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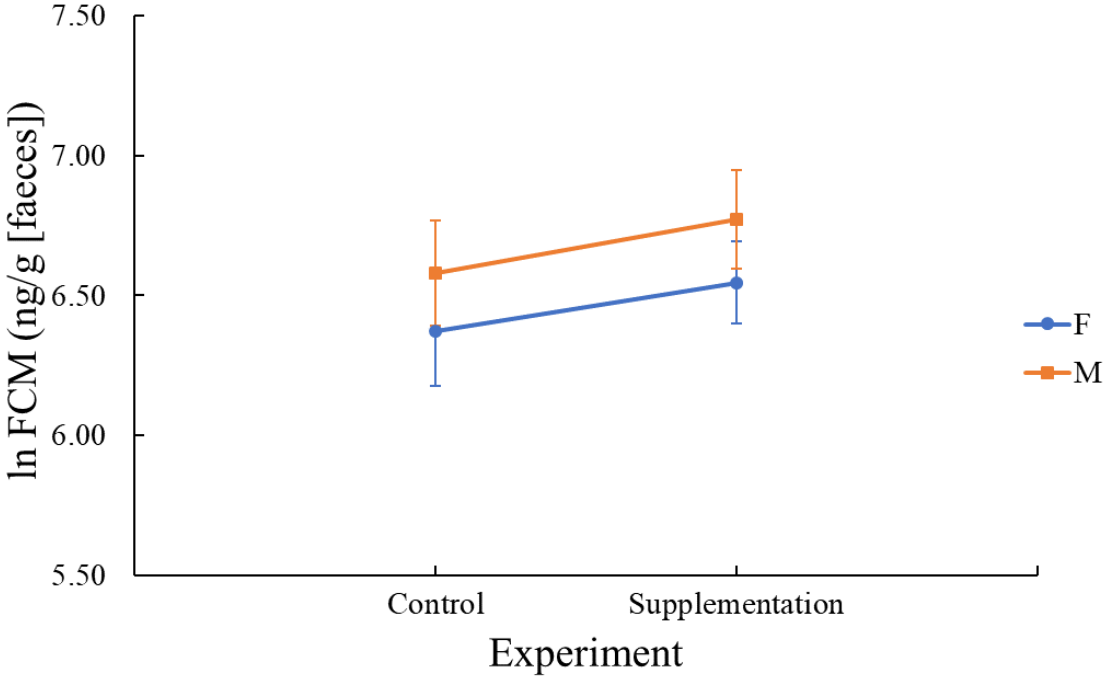


Figure 9. Estimates and 95 % confidence intervals from the model averaging of the log-transformed faecal metabolites (ln FCM) of *Gracilinanus agilis* a) over the months adapted to the life cycle of the individuals, and b) for females and males of control and supplemented grids.

Total cortisol

From a total of 665 plasma samples, we analysed 307 samples, 149 from females and 158 from males. Beacause of the smaller sample size, especially in the subadult class (class 4), we decided to regroup with the juveniles (class 2-3) for modeling.

We did not find a mean difference in total cortisol between dark and light plasma samples (25.83, 95 % CI -10.45 to 60.20). The mean value of the light samples was 145.34 ng/ml (95 % CI 124.37 to 167.56, N = 202) and the mean value of the dark samples was 119.35 ng/ml (95 % CI 95.46 to 148.10, N = 105).

The fit of the global model to the data was best when the response variable was transformed to the natural logarithm (Appendix 4). Six data points were identified as possible outliers, high-leverage and/or influential points, but none changed the pattern of the results when removed. We removed three points from the analysis due to the possibility of error in measure (points 62, 75 and 200).

The first selection of fixed effects had as the single best model the one with the covariate time inside trap (Table 8). The models describing variation among age classes (Age) and between control and supplemented areas (Suppl) had lower AICc values than their competing models.

We built 70 models based on the result of the previous selection. Thirteen models had a cumulative weight of 0.91 and were selected for the model averaging (Table 8, Appendix 17). All models contained the covariates time inside trap and time of blood collection (T.Blood), as well as the effects of sex and reproductive status. Age class was present in all but the last selected model, with a relative variable importance of 0.86, and food supplementation was present in seven of them, with a relative variable importance of 0.35.

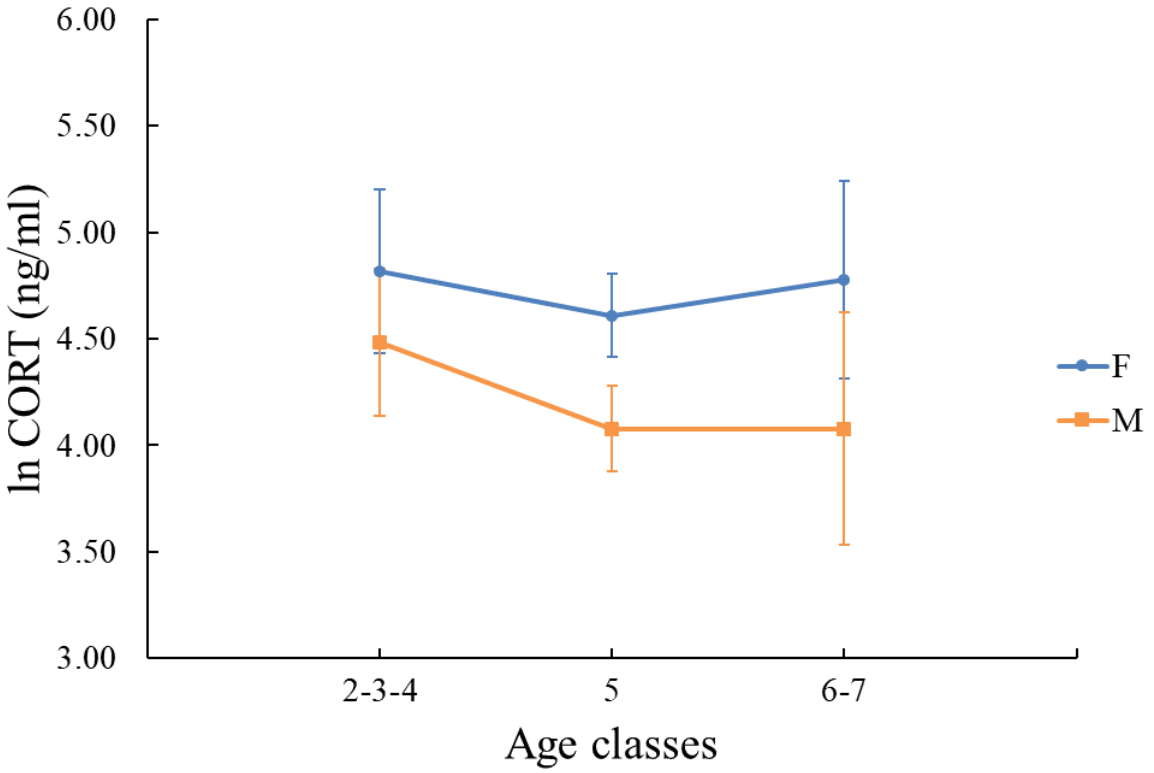
The total cortisol concentrations of females were higher than the concentrations of males in all age classes (Figure 10a), and the difference between the sexes was greater in the class 5 and when they were reproductively active (Figure 10b). Differences between control and supplemented areas were not shown graphically because the coefficients for both the main effect and the interaction were small (Appendix 18). The coefficient for time in the trap was positive and relatively high comparing to the other investigated physiological variables. The coefficient for time of blood collection was positive, had a high standard error and confidence interval overlapping zero.

Table 8. Model selection for the log-transformed total cortisol of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), time of blood collection (T.Blood), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and experiment (Sex*Suppl), sex and age class (Sex*Age), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 17).

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Fixed effects 1					
Time	3	860.06	0.00	1.00	-426.99
T.Blood	3	902.58	42.52	0.00	-448.25
Sex	3	908.76	48.69	0.00	-451.34
Age[a]	4	914.66	54.59	0.00	-453.26
Suppl[b]	3	914.94	54.88	0.00	-454.43
.	2	917.59	57.53	0.00	-456.78
Seas[a]	4	917.66	57.60	0.00	-454.76
Grid[b]	5	918.71	58.65	0.00	-454.26
Rep	3	919.45	59.39	0.00	-456.69
M[a]	9	923.82	63.75	0.00	-452.60
Fixed effects 2					
Time + Age + T.Blood + Sex + Rep + Sex*Rep	9	832.78	0.00	0.18	-407.07
Time + Age + T.Blood + Sex + Rep + Sex*Age	10	833.18	0.40	0.15	-406.19
Time + Age + T.Blood + Sex + Rep	8	833.56	0.78	0.12	-408.52
Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Rep	10	834.27	1.49	0.09	-406.74

Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age	11	834.68	1.90	0.07	-405.86
Time + Age + T.Blood + Sex + Rep + Sex*Age + Sex*Rep	11	834.78	1.99	0.07	-405.91
Time + Age + T.Blood + Sex + Rep + Suppl	9	835.05	2.26	0.06	-408.20
Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	11	835.98	3.20	0.04	-406.51
Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age + Sex*Rep	12	836.31	3.53	0.03	-405.59
Time + T.Blood + Sex + Rep + Sex*Rep	7	836.40	3.61	0.03	-411.00
Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age + Sex*Suppl	12	836.48	3.69	0.03	-405.67
Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Suppl	10	836.84	4.06	0.02	-408.02
Time + T.Blood + Sex + Rep + Suppl + Sex*Rep	8	837.57	4.78	0.02	-410.53

a)



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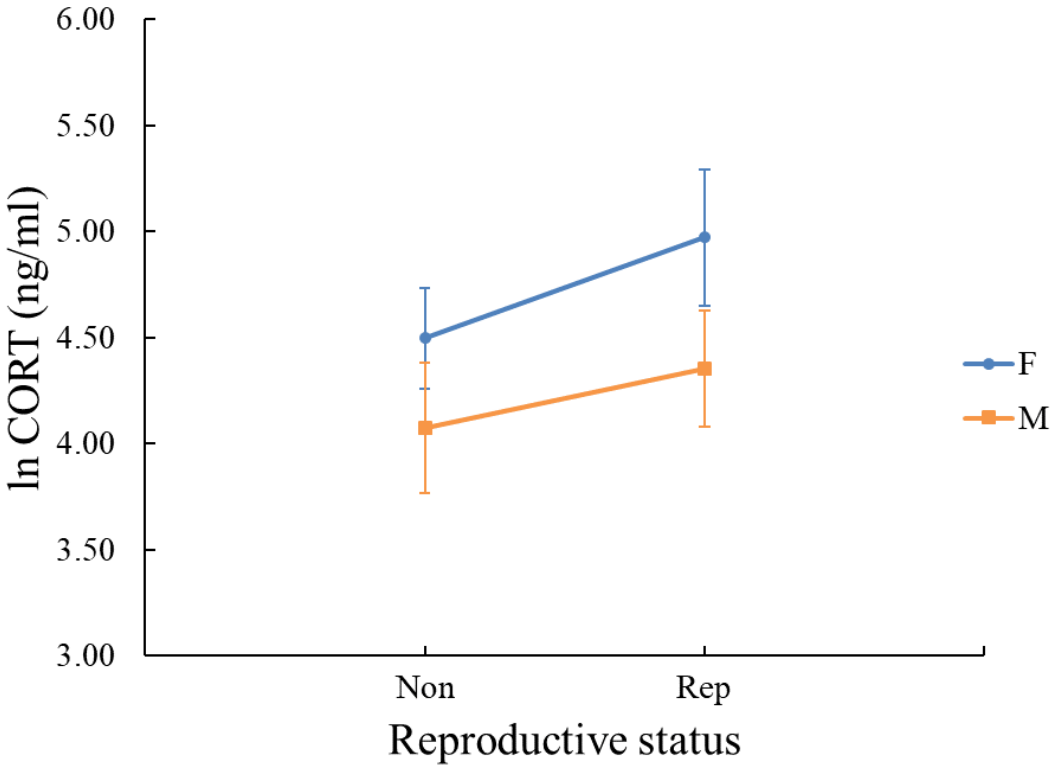


Figure 10. Estimates and 95 % confidence intervals from the model averaging of the log-transformed total cortisol concentration (ln CORT) of *Gracilinanus agilis* for females and males a) among age classes and b) between non-reproductive and reproductive individuals.

Maximum binding capacity

From the saturation binding curve at 4 °C (Appendix 19), we estimated K_d = 2.21 nM (95 % CI 1.78 to 2.75) and B_{max} = 19860.53 (95 % CI 18655.83 to 21195.72). The saturation binding at 37 °C resulted in a poor curve and estimates with higher uncertainty: K_d = 4.74 nM (95 % CI 2.43 to 9.64) and B_{max} = 18081.84 (95 % CI 14227.74 to 24370.86). The removal of the farthest point, which was probably an error in a step of the procedure, generates better estimates: K_d 3.74 (95 % CI 1.98 to 7.42) and B_{max} 17132.83 (95 % CI 14074.66 to 21940.72).

We found a mean difference in the maximum binding capacity (MCBC) between dark and light plasma samples (131.17, 95 % CI 80.82 to 181.91). The mean value of the light samples (328.37 nM, 95 % CI 293.14 to 365.95, N = 201) was higher than the mean value of the dark samples (197.98 nM, 95 % CI 165.18 to 234.56, N = 105). We chose to add the variable color of plasma sample to account for this difference instead of removing data points. Nevertheless, a model selection without these data gave the same result, except for the higher uncertainty given by the smaller sample size.

The fit of the global model to the data was not improved by log-transforming the response variable or using a non-Gaussian family (Appendix 4). Four data points were identified as possible outliers, high-leverage and/or influential points. The removal of data points did not change the pattern of the results. However, we did not have any specific reason to believe they were errors instead of biological variation, so we did not remove any from the analysis.

The first selection of fixed effects had as the single best model the one with the covariate time inside trap (Table 9). The model describing differences among age classes (Age) had lower AICc value than their competing models. The model representing the difference between control and supplemented areas and the one of difference among grids had almost identical performances. We opted for the variation among grids because the model indicated some discrepancy between the two control grids that should be investigated.

We selected seven top-ranked models among 140 candidates to describe the variation in MCBC and they had together a weight of evidence of 0.93 (Table 9, Appendix 20). All main effects were in every selected model, except for reproductive status, which was absent in the fifth model and had a relative variable importance of 0.87.

The MCBC estimates of females were higher than the estimates of males in all age classes, (Figure 11a). Estimates decreased from classes 2-3-4 to the class 6-7, which had more overlapping confidence intervals between sexes. Reproductive individuals had lower mean estimates of MCBC than non-reproductive individuals, and the differences between sexes did

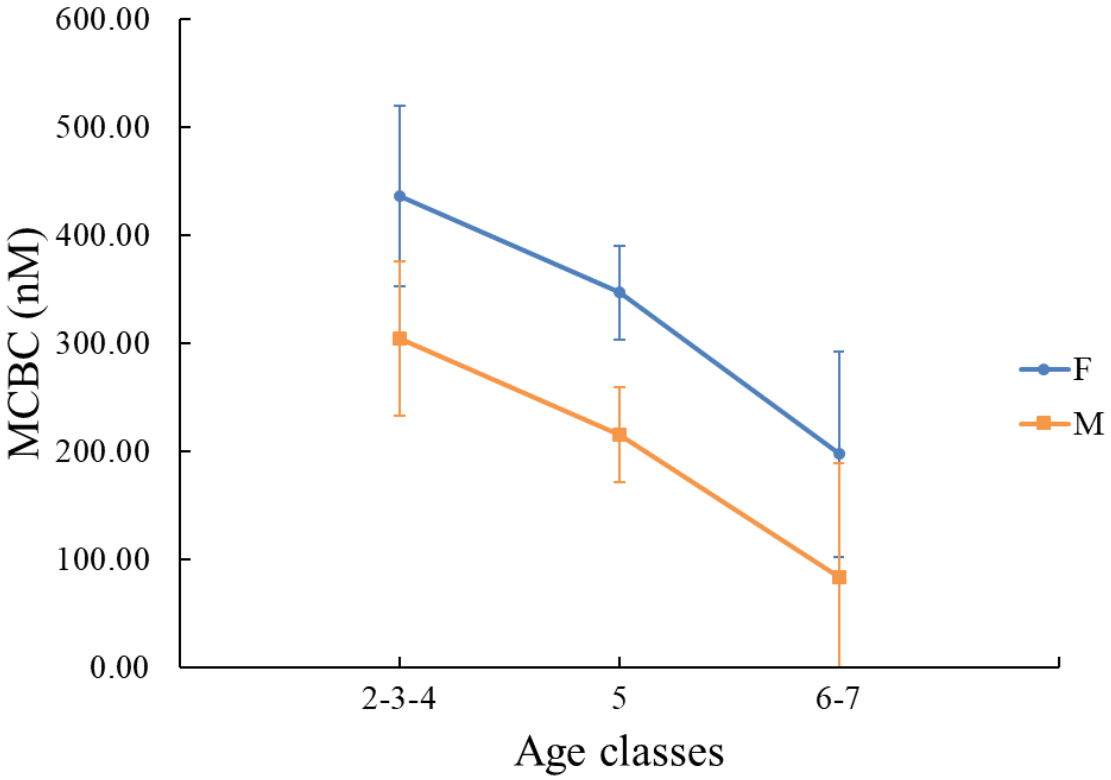
not change according to the reproductive status (Figure 11b). The mean estimate was the highest in FAL, one of the control areas, especially for females (Figure 11c). Dark-red samples had lower estimates than light-red ones (Figure 11d), confirming the bootstraped tests done before model selection. The coefficient for time in the trap was positive but had a confidence interval overlapping zero (Appendix 21). The effect of time of blood collection was positive but small.

Table 9. Model selection for the maximum binding capacity of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), time of blood collection (T.Blood), food supplementation experiment (Suppl), colour of the plasma sample (Colour), the interactions between sex and reproductive status (Sex*Rep), sex and grid (Sex*Grid), sex and age class (Sex*Age), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 20).

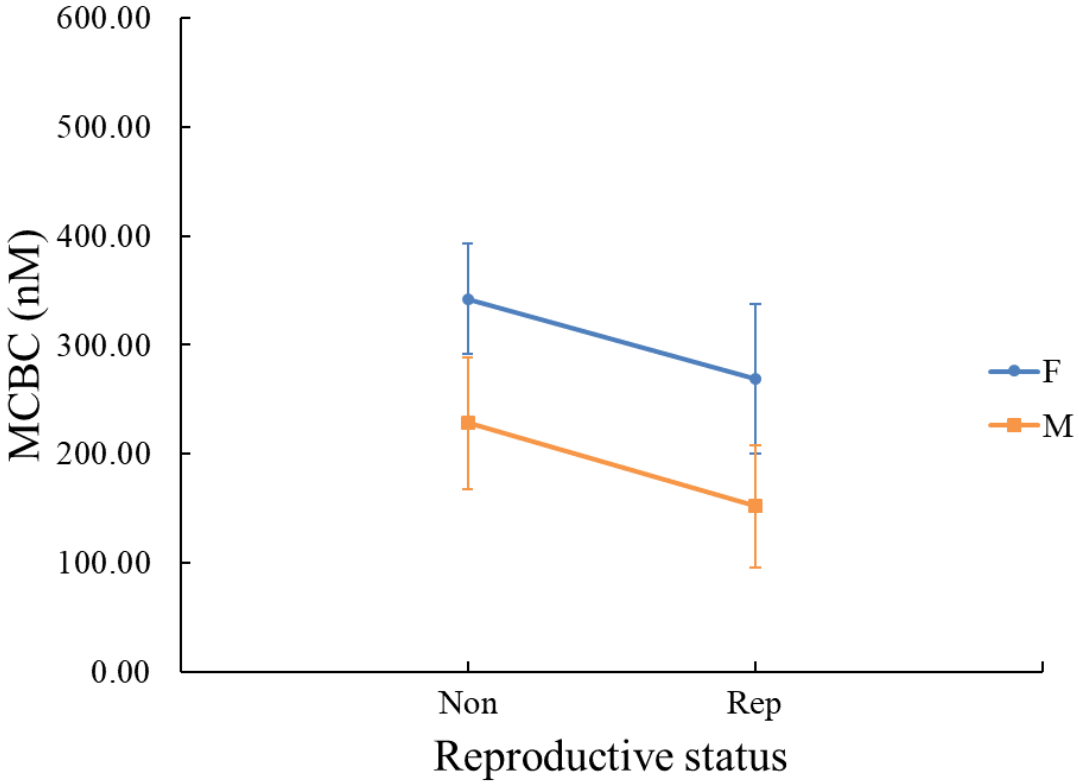
Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Fixed effects 1					
Time	3	4094.50	0.00	1.00	-2044.21
T.Blood	3	4189.93	95.43	0.00	-2091.92
Age[a]	4	4203.51	109.01	0.00	-2097.69
Seas[a]	4	4216.25	121.75	0.00	-2104.06
Rep	3	4223.78	129.28	0.00	-2108.85
M[a]	9	4224.99	130.49	0.00	-2103.19
Colour	3	4225.77	131.27	0.00	-2109.84
Sex	3	4236.85	142.35	0.00	-2115.38
Grid[b]	5	4242.89	148.39	0.00	-2116.35
Suppl[b]	3	4242.95	148.45	0.00	-2118.43
.	2	4243.88	149.39	0.00	-2119.92
Fixed effects 2					
Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Grid	15	3942.88	0.00	0.39	-1955.56
Time + Colour + Age + T.Blood + Sex + Rep + Grid	12	3944.68	1.79	0.16	-1959.77
Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Rep + Sex*Grid	16	3945.01	2.12	0.14	-1955.50

Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Grid	17	3945.80	2.92	0.09	-1954.77
Time + Colour + Age + T.Blood + Sex + Grid + Sex*Grid	14	3946.65	3.76	0.06	-1958.56
Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Rep	13	3946.85	3.97	0.05	-1959.77
Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Age	14	3947.37	4.48	0.04	-1958.92

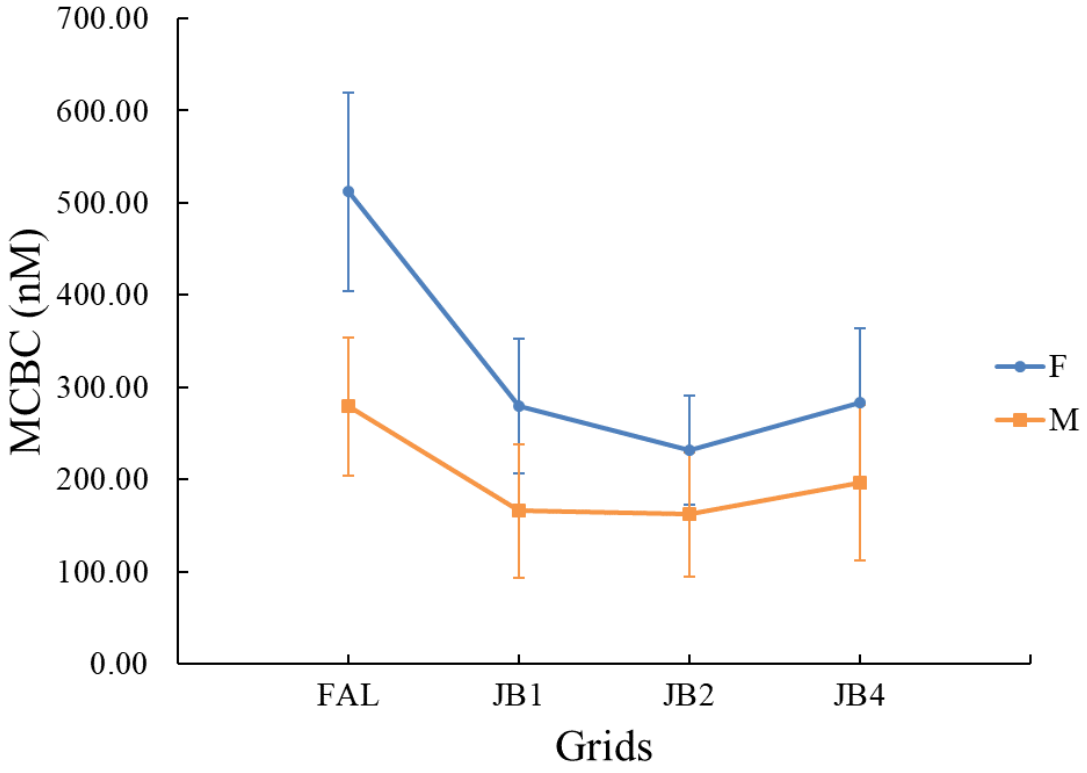
a)


600.00
500.00
400.00
300.00
200.00
100.00
0.00
MCBC (nM)
2-3-4
5
6-7
Age classes
F
M

b)


600.00
500.00
400.00
300.00
200.00
100.00
0.00
MCBC (nM)
Non
Rep
Reproductive status
F
M

c)



d)

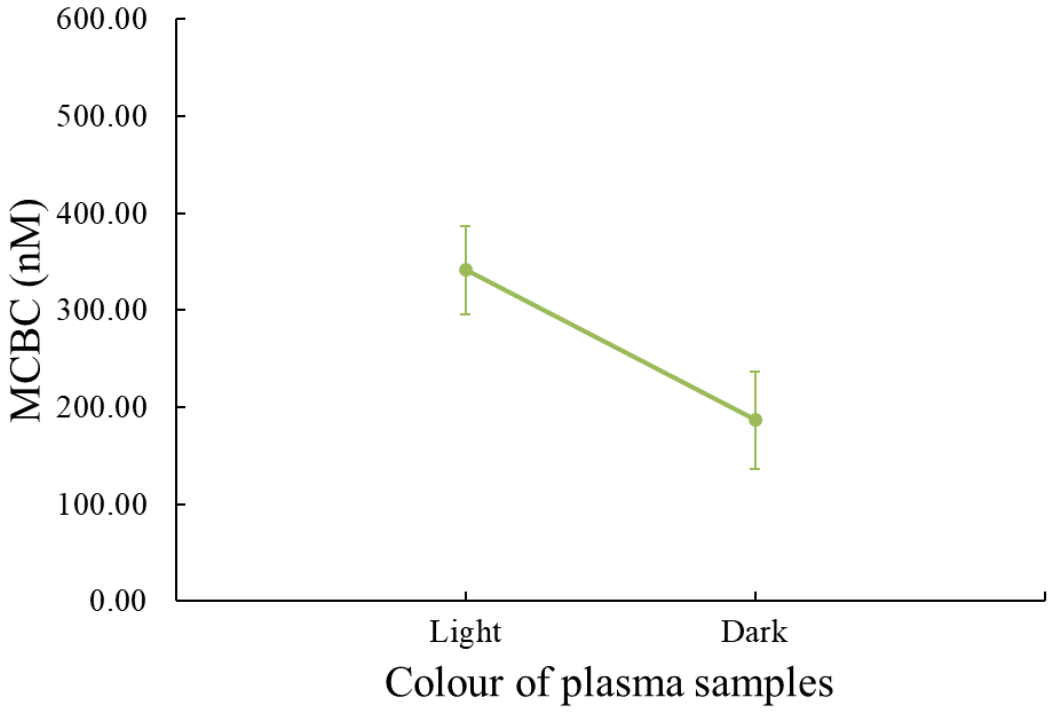


Figure 11. Estimates and 95 % confidence intervals from the model averaging of the maximum binding capacity (MCBC) of *Gracilinanus agilis* for females and males a) among age classes, b) between non-reproductive and reproductive individuals, c) among control (FAL and JB1) and supplemented (JB2 and JB4) grids, and for d) dark- and light-red plasma samples.

Free cortisol

We did not find a mean difference in free cortisol between dark and light plasma samples (4.63, 95 % CI -26.64 to 33.15). The mean value of the light samples was 75.00 ng/ml (95 % CI 57.80 to 94.05, N = 201) and the mean value of the dark samples was 71.08 ng/ml (95 % CI 49.08 to 95.57, N = 105).

The fit of the global model to the data was best when the response variable was transformed to the natural logarithm (Appendix 4). Three data points were identified as possible outliers, high-leverage and/or influential points, but none changed the pattern of the results when removed. We removed all three points from the analysis due to the possibility of error in measure (points 66, 83 and 199), in addition to the points that were considered errors in measure in the analysis of the total cortisol.

The first selection of fixed effects had as the single best model the one with the covariate time inside trap (Table 10). Although the differences were small between the models for season and age (ΔAICc = 1.46) and between the models for food supplementation and grid (ΔAICc = 2.01), we opted for the best-ranked model of each pair. Since the model with age was reduced in 1 parameter (juveniles and subadults together), variation among groups would not be so different from pre, reproductive and post reproductive periods. The model with grid did not indicate a discrepancy between grids of the same treatment.

We built 70 models based on the result of the previous selection. Fourteen models had a cumulative weight of 0.91 and were selected for the model averaging (Table 10, Appendix 22). All models contained the covariates time inside trap and time of blood collection (T.Blood), as well as the variation among pre, reproductive and post reproductive periods. Food supplementation was present in 10 out of 14 models, with a relative variable importance of 0.79. The variables reproductive status and sex had each 0.45 of relative importance.

Free cortisol levels increased from pre-reproductive to post-reproductive seasons (Figure 12a). The difference between sexes and reproductive status were small and confidence intervals were highly overlapped (Figure 12b). The effect of food supplementation was positive for free cortisol, but uncertainty was also high (Figure 12c).

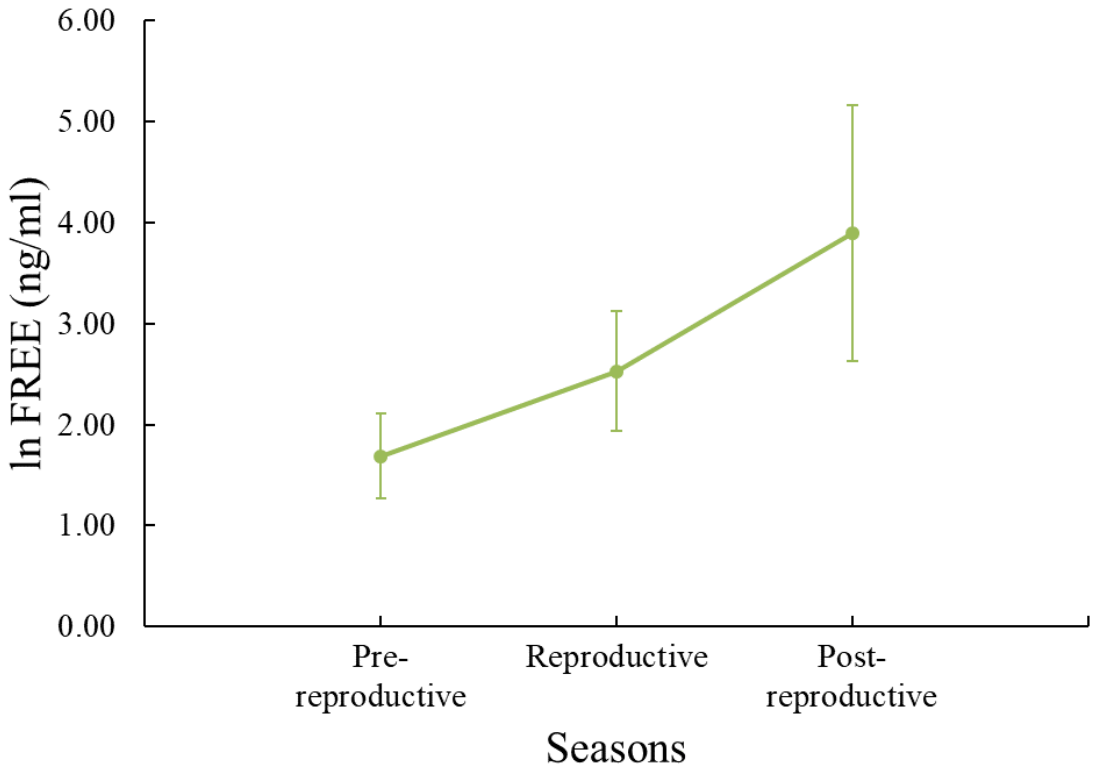
The coefficient for time in the trap was positive but small, and confidence interval did not overlap with zero (Appendix 23). The effect of time of blood collection was positive and higher than for the total cortisol levels. The coefficient for time of blood collection was lower than for the total cortisol levels, had a high standard error and confidence interval overlapping zero.

Table 10. Model selection for the free cortisol of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, age class (Age), reproductive status (Rep), reproductive season (Seas), grid, time inside trap (Time), time of blood collection (T.Blood), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and reproductive season (Sex*Seas), and sex and experiment (Sex*Suppl), and no effect (.). Superscript letters indicate variables that would not be used together when building the candidate models set (a: different forms of time variation; b: different forms of spatial variation). K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. The fixed effects 2 selection shows only the first models whose weights sum at least 0.90. The complete list is in the supplemented information (Appendix 22).

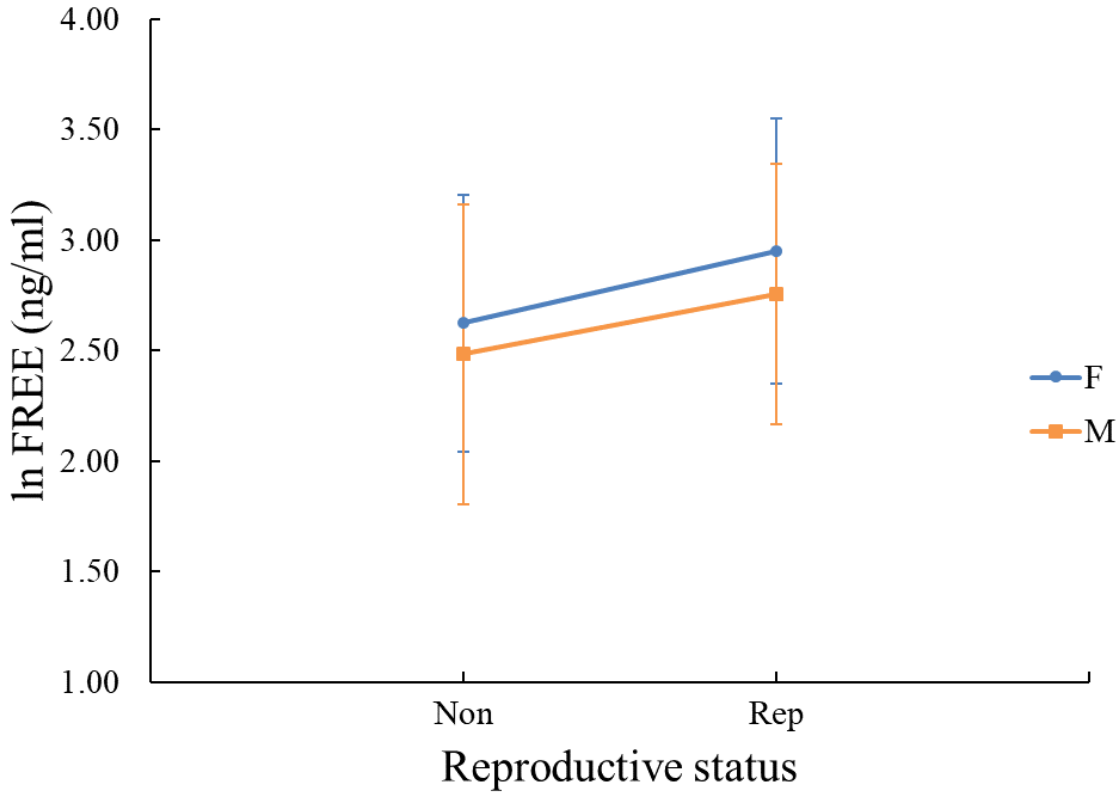
Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Fixed effects 1					
Time	3	1395.69	0.00	1.00	-694.80
T.Blood	3	1443.75	48.06	0.00	-718.83
Seas[a]	4	1449.83	54.14	0.00	-720.85
Age[a]	4	1451.29	55.60	0.00	-721.58
Suppl[b]	3	1454.31	58.62	0.00	-724.11
Grid[b]	5	1456.32	60.63	0.00	-723.06
M[a]	9	1457.29	61.60	0.00	-719.34
Rep	3	1459.39	63.70	0.00	-726.66
Sex	3	1463.33	67.64	0.00	-728.62
.	2	1463.35	67.66	0.00	-729.66
Fixed effects 2					
Time + Seas + T.Blood + Suppl	7	1357.08	0.00	0.23	-671.34
Time + Seas + T.Blood + Rep + Suppl	8	1357.83	0.76	0.16	-670.66
Time + Seas + T.Blood + Sex + Rep + Suppl	9	1358.66	1.59	0.10	-670.01
Time + Seas + T.Blood + Sex + Suppl	8	1358.89	1.81	0.09	-671.18

Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Rep	10	1359.79	2.71	0.06	-669.49
Time + Seas + T.Blood	6	1360.40	3.32	0.04	-674.05
Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Suppl	10	1360.66	3.59	0.04	-669.93
Time + Seas + T.Blood + Sex + Suppl + Sex*Seas	10	1360.66	3.59	0.04	-669.93
Time + Seas + T.Blood + Sex + Suppl + Sex*Suppl	9	1360.88	3.80	0.03	-671.11
Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Seas	11	1361.38	4.30	0.03	-669.21
Time + Seas + T.Blood + Rep	7	1361.42	4.35	0.03	-673.51
Time + Seas + T.Blood + Sex + Rep	8	1361.70	4.62	0.02	-672.59
Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	11	1361.83	4.76	0.02	-669.44
Time + Seas + T.Blood + Sex	7	1361.86	4.78	0.02	-673.73

a)


6.00
5.00
4.00
3.00
2.00
1.00
0.00
ln FREE (ng/ml)
Pre-reproductive
Reproductive
Post-reproductive
Seasons

b)


4.00
3.50
3.00
2.50
2.00
1.50
1.00
ln FREE (ng/ml)
Non
Rep
Reproductive status
F
M

c)

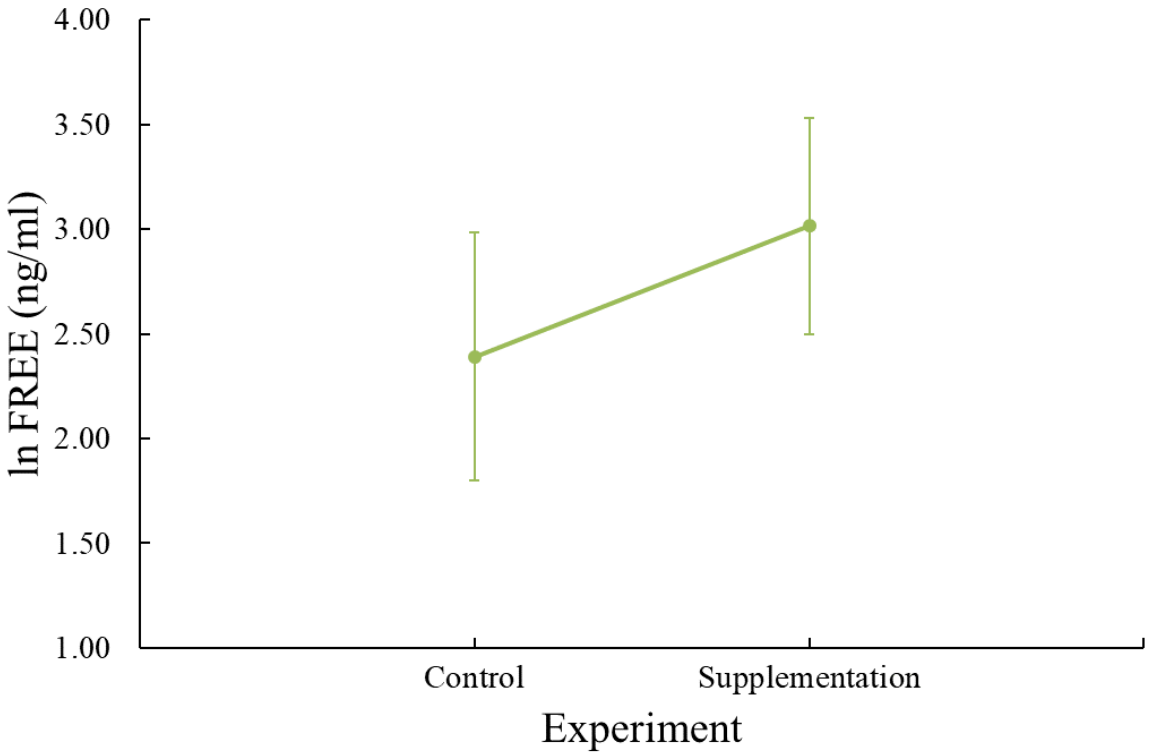


Figure 12. Estimates and 95 % confidence intervals from the model averaging of the log-transformed free cortisol (ln FREE) of *Gracilinanus agilis* for a) pre-reproductive, reproductive and post-reproductive seasons; b) females and males with non-reproductive and reproductive status; and c) differences between control and supplemented grids.

Discussion

Our results were consistent with the predictions of the semelparous strategy for *G. agilis*. The species showed an adaptive stress response, with changes in hormone concentrations, neutrophil/lymphocyte ratio, body condition, and haemoglobin concentration related to the failure of the stress axis feedback mechanisms. Food supplementation was not important for the variation described in the physiological parameters and had only a small effect in FCM and free cortisol levels.

The neutrophil/lymphocyte ratio (N/L), an indicator of stress, showed meaningful changes in respect with the reproduction of *G. agilis*. The ratio increased from the pre-reproductive to the reproductive seasons, and stayed high during the post-reproductive season, though showing high uncertainty. Reproductive individuals had higher N/L than non-reproductive individuals in the three seasons, but no clear difference between sexes was found, in contrast to the findings on the semelparous dasyurids (Cheal et al. 1976, Bradley 1990). However, this difference found in reproductive status and reproductive seasons also reflect on differences between sexes. The pre-reproductive season is the period from December to June/July, when females still do not show signs of reproduction. The reproductive individuals in the pre- season are the males that had more developed scrotal width (length > 10 mm), in contrast to the males whose testis had not reached this size. This measure seems to be an indication of the male sexual maturation. Therefore, the non-reproductive males showed a pattern similar to the females during this period, while the sexually matured males were already showing the first signs of stress. This result is in accordance with the N/L of the opossum *Didelphis virginiana* in captivity, which was higher in adults than in immature individuals (Giacometti et al. 1972). In September, the beginning of the reproductive season, the scrotal width of all males reached the threshold value, but not all females had swollen teats or milk production. This means the non-reproductive individuals were represented only by females in this period, and the males and reproductive females showed similar N/L ratios. In the post-reproductive season, we had fewer data, and mostly from females because the great majority of old males disappeared. Still, available data indicates the N/L ratio decreased when the females were not reproducing, even after they experienced high ratio before when they were breeding.

The use of leukocyte profiles, particularly the N/L is considered a reliable stress metric in vertebrates (Davis et al. 2008). Neutrophils (heterophils equivalent) and lymphocytes are the most abundant leukocytes, and their responses to stress are similar among groups. Neutrophils are highly motile phagocytic leukocytes, and the first responders to inflammation (Weiser

2012a). Lymphocytes are divided in subpopulations with different functions, including humoral immunity, cell-mediated immunity and production of cytokines, which are proteins that regulate immune response (Weiser 2012a). The typical stress response is the decrease in the lymphocyte concentration (lymphopenia) and the increase in the neutrophil concentration (neutrophilia). Lymphopenia may be caused by apoptosis induced by glucocorticoids and redistribution from the blood circulation to other tissues (Weiser 2012b, Oppong & Cato 2015). In contrast, glucocorticoids reduce adherence of the neutrophils and hence cells move from the marginating pool (microcirculation) to the circulating pool (large vessels) (Weiser 2012c).

Interpretation of N/L alone must be done with caution. Neutrophilia can occur not only in cases of increased cortisol, but also in cases of inflammation and acute stress (epinephrine release) (Weiser 2012c). It is possible to identify the cause of inflammation noting an increased concentration of immature neutrophils, resulted from a shorter rate of renewal in blood, or the cause of acute stress with an unchanged or even increased lymphocyte concentration by the increase of blood flow (Weiser 2012c). Moreover, it is important to distinguish NRL from a measure of immune response itself. This metric gives information about levels of stress experienced by the individuals but not about immunocompetence or suppression of those individuals (Davis et al. 2008). Blood samples contain leukocytes from exclusively the circulating pool, whereas they can also be in the storage pool in the bone marrow, in the marginating pool or in the tissues (Weiser 2012b).

The body condition (SMI), an indicator of health status, had marked changes throughout the lives of females and males of *G. agilis*. Variation through time was parallel for the sexes because interaction between these variables was not included in the model. The rapid increase from June/July to September reflect the body changes for the start of reproduction, specially for males, which had higher SMI than females. This pattern agrees with the anabolic effect of testosterone as seen in *Antechinus* (Naylor et al. 2008) and *Phascogale* (Bradley 1990). The high increase rate of the scrotal width from April to June (chapter 1) probably reflects the higher concentration of testosterone, and the consequence is the increase in body mass relative to body length.

The SMI increased until December, the end of reproductive season, but then started to decline. This decline in condition during the post-reproductive season was not so sharp as experienced by semelparous dasyurids in general, being more similar the moderate weight loss in *P. calura* males (Bradley 1990, 2003). A poor condition may be related to the catabolic effects of glucocorticoids on skeletal muscle (Bodine & Furlow 2015). A negative nitrogen balance was observed in males of *A. stuartii*, even when calorie consumption increased,

indicating a net protein breakdown exceeding protein synthesis (Woollard 1971). From December onwards, the individuals started showing typical signs of senility, such as loss of fur, tooth wear, scars and wounds, and even hematuria (blood in urine) in some males.

Surprisingly, a new increase in SMI occurred in the second September, when seven old females were reproductive (two were not). Only two males were captured in the second September, but we were not certain they could actually reproduce. Among the semelparous Australian species, some males can survive more than a year, but they cannot undergo spermatogenesis anymore (Naylor et al. 2008, McAllan 2009).

Haemoglobin concentration (Hb), the other indicator of health status used, was slightly higher for males than females, as observed for other small didelphid, the gray short-tailed opossum *Monodelphis domestica* (Evans et al. 2010), and for *A. stuartii* (Agar & McAllan 1995). We detected that reproductive individuals had higher Hb than non-reproductive individuals, and this difference was mostly a reflection of the peak of Hb in September, month when the great majority of females and all males were reproductive. This peak of Hb coincided with the peak of SMI, and at least for males, might have been driven by an increase of testosterone (McAllan 1998).

Haemoglobin concentration did not stay high during the reproductive season in the same way as the SMI did, but rather had a profound decline in December. A decrease in Hb also occurred in *A. stuartii* in the end of the reproductive season, and greater for males, probably because of haemorrhagic ulcerations and intensified protozoan and bacterial infections (Cheal et al. 1976, Barker et al. 1978). The subsequent months showed a variation, which was probably due to the smaller sample sizes, especially for males, since we had only one or two males sampled in each session.

The glucose concentration (Gl), an index of energy mobilization, did not differ between sexes, but was higher in reproductive individuals. Gl did not show marked temporal fluctuation, although the observed time variation suggests higher concentrations during the post-reproductive season (higher uncertainty due to smaller sample sizes, again). Hyperglycemia is expected to occur when glucocorticoid levels increase because these hormones act in multiple aspects of glucose homeostasis (Kuo et al. 2015). In the liver, they stimulate gluconeogenesis (i.e. the formation of glucose from noncarbohydrate sources, such as protein and fat) and increase glycogen storage; in the muscle and adipose tissue, glucocorticoids inhibit glucose uptake and oxidation, reduce glycogen storage and increase protein degradation and lipolysis; and in the pancreas, they inhibit insulin secretion and promote glucagon release (Kuo et al. 2015). The outcome observed in males of *A. stuartii* after mating, however, was hypoglycaemia,

and only the increase in liver glycogen concentration could be related to high cortisol concentration (Barnett 1973).

Biological validation of the faecal cortisol metabolites (FCM) revealed that live-trapping experiences for up to 18 h were not sufficient to increase FCM of *G. agilis*. Results from both scenarios of model selection illustrated minor or none variation among the time groups, and negligible difference in the time of faecal sample collection and between sexes. Thus, we consider that the FCM values obtained in population monitoring were not affected by our capture protocol. A recent study with the same species showed that FCM increased after 24 h of captivity (Hernandez et al. 2018). However, the difference between sampling times was restricted to 24 h (0 h, 24 h, 48 h), which does not reflect the time individuals stay in traps in a regular capture-mark-recapture study. If animals had a stress response to captivity after 24 h, they could have started responding to trapping anytime before. On the other hand, we designed our validation with 3 h intervals so that we could detect when individuals would start a capture-induced stress response.

The FCM from the monitoring study had a peak in September, reflecting how challenging is the reproduction cost for individuals. Contrary to our expectations, levels did not remain high during reproductive and post-reproductive seasons, but decreased from the second December to the second June/July, and then increased again in the second September. In the semelparous dasyurid marsupials, cortisol levels increase drastically just before and during reproduction and stay high until the males die-off (Bradley 2003, Naylor et al. 2008). Although males had higher FCM levels than females, a difference between the sexes after the peak was not detected through model selection.

The present study agrees to some extent with the only other study on *Gracilinanus* to measure FCM (Hernandez et al. 2018), where FCM levels showed an increase in the dry season. September is indeed the last month of the dry season in central Brazil. However, we extend the finding by distinguing June/July (dry months) from September. We detected that FCM was low during the former months, even lower than in the second December, well within the wet season period. In June and July, most males had already reached sexual maturity, but no female showed signs of reproductive activity. During our long-term population study, the earliest lactating female was caught in the 13th of August (2010). So, individuals might start mating in the end of July and August. For this reason, testosterone levels might have been high among males during this period of June/July, but maybe not circulating cortisol yet. Moreover, we had new information regarding post-reproductive individuals. The decrease we found from the second December to July/June represented exclusively old individuals.

We confirmed a positive effect of the presence of urine in the faeces of *G. agilis*. This was not surprising since contamination with urine can affect FCM measurements (Palme et al. 2013). Such contamination was not rare for our faecal samples, since marsupials excrete both products from the same opening (cloaca), and sometimes at the same time during handling. It remains unknown, however, how much cortisol metabolites are excreted in urine and faeces for this species.

The total plasma cortisol levels did not show a meaningful variation among age classes, or through time. However, it is noteworthy that females had higher total cortisol levels than males in all age classes, and irrespective of reproductive status. Females also had higher CBG levels than males through life, so that the effects of circulating cortisol could be buffered. But contrary to the expected for the semelparity syndrome, our study provides evidence that females also had decreased CBG levels, probably related to reproductive effort.

The CBG levels reached their peaks in the early stages of life, reducing in class 5 and even more in classes 6-7. The age class 5 represents the adults of the population, but since *G. agilis* has a complete dentition early in life, this class begun to appear already in the pre-reproductive season with immature individuals and goes until the end of reproductive season. For this reason, we can presume that CBG levels start decreasing before reproduction. Males of *G. agilis* seem to become sexually mature before the beginning of the reproductive season, showing a substantial increase in their scrotal sacs and the presence of the throat gland. There is evidence that the rise in the testosterone induce fall in the CBG levels in the dasyurid males (Bradley et al. 1980, McDonald et al. 1981, Bradley 1987), though it is not true for a partially-semelparous rodent (Edwards et al. 2016).

We detected a difference between control and food supplemented areas in both FCM and free cortisol levels. This difference, however, was small and opposite to our prediction. Food supplementation effect was positive for the stress response, whereas we predicted that more food availability would reduce the stress of reproduction. It is possible that the increased population density in the areas could have led to a slighlty greater stress response, compensating any potential effect of an increase in available resources. Alternatively, the failure of the HPA axis is completely independent of the food resource availability, since it is suggested to be driven by sperm competion (Fisher et al. 2013) or seasonal programming (Edwards et al. 2016). In species that do not experience failure of the HPA axis, food supplementation can increase CBG levels and reduce free cortisol (Boonstra & Singleton 1993). Previous studies on the relation between resource availability and response of semelparous species are not in agreement. Food supplementation did not affect overwinter survival (Karels et al. 2000) or the

stress response (Boonstra et al. 2001) of a partially semelparous rodent (the arctic ground squirrel *Spermophilus parryii*), but there is evidence that resource availability may determine survival in *Dasyurus hallucatus*, a facultative semelparous dasyurid (Mills & Bencini 2000, Wolfe et al. 2004). Thus, the responses of semelparous mammals to resource availability seem to vary as function of idiosyncratic species characteristics and also differences in environmental conditions.

The FCM variation that we detected was not in full agreement with free plasma cortisol levels. There was a marked increase in FCM levels with the beginning of the reproductive season, which was followed by a decrease still in the reproductive season. MCBC, on the other hand, decreased in a way that caused the highest free cortisol levels to coincide with the lowest FCM levels (second March/April and second June/July). We accounted for capture-induced stress response and variation of the samples, in both faecal and plasma, but there are other possible reasons why FCM did not mirror free cortisol. First, we used only the 37e EIA to measure FCMs and it is possible that other would be best for the species. A study comparing assay performance of five EIAs for 13 marsupial species showed a considerable variation among essays in the percentage of individuals with a detectable peak and strength of the signal (Fanson et al. 2017). Second, it is possible that some samples degraded during transportation or in storage. These explanations, however, would probably not generate the seasonal pattern that we observed.

We believe that physiological seasonal changes may have introduced variation of FCM concentrations unrelated to endocrine processes. The hydric requirements of *G. agilis* are probably higher in the cool-dry season, period of water deficit in the Cerrado, and there is evidence that the species is adapted to conserve water at low temperatures (Cooper et al. 2009). Thus, differences in the water balance and consequently urine excretion may change the proportion of the excretory routes of the metabolites. Moreover, the diet preferences of this marsupial vary between seasons. *Gracilinanus agilis* individuals select more termites and hemipteran bugs (sources rich in fat and water) and less ants (rich in quitin) in the dry season, whereas they feed on arthropods according to their availability in the wet season (Camargo et al. 2014a). This latter pattern is possibly because fruits are more available in the wet season (Camargo et al. 2014a). Different food items have different digestibilities, which influence the intestinal passage time and consequently the rate of hormone reabsorption (Lewis et al. 1997). Therefore, using FCM as a stress metric can be challenging in species with a mixed diet type (Von der Ohe et al. 2004).

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CHAPTER 3: Bot fly parasitism reduces haemoglobin concentration but not body condition of the gracile mouse opossum (*Gracilinanus agilis*)

Introduction

Parasitism plays an important role in population dynamics of small mammals (Krebs 2011). This kind of interaction that can affect host population sizes by potentially reducing survival, reproduction, and individual movements, and can even generate population fluctuations (Tompkins & Begon 1999). This is specifically important for small populations as observed in patched or fragmented habitats, which are potentially more prone to local extinction (e.g. Macdonald 1996, Allan et al. 2003). On wild populations, the role of parasites as significant drivers of population-level effects on hosts and which factors influence on the capacity of a parasite to cause damage to their hosts is still unclear (Watson 2013). Moreover, parasitism is usually a neglected interaction in small mammal studies because of the difficulty in evaluating the multitude of disease effects on a population, since small mammals are generally hosts for many pathogens or parasites (e.g. Püttker et al. 2008, Linardi 2012).

Cuterebrid botflies are a common group of mammal parasites in the New World (Slansky 2007). They cause myiasis, which is characterized by the formation of a large skin furuncle or warble containing a larva inside (Catts 1982, Colwell 2001, Slansky 2007). Their larvae feed on sera and white blood cells at subdermal sites of the host, obtaining sufficient nutrients for a fast growth and development to the adult phase (Catts 1982, Colwell 2001). The adults, in their turn, do not interact with their hosts, since they do not oviposit on the hosts, but on substrate at sites frequented by the potential hosts (Catts 1982). Cuterebrid botflies tend to be highly host-specific and possibly because of the parasite-host coevolution, they are considered to have little or no deleterious effect on fitness of their coevolved hosts (Catts 1982, Slansky 2007). However their oviposition behavior makes parasitism with non-coevolved hosts possible, leading to negative effects such as infection, prolonged healing of postexit warbles, reduced survival and reproduction, and even death (Catts 1982, Slansky 2007).

Some studies demonstrated that cuterebrid infestation depressed survival and reproduction (e.g. Sealander 1961, Boonstra et al. 1980, Nichols 1994), others found no effect (e.g. Bergallo et al. 2000, Spessot et al. 2013), and still others found beneficial effects on hosts (Goertz 1966, Hunter et al. 1972, Clark & Kaufman 1990, Munger & Karasov 1991, Jaffe et al. 2005, Cramer & Cameron 2006). Studies that found these positive effects suggest that it may

be an artifact as parasitized individuals could have reduced movements and then reduced chances of emigration (Wecker 1962), or just that individuals that live longer also have a longer exposure to the botfly and consequently a greater probability of being infested (Hunter et al. 1972). Moreover, there is evidence for opposite effects between survival and reproduction in some cases: even when parasitized individuals have higher survival rates, reproduction can be negatively affected through decrease in activity or success, contributing to the decline in population growth rates in years of high prevalence (Wecker 1962, Burns et al. 2005).

We investigated the effects of botfly parasitism on a neotropical marsupial – the gracile mouse opossum *Gracilinanus agilis* – in a highly seasonal environment (Brazilian Cerrado), where marked dry and wet seasons occur every year. We examined the potential cost of these parasites on host condition variables (i.e., body condition, haemoglobin concentration). We predicted that both body condition and haemoglobin concentration would be lower in parasitized animals. Furthermore, to better understand the underlying factors influencing health condition, we evaluated potential effects of several factors that could interact with our main variables of interest, namely sex, food supplementation, season, daily climatic variables and time in livetraps. We predicted: (1) that females would have lower body condition and haemoglobin concentration than males, (2) that the difference in the botfly effect on individuals' health would be less pronounced in the food-supplemented areas, (3) that animals would have lower body condition and higher haemoglobin concentration in the dry season than in the wet season.

Methods

Natural history

Gracilinanus agilis (Burmeister 1854) is a nocturnal, solitary, and scansorial mouse opossum of the family Didelphidae (Creighton & Gardner 2007). It inhabits mainly forested areas in central Brazil, eastern Peru, eastern Bolivia, Paraguay, Uruguay, and northern Argentina (Creighton & Gardner 2007). Its diet is composed of fruits, invertebrates, and small vertebrates (Bocchiglieri et al. 2010, Camargo et al. 2014). It is sexually dimorphic in size (females = 13-25 g, males = 15-40 g; Costa et al. 2003) and has a synchronized reproduction from the end of the dry season (August-September) until the adult population reduction (December-January) (Aragona & Marinho-Filho 2009, Andreazzi et al. 2011), as observed in

the study area (Mendonça et al. 2015). Populations of this species may have semelparous (Puida & Paglia 2015, Lopes & Leiner 2015) or partially semelparous (Martins et al. 2006a) reproductive strategies.

The botfly *Cuterebra apicalis* occurs from Mexico to Argentina (Colwell et al. 2006), and parasitizes the gracile mouse opossum (Pujol-Luz et al. 2004, Cansi 2011a), and at least 20 other mammal species, including 17 native and 3 introduced ones (the Norway rat *Rattus norvegicus*, the black rat *R. rattus* and the domestic dog *Canis lupus familiaris* (Forattini & Lenko 1959, Twigg 1965, Everard & Aitken 1972, Led et al. 1976, Mello 1979, Leite & Williams 1988, Bossi & Bergallo 1992, Vieira 1993, Pinto & Claps 2005, Cansi 2011b). The period of development within a typical host (*Cerradomys subflavus*) is 21-26 days (Leite & Williams 1988).

Study area

We collected field data in four patches of "cerradão" (savannah woodland) in central Brazil. The "cerradão" is a xeromorphic forest-like physiognomy of the biome Cerrado, with a canopy height varying from 8 to 12 m, and a canopy cover ranging from 50 to 90 % (Oliveira-Filho et al. 2002). The climate is tropical savannah (Aw: Köppen-Geiger classification; Kottek et al. 2006), with the dry season between May and September and the wet season between October and April (Eiten 1972). Three sites (JB1 - 23.83 ha, JB2 - 27.33 ha, JB4 - 3.32 ha) were located at the Botanical Garden of Brasília (15˚52' S, 47˚50' W) and one site (FAL - 7.53 ha) at the ecological and agricultural field station of the University of Brasília (15˚58' S, 47˚59' W) located 25 km SW of Brasília, Federal District, Brazil. Afood supplementation experiment was carried out in two (JB2 and JB4) of our four grids. Here we provided milled cat food every 2-3 weeks to each capture station of the trapping grip, as well as to and an additional buffer, through feeders placed in the understory (see Mendonça et al. 2017 for details).

Data collection

We set four 1.44-ha trapping grids (120 m x 120 m), each comprising 81 capture stations 15 m apart. Each capture station had one Sherman live trap on the ground and one on a tree branch (1.5 - 2.0 m), but only the trap placed in the understory had a timer. Traps were baited with a mixture of banana, peanut butter, maize flour, cod liver oil, and vanilla essence.

We trapped each grid for 8 six-night capture sessions from April 2005 to December 2016. Opossums were marked with tags in both ears to avoid losing identification (model 1005-1; National Band and Tag, Newport, Kentucky). We recorded the individual number, species, sex, and botfly occurrence for each capture, but body mass (to the nearest 0.1 g) and head-body length (to the nearest mm) for only the first capture of each session.

We considered the individual parasitized if the presence of a botfly larvae was confirmed or if it had a characteristic scar tissue indicating recent larvae emergence. Most the cuterebrids occurred singly in the abdomen or on the back. We usually removed and weighed (to the nearest 0.1 g) the mature larvae. These were maintained in vials covered with gauze and containing moist sawdust until the flies emerged. All individuals that emerged were identified as *Cuterebra apicalis*, and this validated previous research (Pujol-Luz et al. 2004, Cansi 2011a).

We collected the blood sample from the individuals only once in each capture session by submandibular bleeding using an insulin (8 mm x 0.3 mm; 30 G) needle, dispensing the need for anesthesia (Hoff 2000, Golde et al. 2005). Haemoglobin concentration (g/dL) was determined immediately with a portable haemoglobin analyzer (Hemo Vet; EKF Diagnostics) with 5 µL of blood. Although hematocrit is the primary value for interpretation in the field of veterinary medicine, haemoglobin concentration is more accurate than hematocrit when both blood parameters are calculated by an automated counter (Thrall 2012a).

We obtained daily climatic data (maximum temperature, minimum temperature, precipitation, and relative humidity) from the meteorological station at the Roncador Ecological Reserve (RECOR/IBGE). The four grids were in a sufficiently short distance from one another (800 m -15.5 km) that we assumed the same climate affected all grids.

Data analysis

We considered only one record of each individual during the entire study period for the analysis. Since we had more records of non-parasitized than parasitized individuals, and more parasitized in the wet season than in the dry season, we tried to keep groups more balanced giving preference to records of parasitized individuals in the dry season.

We evaluated body condition using the scaled mass index (SMI) method (Peig & Green 2009, 2010). SMI is the body mass of an individual standardized to the mean body size of all individuals from the same body mass to head-body length relationship (Peig & Green 2009, 2010). We calculated the final body mass subtracting the mass of the ear-tags (0.5 g) when the animals were already marked, and the weight of botfly larvae in cases when the animals were

infected. We used an average larva weight (1.675 g) based on field data when we did not have the exact information. We were not concerned about number of larvae occurring in the same host for calculating the average weight since we observed a lower mass of each larva in cases of multiple infections, so that the total mass was similar to cases of infection by a single bot. We tested for between-sex differences in the linear regressions of log body mass against log head-body length as *G. agilis* is sexually dimorphic in size before deciding for the calculation of SMI based on all individuals together or separated by sex.

First, we used random forest analyses to evaluate the relative importance of different variables, choosing a subset based on the percent increase in mean square error (MSE) to reduce the number of models for further selection. Random forest is an ensemble learning method that combines many decision trees by repeatedly resampling data with replacement, helping to avoid overfitting and accounting for collinearity among variables (Cutler et al. 2007). The random forests algorithm performs a random selection of features to split each node and differs from bootstrap aggregating, or bagging, which uses an ordinary bootstrap sample of the entire feature set (Breiman 2001). The percentage increase in mean square error reflects the importance of a variable because it is the error that would result for the out-of-bag data from the removal of the given variable (De'ath & Fabricius 2000, Calle & Urrea 2010).

We checked the response variables haemoglobin concentration (Hb) and body condition (SMI) for normality and homoscedasticity. The tested explanatory variables were parasitism by *C. apicalis* (Botfly), supplementation experiment (Supplem - control/manipulated areas), climatic season (Season - dry/wet), area (four grids), sex (females and males), time of capture (Time.Capt - in minutes), and the climatic variables: maximum temperature (Max.Temp), minimum temperature (Min.Temp), precipitation (Precip), and relative humidity (Humid). For the response variable body condition (SMI), the explanatory variable sex would not be included in the random forest (but would be in all models from model selection) if the index was previously calculated separated for females and males. Spearman correlations were performed before model analyses between the four climatic variables. We considered only the pairs including maximum temperature together in the same model because all other pairs had a moderate to high correlation (> 0.40).

We evaluated the plausibility of the candidate models based on the Akaike's information criterion corrected for small samples (AICc; Burnham & Anderson 2002). We used for comparisons the AICc difference between models and the one with the lowest value (ΔAICc), and Akaike weight (w), which reflect the relative evidence of fit of a model to the data, proportional to the candidate set of models (Burnham & Anderson 2002). We used model

averaged estimates to calculate predicted values of the response variables and plot them against the variables from the best models. Analyses were run using 'randomForest' (Liaw & Wiener 2002), lme4 (Bates et al. 2015) and MuMIn (Barton 2018) packages in R, version 3.4.2 (R Core Team 2017).

Results

From April 2015 to December 2016, we obtained 2073 captures of 555 *G. agilis* individuals, and detected botfly larva on 169 individuals (30.5 %). The highest prevalence rates (number of infected individuals / total number of individuals) were in April 2015 (31.5 %) and December 2016 (30.3 %), and the lowest in September of both years (0.00 % in 2015 and 1.4 % in 2016; Figure 1). Considering all captures, in 87.6 % of the cases the parasitized opossums had one larva, 8.6 % had two, 3.2 % three, and 0.5 % four. Only 16 individuals (9.5 %) were parasitized more than once during this period.

Mean haemoglobin concentration (Hb) for the species was 14.0 ± 2.1 g/dL, from a total of 405 records, 306 records of non-parasitized (mean Hg = 14.5 ± 1.7 g/dL), and 99 records of parasitized individuals (mean Hb = 12.3 ± 2.1 g/dL; Appendix 1). Mean body condition (SMI) was 18.8 ± 3.5 g, from 400 records, 304 records of non-parasitized (mean SMI = 18.7 ± 3.5 g), and 96 records of parasitized individuals (mean SMI = 19.1 ± 3.8 g). We removed two animals that had no value of head-body length, and three outliers we considered as wrong measures. We calculated SMI for females and males separately since model selection for body mass to head-body length relationship resulted in the model including interaction with sex accounting for an Akaike weight of 0.96 and the model without sex, only 0.04 (Table 1).

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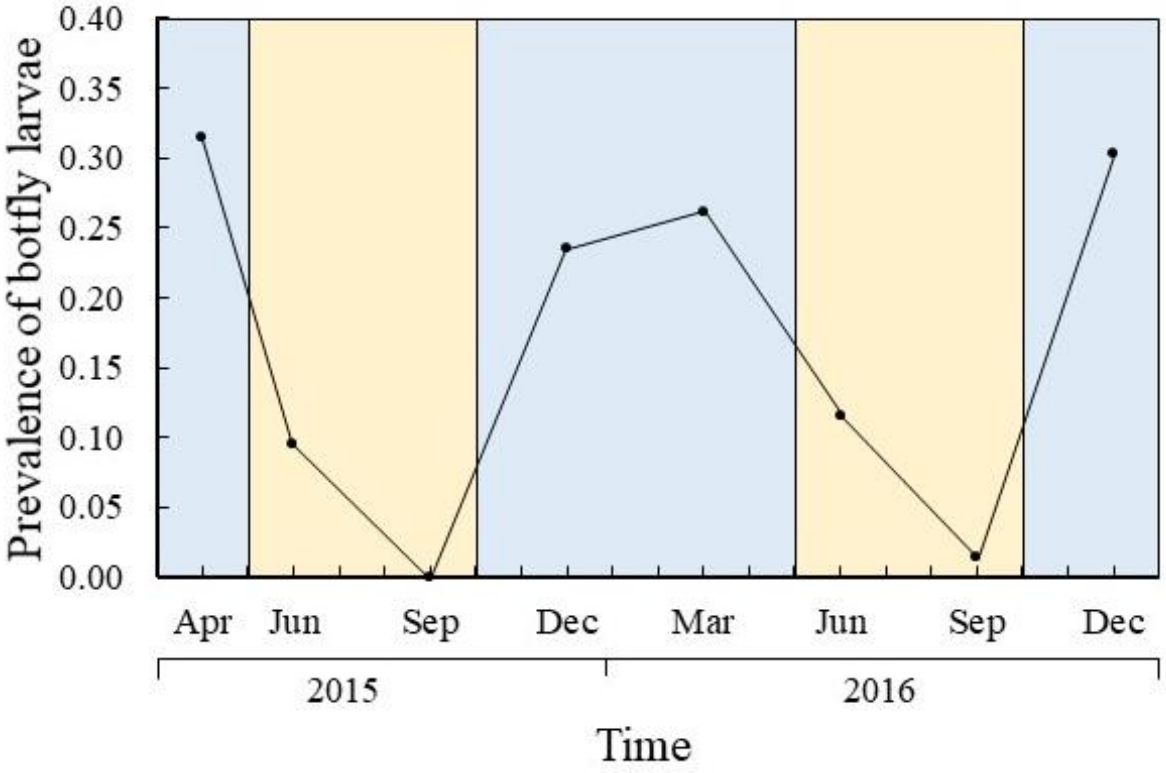

Figure 1. Prevalence of *Cuterebra apicalis* botflies in the marsupial *Gracilinanus agilis* during the haemoglobin study in four patches of "cerradão" from April 2015 to December 2016. Blue bars represent wet seasons and yellow bars, dry seasons.

Table 1. Model selection of the linear models of natural log of the body mass (Mi) against natural log head-body length (Li) with and without the effect of sex. K is the number of parameters, AICc is the Akaike's information criterion corrected for small samples, ΔAICc is the difference of AICc value to the best model, w is the Akaike weight, LL is the loglikelihood of the model.

Models	K	AICc	ΔAICc	w	LL
ln(Mi) ~ ln(Li) * Sex	5	-419.39	0.00	0.96	214.77
ln(Mi) ~ ln(Li)	3	-412.82	6.57	0.04	209.44

The most important variable for determining Hb was botfly occurrence, followed by relative humidity and maximum temperature (Figure 2). On the other hand, parasitism was the least important variable for SMI, with a negative percentage increase in mean standard error, meaning that error actually decreased when this variable was permuted. All four climatic variables were selected as the most important variables for SMI. Time inside traps was the last one in the Hb ranking and the second-last in SMI ranking. The supplementation of food was also of minor importance for both response variables.

Since parasitism was the most important variable for determining Hb and directly related to our main pprediction, in model selection we only built simple, additive, and multiplicative models including this factor, totaling 9 models (Table 2). The two first-ranked models had Hb varying with maximum temperature and relative humidity, both with interaction of parasitism and humidity, and either by additive or multiplicative combination of parasitism and maximum temperature. We selected only these two for model averaging because they summed a cumulative weight of 0.99.

Estimates of Hb were lower for parasitized than non-parasitized individuals trapped under same conditions (Figure 3, Appendix 2). Both groups had an increase in Hb with increasing maximum temperature. Hb increased with decreasing humidity among non-parasitized individuals, but declined with decreasing humidity among parasitized individuals. Thus, Hb of parasitized individuals was closer to that of non-parasitized ones when humidity was high, and differed from them when humidity was low.

We had a set of 11 candidate models for SMI model selection (Table 3). Since SMI was calculated separatedly for each sex, we added this variable in all models of the model selection. We only joined maximum temperature with other climatic variables together in the same models. The two best models had SMI varying with maximum and minimum temperatures, and together had a cumulative weight of 0.80. Model averaged estimates from selected models showed a slight positive slope for the relationship between SMI and minimum temperature and negative relationship between SMI and maximum temperature (Figure 4, Appendix 3).

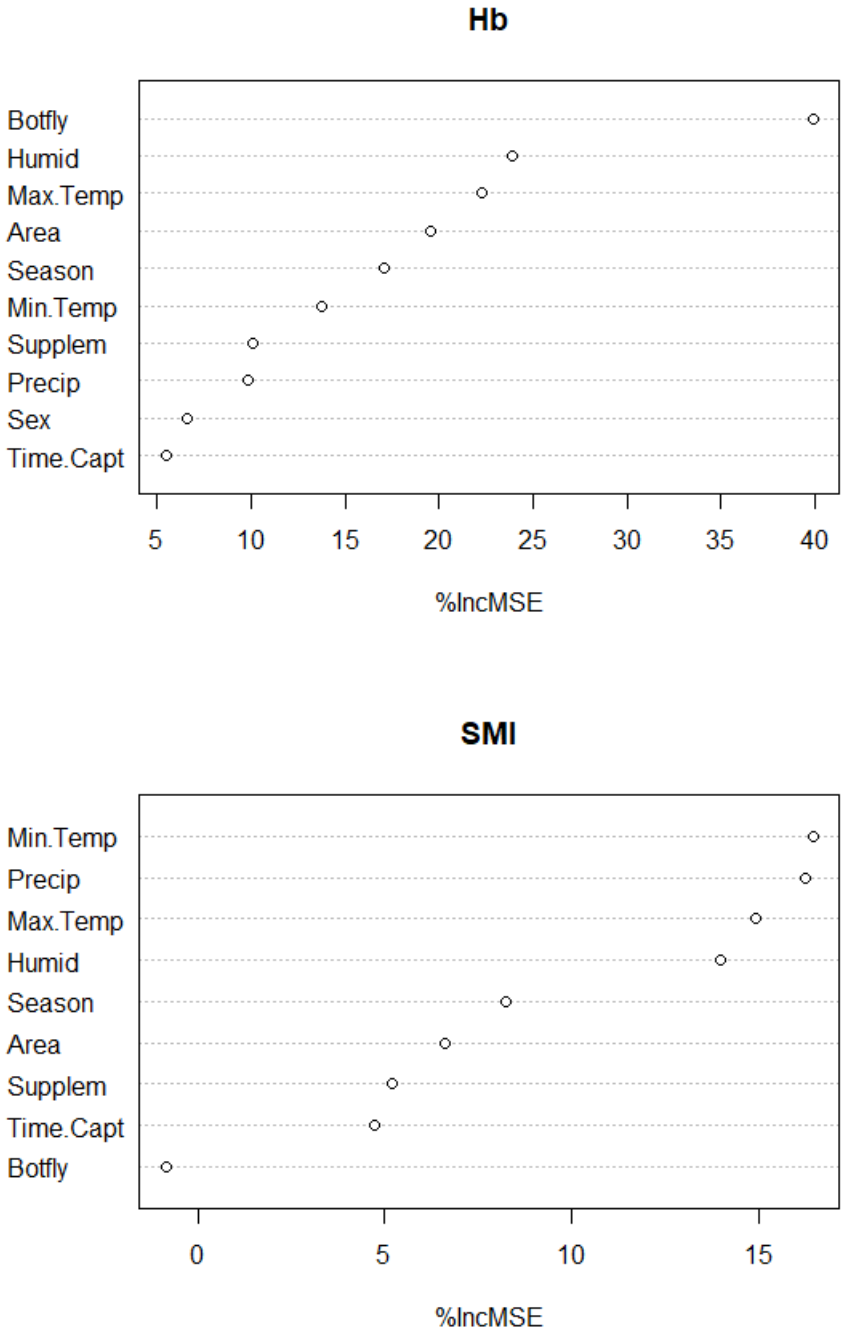

Figure 2. Variable importance plot resulting from the random forest analyses of the effects on haemoglobin concentration (Hb) and body condition (SMI). Variables were ranked with regard to importance on the y-axis. %IncMSE is the percentage increase in mean square error. The explanatory variables were parasitism by botflies (*C. apicalis*), food supplementation (Supplem - control/experiment), climatic season (Season - dry/wet), area (four grids), sex (females and males), time of capture (Time.Capt - in minutes), and the climatic variables: maximum temperature (Max.Temp), minimum temperature (Min.Temp), precipitation (Precip), and relative humidity (Humid).

Table 2 Model selection of the haemoglobin concentration of *Gracilinanus agilis* as a function of parasitism (Botfly), daily maximum temperature (Max.Temp), and daily relative humidity (Humid). K is the number of parameters, AICc is the Akaike's information criterion corrected for small samples, ΔAICc is the difference of AICc value to the best model, w is the Akaike weight, LL is the loglikelihood of the model. The signals + and * indicate the additive and the multiplicative effects between variables.

Models	**K**	**AICc**	**ΔAICc**	**w**	**LL**
Botfly + Max.Temp + Humid + Botfly*Humid	6	1590.70	0.00	0.68	-789.24
Botfly + Max.Temp + Humid + Botfly*Max.Temp + Botfly*Humid	7	1592.24	1.54	0.31	-788.98
Botfly + Max.Temp + Humid	5	1600.80	10.10	0.00	-795.32
Botfly + Humid + Botfly*Humid	5	1601.83	11.13	0.00	-795.84
Botfly + Max.Temp + Humid + Botfly*Max.Temp	6	1602.70	12.00	0.00	-795.24
Botfly + Max.Temp	4	1606.27	15.58	0.00	-799.09
Botfly + Max.Temp + Botfly*Max.Temp	5	1607.70	17.00	0.00	-798.77
Botfly + Humid	4	1614.05	23.35	0.00	-802.97
Botfly	3	1640.02	49.33	0.00	-816.98

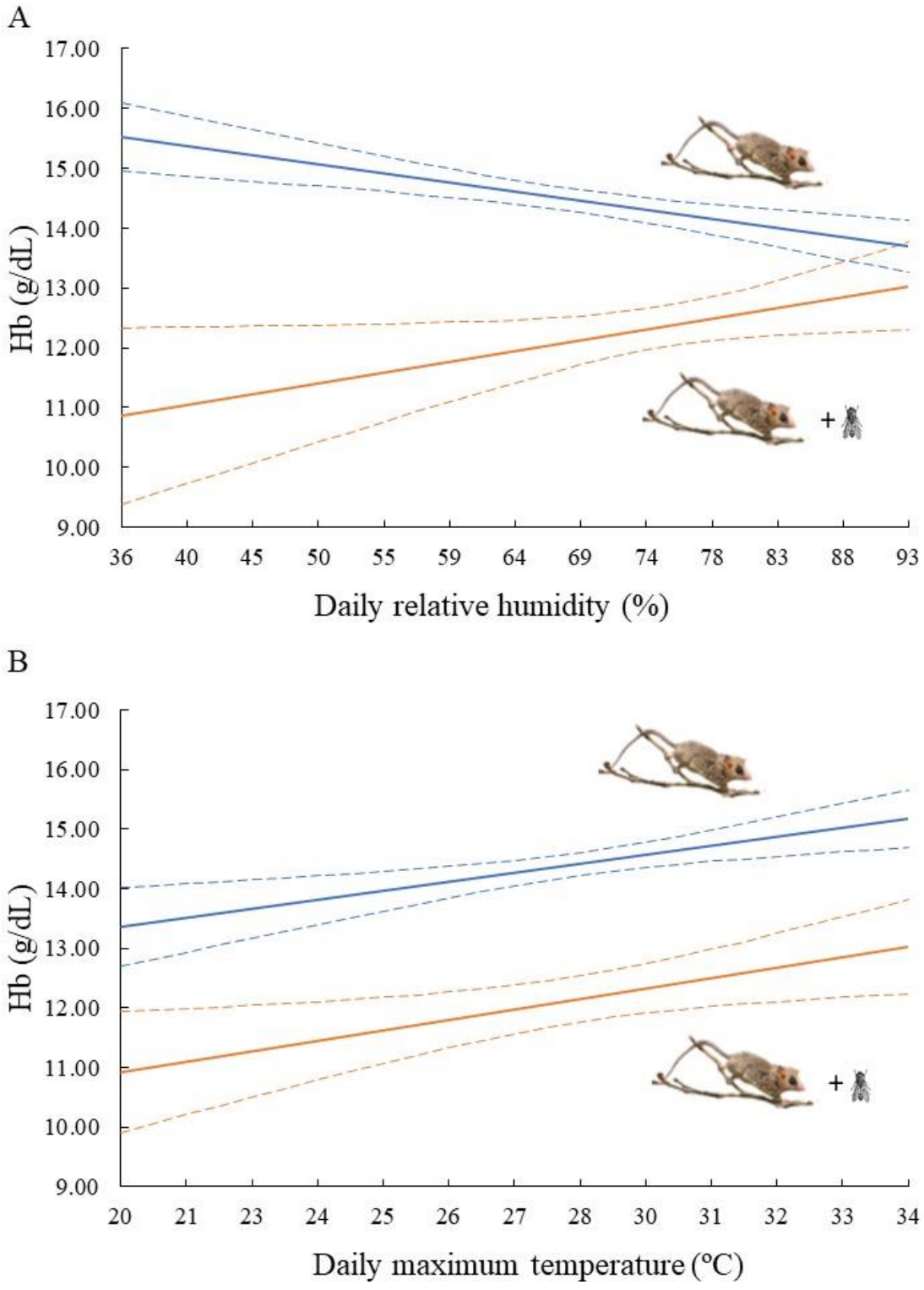

Figure 3. Estimates of haemoglobin concentration of *Gracilinanus agilis* (Hb; solid lines) and 95 % confidence limits (dashed lines) resulted from model averaging the two first models of the candidate set and varying with daily relative humidity and daily maximum temperature for the non-parasitized (blue) and parasitized (orange) individuals. a) daily maximum temperature and b) daily relative humidity are maintained constant at their means, 28.53 ºC and 69.76 % respectively.

Table 3. Model selection of the body condition index of *Gracilinanus agilis* as a function of sex, daily maximum temperature (Max.Temp), daily minimum temperature (Min.Temp), daily relative humidity (Humid), and daily precipitation (Precip). K is the number of parameters, AICc is the Akaike's information criterion corrected for small samples, ΔAICc is the difference of AICc value to the best model, w is the Akaike weight, LL is the loglikelihood of the model. The signals + and * indicate the additive and the multiplicative effects between variables.

Models	K	AICc	ΔAICc	w	LL
Sex + Max.Temp + Min.Temp	5	2071.22	0.00	0.51	-1030.53
Sex + Max.Temp + Min.Temp + Max.Temp*Min.Temp	6	2072.30	1.08	0.29	-1030.04
Sex + Humid	4	2074.66	3.44	0.09	-1033.28
Sex + Min.Temp	4	2075.75	4.54	0.05	-1033.83
Sex + Max.Temp + Humid	5	2076.62	5.40	0.03	-1033.23
Sex + + Max.Temp + Humid + Max.Temp*Humid	6	2078.63	7.41	0.01	-1033.21
Sex + Precip	4	2080.92	9.71	0.00	-1036.41
Sex + Max.Temp + Precip	5	2081.77	10.55	0.00	-1035.81
Sex	3	2081.94	10.73	0.00	-1037.94
Sex + Max.Temp	4	2082.37	11.16	0.00	-1037.14
Sex + Max.Temp + Precip + Max.Temp*Precip	6	2082.55	11.34	0.00	-1035.17

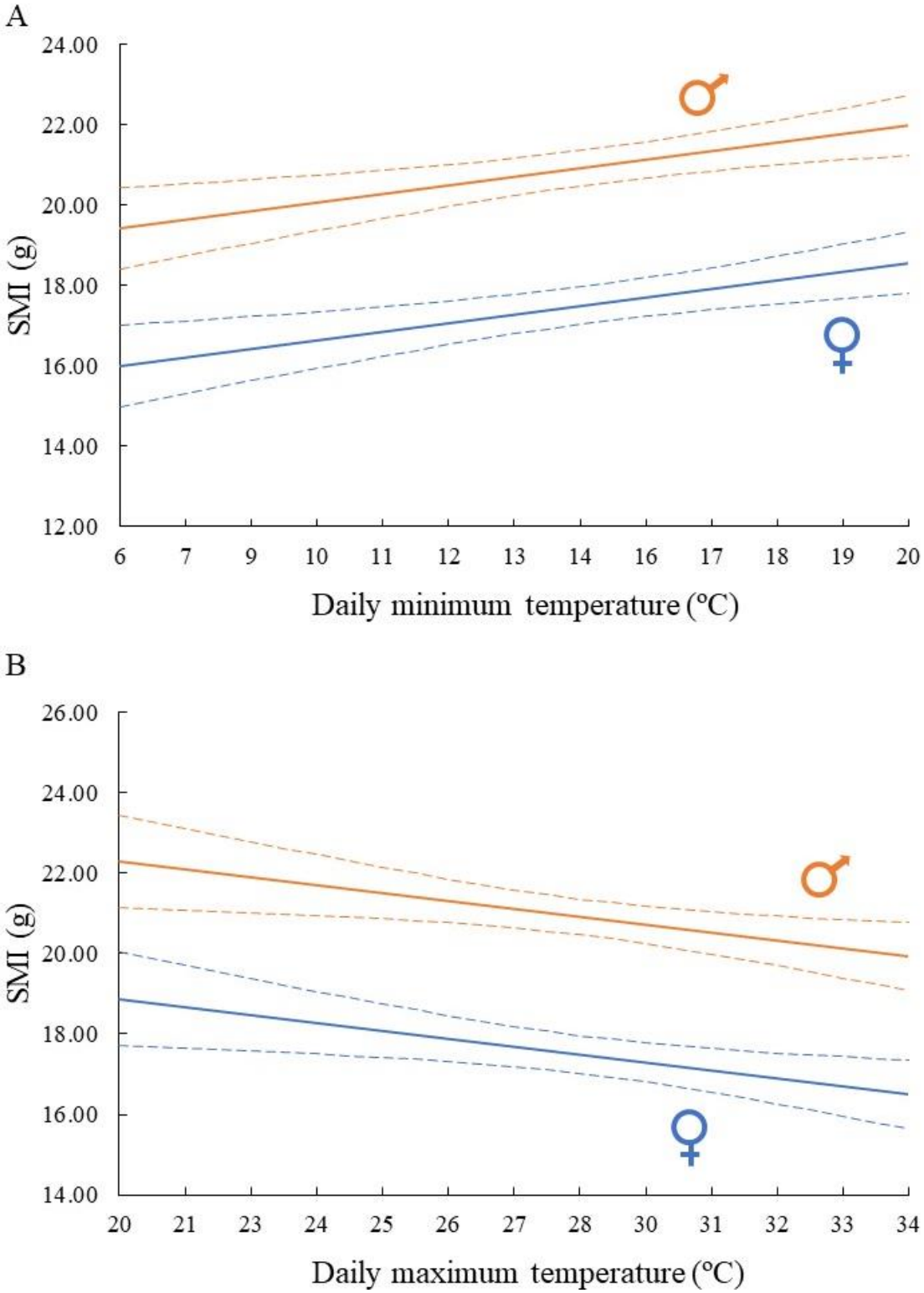

Figure 4. Estimates of body condition indexes of *Gracilinanus agilis* (SMI; solid lines) and 95 % confidence limits (dashed lines) resulted from model averaging the two first models of the candidate set and varying with daily minimum and maximum temperatures. a) daily maximum temperature and b) daily minimum temperature are maintained constant at their means, 28.49 ºC and 14.38 ºC respectively.

Discussion

Our study was the first one to investigate the effects of botfly parasitism on a neotropical marsupial. Our main hypotheses and predictions were partially supported, and the haemoglobin concentrations were lower when *G. agilis* individuals were parasitized by the botfly *C. apicalis*. However, body condition did not differ between parasitized and non-parasitized animals.

Our results suggest the presence of botfly larvae leads to a certain degree of anaemia, and this has also been seen in previous studies with rodents (Sealander 1961, Dunaway et al. 1967, Bennett 1973, Hunter & Webster 1974). Anaemia is a considerable reduction in the red blood cells, caused by either abnormal loss or decreased production, and leads to a deficiency in oxygen transport (Campbell 2015). Even though cuterebrid botflies feed on the host's interstitial fluid instead of its blood (Hunter & Webster 1974), anaemia can be a consequence of inflammatory processes caused by infectious agents and nutritional deficiencies (Thrall 2012b).

The model selection indicated daily climatic variables as important for explaining body condition and haemoglobin concentration. Among the non-parasitized individuals, haemoglobin increased with the increase of the maximum temperature and the decrease of the relative humidity, a pattern found at the peak of the dry season. As expected, it appears that animals were dehydrated on the hottest and driest days. The evaporative water loss rate of *G. agilis*, rate at which the individual loses water through respiration, increases linearly with environmental temperature (Cooper et al. 2009). During the dry seasons of 2015 and 2016, we commonly observed individuals with sunken eyes, and even with a gap between the eyeball and the surrounding tissue, which is a symptom of 8-12 % of dehydration in mammals (Silverstein & Campbell 2012, Donohoe 2016).

The responses of the parasitized individuals to environmental variables differed from those of the non-parasitized ones. The relationship between predicted Hb and daily maximum temperature was similar but with lower values for the parasitized animals. For relative humidity, however, we detected an opposite pattern: haemoglobin increased with increasing humidity. This pattern is counterintuitive because anaemia and dehydration alone show opposite effects, and we would expect anaemia being masked by dehydration, as observed in dogs and cats clinical cases (Lynch et al. 2016). It seems there was a synergistic effect, in which the effect of botfly parasitism was much more pronounced in face of an additional stressor, dehydration. Botflies are estimated to have approximately 80 % of water content (Smith 1977), so this uptake during larvae fast growth could be challenging for the hosts in times of water limitation.

Interactions between the effect of botfly and an environmental stress were also observed regarding higher trap mortality of *Peromyscus eremicus* during cold nights in a desert climate (Nichols 1994), and lower winter survival for a thermoregulation deficient rodent (*Akodon azarae*; Zuleta & Vignau 1990). Although temperatures have an effect on *G. agilis* activity (Vieira et al. 2017), low nocturnal temperature was not a key environmental stressor in our study, probably because this marsupial faces less harsh minimum temperatures than those that occur in deserts during night and also because it can enter in torpor.

Nevertheless, this synergistic effect between anaemia and dehydration would probably cause a minor effect on the host populations because the presence of botflies seems to injure more the hosts with the extra physiological stress in September, during the peak of the dry season, when prevalence reaches the lowest values. However, botfly parasitism has the potential to become a major effect on small mammal populations, especially the ones isolated in patches, in face of climate change towards more occurrence of days under draught conditions in central Brazil (Dai 2011, Bustamante et al. 2012, Prudhomme et al. 2014).

We did not find between-sex differences in haemoglobin concentration of *G. agilis*. For other small didelphid (the short-tailed opossum *Monodelphis domestica*), however, an opposite pattern was reported, in which haemoglobin concentration of males was 8 % greater than females (Evans et al. 2010). Mean Hb of *G. agilis* was close to the overall values reported for *M. domestica* (13.0 g/dL, range 12.2 - 13.8 g/dL), but lower than dasyurid marsupials (Australian mouse-like marsupials) of similar size (Clark 2004).

Our results indicated that potential deleterious effects of botfly parasitism on marsupial host are not apparent through evaluation of body condition. This parameter is assumed to be an indicator of health since it would reflect body fat reserves or lean muscle mass of the individuals. There is still much controversy regarding the validity of those assumptions (Schulte-Hostedde et al. 2001, Wilder et al. 2016) and which of the many available indices must be used (Jakob et al. 1996, Peig & Green 2009, 2010, Labocha et al. 2014). Body condition, however, is still widely used in ecological studies for its practicality and for being a non-invasive approach.

Although some studies investigating the effects of cuterebrid botflies recorded body mass loss (Dunaway et al. 1967, Smith 1978), others found that individuals had the same or a better condition when parasitized (Bergallo et al. 2000, Cramer & Cameron 2006) or a faster growth in smaller animals (Boonstra et al. 1980). In laboratory experiments, the host changes from losing weight to increasing food intake during the period of infestation to compensate for the food reserves drainage (Hunter & Webster 1974). This shift occurs at the time the botfly

larva needs to grow rapidly to a large size (many thousand-fold), and it continues to cause protein deficiency and to alter the host blood pattern (Hunter & Webster 1974). Therefore, unless there is no food limitation in the field, wild individuals would show the same pattern of change in weight of their counterparts in the laboratory.

Most of the records of parasitism by *C. apicalis* in our study area occurred with gracile mouse opossum, which is an indication of high specificity of the botfly. The position of the larvae, however, varied in their body. For the 165 individuals whose information about the position of larvae was recorded, in 86.3 % of cases the larvae were located in an abdominal position at the host body and only 1.4 % of cases in an inguinal position. The remainder were lateral, dorsal, pectoral, and even in the region of the throat. Warble site specificity is characteristic of botflies in their native hosts (but appears less defined in secondary hosts; Hunter & Webster 1973, Boonstra et al. 1980, Slansky 2007). For *G. agilis*, even considering that in most cases the warbles were located on the abdominal position, it is not clear if the marsupial can be considered a typical host for *C. apicalis*.

The variables daily minimum and maximum temperatures, although selected for being related with body condition of *G. agilis*, are unlikely to represent a major effect for two reasons. Firstly, those climatic variables had low values of the percentage increase in mean square error (% IncMSE). Secondly, the predicted body condition indices from the model averaging had a small range of variation in relation to both temperature amplitudes. The possible explanation for the slight negative relationship between maximum temperature and body condition is the same as mentioned previously regarding Hb, related to the increase in water loss through respiration with increasing temperatures. Moreover, the positive relationship between minimum temperature and body condition could be explained by the increase in respiratory frequency and oxygen consumption with the decrease in temperature (Cooper et al. 2009). These relationships, however, do not occur in torpid animals. During torpor, body temperature can drop to 14.6 ºC (at 12 ºC), which results in absolute energy and water savings (Cooper et al. 2009).

Contrary to our predictions, the relevance of the variables food supplementation was very low, both for haemoglobin concentration and body condition. We expected that the areas with artificial increase in food resource would have animals with better body condition, as observed in other studies with small mammals (Boutin 1990, Prevedello et al. 2013). We even predicted that the individuals from areas subject to food supplementation would show a less pronounced effect of the botfly parasitism than the ones from the non-manipulated areas, as more resources and consequent better nutrition might enhance host immune defense by increasing pathogen clearance or resistance to infection (Becker et al. 2018). In our study, it is

possible that an increase in host density in areas with artificial food addition would maintain the available energy per individual somewhat similar in comparison to control areas. Also, we expected that the degree of dehydration would increase with the time spent by the animals inside traps, reducing the plasma volume in the blood and consequently increasing the red blood cell concentration (Buffenstein et al. 1999, Fletcher & Boonstra 2006), which did not occur, either.

In conclusion, our results indicate that the mouse opossum *G. agilis* was affected by botfly parasitism by *C. apicalis*, even though the effect was not apparent in body condition. Erythrocyte metrics such as haemoglobin concentration can detect changes in population health when they are not evident in the demographic parameters (Johnstone et al. 2017), and that extends to mass/length data. Parasitized animals seem to conceal the nutrient deficiency with the increase in food intake, maintaining or even gaining weight. We demonstrated that the effect of myiasis could be magnified by environmental stressors and that may be critical for the maintenance of populations in small forest patches such as the woodland savannah ("cerradão").

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FINAL REMARKS

The main goal of this thesis was to evaluate the changes in population and physiological parameters of the marsupial *Gracilinanus agilis* in relation to its semelparous life-history strategy as well as to extrinsic factors, such as food supplementation, seasonality and botfly parasitism. The results supported most of the predictions of the semelparous strategy for *G. agilis*. In chapter 1, we showed that the studied populations had seasonal reproduction, age structure, recruitment and survival probabilities, leading to population decline in the end of the reproductive season. In chapter 2, a broad picture of the adaptive stress response of a neotropical marsupial was obtained for the first time. Such response was characterized by the increase in free cortisol levels and by the downstream effects of the chronic activation of the stress axis. Contrary to findings from a previous study (Hernandez et al. 2018), we demonstrated that faecal cortisol metabolites do not reflect free plasma cortisol and, therefore, is not a good indication of adrenal activity for *G. agilis*. In chapter 3, we revealed that the health condition of *G. agilis* was affected by botfly parasitism through reduction in haemoglobin concentration, and that seasonality magnified the parasitism effect. Since body condition did not reflect haemoglobin concentration, the result suggests a deteriorated health condition may stay undetected in typical ecological studies that do not include physiological parameters.

The food supplementation experiment caused minor or no effect on the studied variables. We do not believe, however, that this result means the experiment was unsuccessful, for several reasons. Firstly, we ensured *ad libitum* food through visitations every two/three weeks during the experiment. Secondly, many pieces of evidence indicated that individuals of *G. agilis* consumed the food in the feeders. Camera traps installed in front of random-selected feeders registered individuals of *G. agilis* visiting them. Faeces characteristic of small didelphids were often found with the partially-eaten food, and even some animals were found sleeping in nests inside the feeders on a number of occasions. Moreover, we collected hair samples with hair traps inside the entrance tubes that were identified as *G. agilis* (also arboreal rodents and *Didelphis albiventris* [probably only juveniles] were identified using this method). We could not determine the proportion of food each species used, but the other pieces of evidence ensure *G. agilis* was not prevented from using the feeders by the other species. We could not determine the proportion of individuals that used the feeders, but the mean home range size for *G. agilis* from the same study areas was relatively small (0.20 ha, Sano 2017), reducing the chances of only a few individuals controlling the resources from the feeders. Finally, we believe the cat food chosen was a suitable source of energy (3912 kcal/Kg of

metabolizable energy) and protein (310 g/Kg or 31 %) for this insectivorous-omnivorous species. In a dietary preference experiment, adults of *G. agilis* consumed 26.4 % of protein content and juveniles, 20.2 % (Astúa de Moraes et al. 2003). Therefore, this food was primarily more adequate to the marsupial than to the rodent species, which have a more frugivorous diet (Oliveira & Bonvicino 2011, Paglia et al. 2012). Furthermore, the brand "Premier Golden Gatos Sabor Salmão" had been chosen since *G. agilis* individuals consumed more this specific brand and flavour than others of cat and dog food in a food-preference experiment conducted before the start of the food supplementation. However, this species might need other nutrients not provided by the cat food and we were not able to evaluate to which extent the animals feeded on other resources than the supplemented food.

Prevedello et al. (2013) suggested that the small size of the manipulated areas (< 10 ha) and the intense immigration are the main reasons for the positive effect on abundances in food supplementation experiments in general. Although our grids were relatively small (1.44 ha), our experiment was distinct from most previous studies on this subject in two aspects. Firstly, our study areas were patches of "cerradão" surrounded by cerrado *sensu stricto*, and this configuration limits the openness of the populations and consequently immigration because *G. agilis* is more abundant in forested habitats. Secondly, we created a boundary strip around the grids to avoid a crowding effect, increasing the total supplemented areas to about 3.24 ha. Since the mean home range size for *G. agilis* was small and did not change with the food supplementation experiment (Sano 2017), we believe the boundary strips were effective. Therefore, the population increases found in the supplemented areas were less likely to be an effect of immigration. In spite of that, we found minor or no demographic and physiological responses.

It remains unclear if populations of *G. agilis* are food-limited. Perhaps the food supplementation would have caused more detectable effects on the studied populations if it was continued for more generations. In a longer experiment, the effects on the reproductive effort could be more pronounced, leading to more considerable effects on population parameters. Unfortunately, it is not always possible to maintain long-term studies, especially the ones that require more effort and financial investment such as experiments in natural systems.

According to our findings from population data, *G. agilis* would not be semelparous *stricto sensu* because there was not a complete male die-off, since a few males were alive in the post-reproductive season. Moreover, we found evidence that some females not only survived but also reproduced in their second year, a finding contrary to the expected (but not always observed) monoestrous reproduction of semelparous species. However, the variation in

physiological data indicated that this didelphid marsupial shows an adaptive stress response similar to the semelparous dasyurid marsupials, represented by a high free cortisol levels during the reproductive season, and even higher during the post-reproductive season. The mechanism in the studied didelphid, however, seems not to involve an increase in total cortisol but only a reduction in CBG circulation, while the mechanism in dasyurids usually involves both cortisol production and CBG reduction. Another difference is that *G. agilis* females also showed elevated free cortisol levels, while dasyurid females maintain high CBG levels and consequently low free cortisol levels. It is yet to be answered how *G. agilis* females can cope with high cortisol levels during lactation. Nonetheless, these differences between marsupial groups support the idea that the adaptive stress response and the semelparous life history evolved independently many times, and the mechanisms may be dependent on life-history traits, such as the length of the reproductive season of the species.

We suggest that future research should focus on the circulating sex hormones of *G. agilis* to better understand how the gonadal axis influences the stress axis and, therefore, to have a complete description of the endocrine changes in both females and males. These investigations would demonstrate if an increase in testosterone production is directly related to the observed increase in the scrotal width, and if the depression in male CBG levels is testosterone-dependent as it is in dasyurids. Moreover, this kind of research could shed light on the female CBG reduction not observed in other semelparous species. Studies on spermatogenesis would also clarify if the production ceases at any period of the *G. agilis* male life cycle, and would finally answer the question if the surviving males are able to reproduce in a second reproductive season.

Furthermore, future research on stress response should be expanded to other neotropical marsupials. Knowledge on the physiological strategies in marsupials comes only from Australasian species, except for this and other two studies (*G. agilis*: Hernandez et al 2018, *Didelphis virginiana*: Woods & Hellgren 2003). The research on the ecology of stress is still incipient in the Neotropics and there are many possibilities for researches to explore. Both experimental and observational studies in wild populations are needed to build up the knowledge of the physiological mechanisms behind life-history traits of didelphid marsupials. For example, the hormonal-challenge protocol is a useful way of testing the negative feedback regulation of the HPA axis and the responsiveness of adrenal glands (Boonstra 2005), and could provide important complementary information to studies based on the natural variation, such as this thesis.

Finally, we suggest that mammal researchers should reconsider the use of the term semelparity. Demographic and physiological studies have been pointing towards a gradient of

life histories instead of simple categories (Fisher et al. 2013), or even more than one gradient (Bielby et al. 2007), which makes it difficult to determine the extreme point of semelparity. For example, even in the considered true semelparous species of the genus *Antechinus*, which show the typical activation of the HPA axis, there is evidence of not so extreme mortality: males in captivity can survive the reproductive season if they are released from social stress and food limitation (Naylor et al. 2008). On the other hand, a *G. agilis* population was considered partially semelparous because some males survived the reproductive season (Martins et al. 2006), even without any indication that they could reproduce again. In some other cases, species that showed complete male die-off in natural populations without the increase in cortisol levels were also considered semelparous (Oakwood 2001, Woods & Hellgren 2003). Therefore, the term semelparity and its derivatives such as partial semelparity have been used in different situations and, although appealing, they have become rather vague and should be avoided. The range of possible life histories is much more complex than what was thought at the time "semelparity" was first used to describe a strategy in marsupials. Maybe it is still early to propose a new classification, since we do not have a complete view of life history variation. At this moment, a new classification could be as misleading as the current one.

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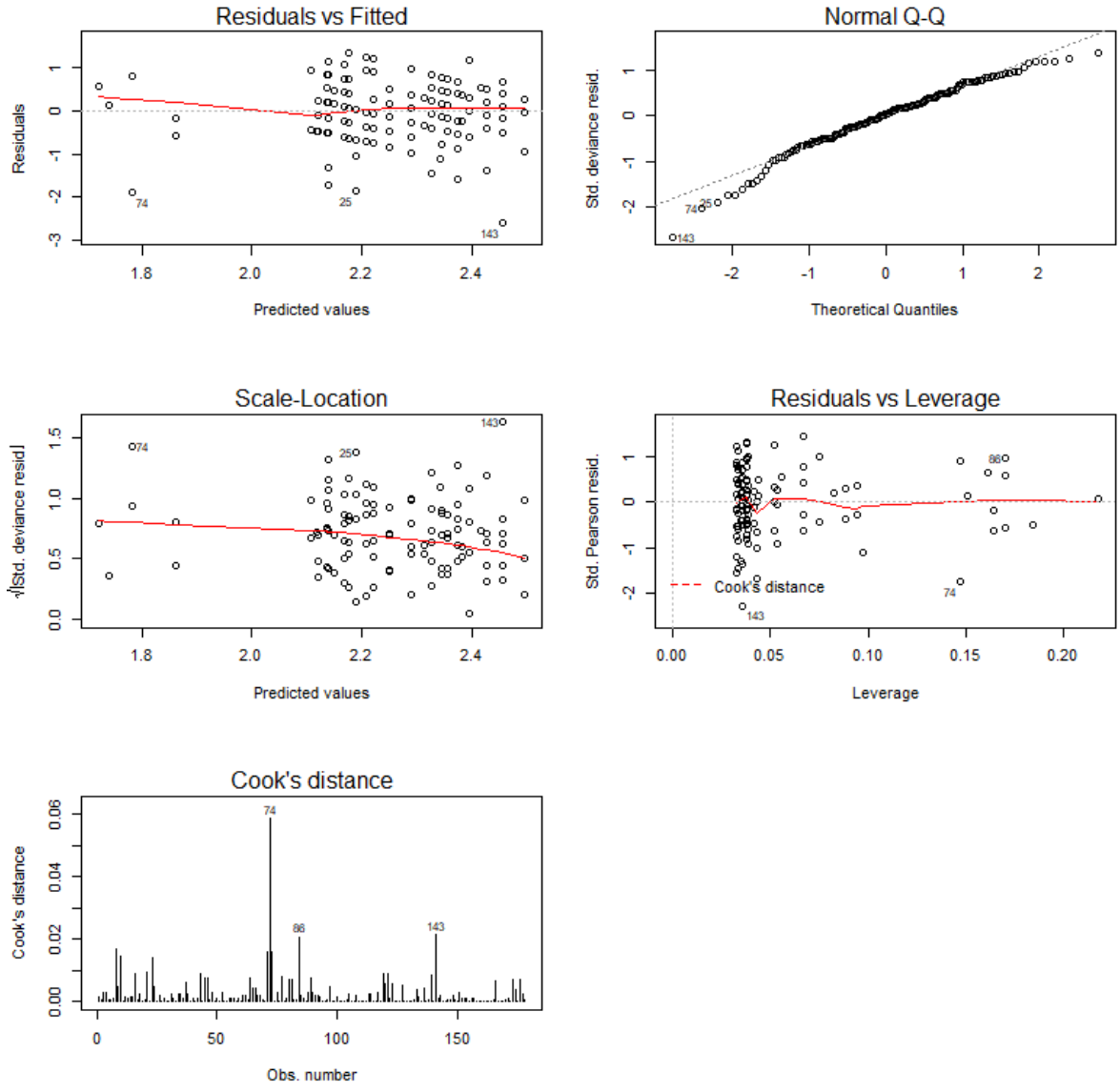
SUPPLEMENTARY MATERIAL - CHAPTER 1

Appendix 1. Diagnostic plots of the generalized linear model for the litter size (LS) of *Gracilinanus agilis* using Poisson family (log link function). The effects in the model were: month adapted to the life cycle of the individuals (M), generation (Gen) and grid. Graphics for each model in clockwise direction: residuals vs fitted plot, normal QQ plot, residuals vs leverage plot, cook's distances plot and scale-location or spread-location plot. Labeled points represent possible outliers, high-leverage and/or influential points, and were investigated. Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points.

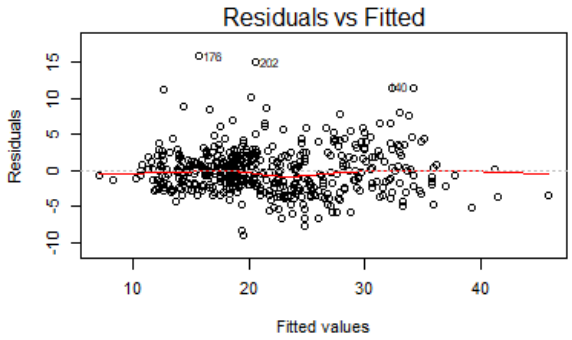


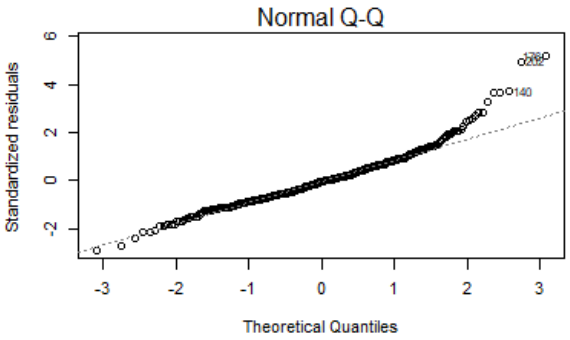
Appendix 2. Model-averaged beta coefficients for the litter size of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

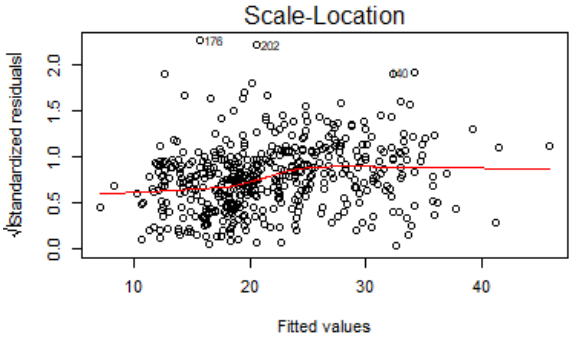
Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	2.42	0.07	2.29	2.55
Nov/Dec	-0.21	0.05	-0.31	-0.10
Feb/Mar	-0.63	0.16	-0.95	-0.31
Sep	-0.28	0.15	-0.58	0.01
2015	-0.04	0.06	-0.16	0.09
2016	-0.07	0.06	-0.19	0.06
JB1	0.01	0.10	-0.08	0.08
JB2	0.03	0.09	-0.08	0.09
JB4	0.11	0.09	-0.09	0.13

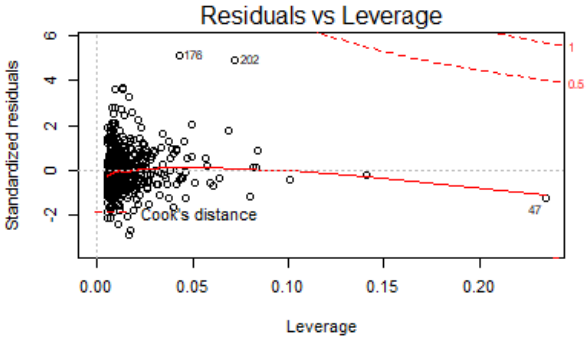
Appendix 3. Diagnostic plots of the generalized linear model for male body mass of *Gracilinanus agilis* using a) linear; b) linear, with the response variable transformed to natural logarithm; c) generalized linear, using gamma family and log link function; d) and generalized linear, using gamma family and inverse link function. The model was a function of head-body length (HB), scrotal width (SW), and groups of males with SW < 9 mm and of males with SW > 10 mm (Group), as well as interactions among those variables. Graphics for each model in clockwise direction: residuals vs fitted plot, normal QQ plot, residuals vs leverage plot, cook's distances plot and scale-location or spread-location plot. Labeled points represent possible outliers, high-leverage and/or influential points, and were investigated. Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points.

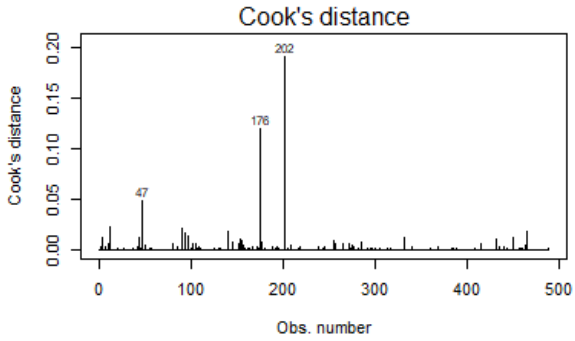
a) Mass ~ HB*SW*Group



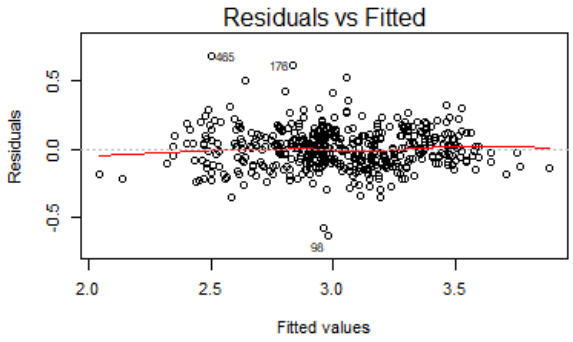


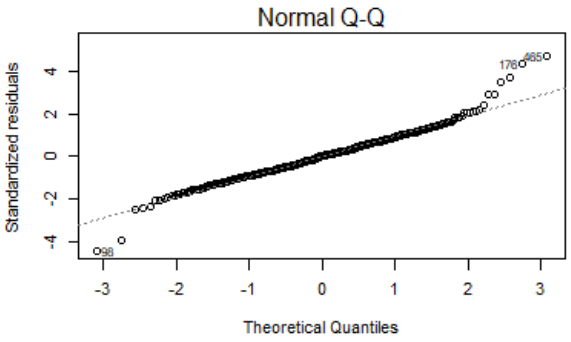


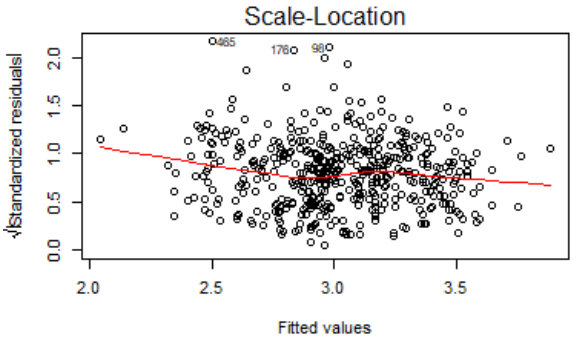


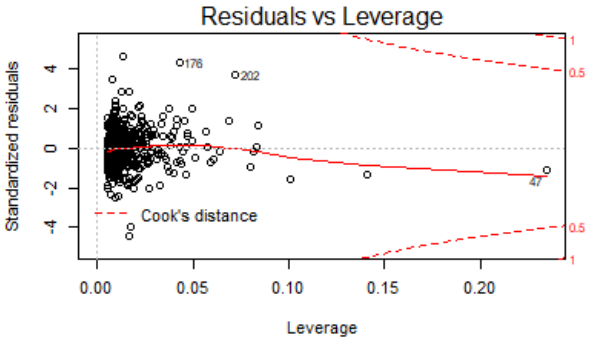


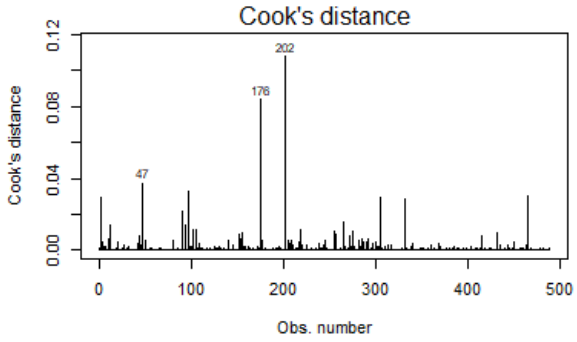
b) ln(Mass) ~ HB*SW*Group



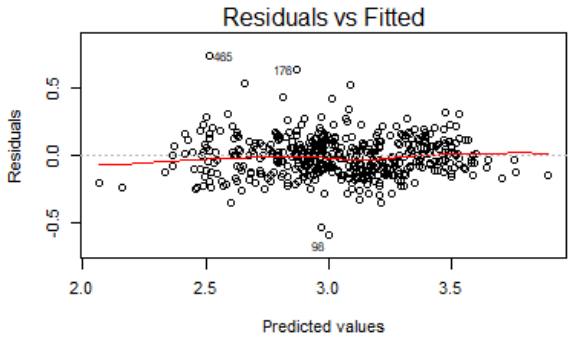


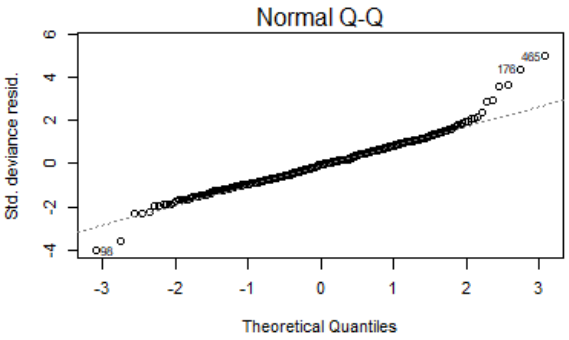


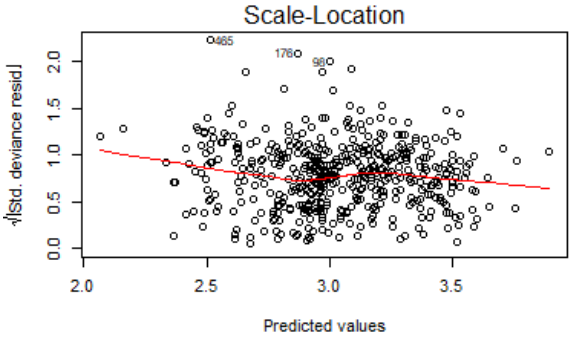


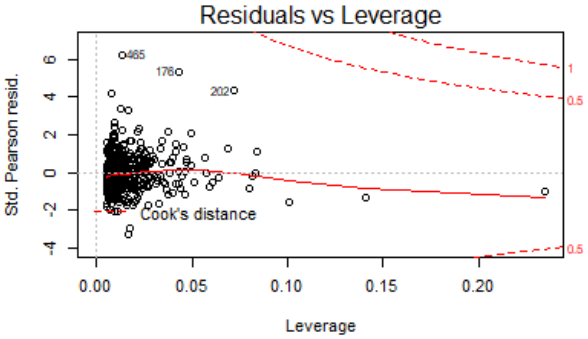


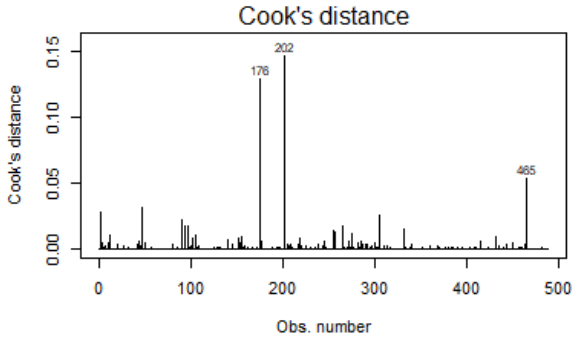
c) Mass ~ HB*SW*Group, Gamma family (log link)



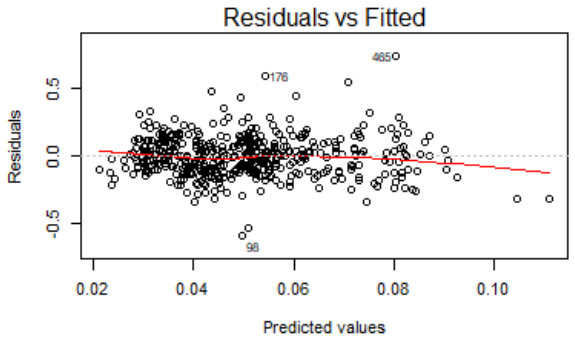


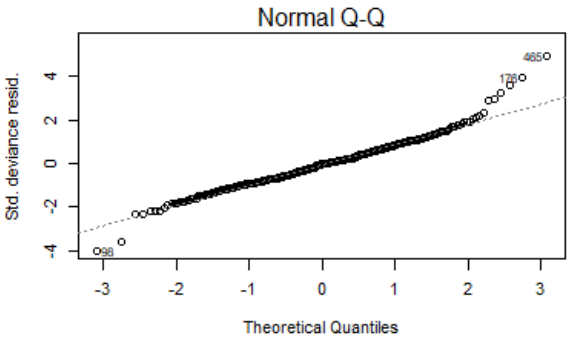


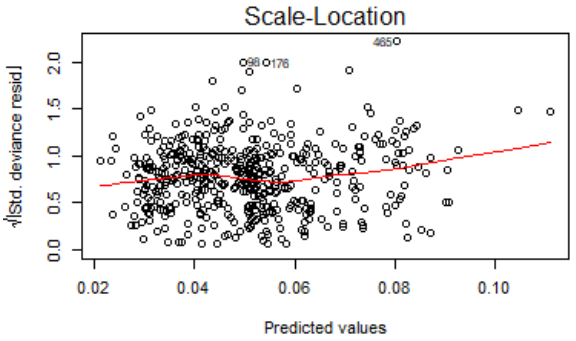


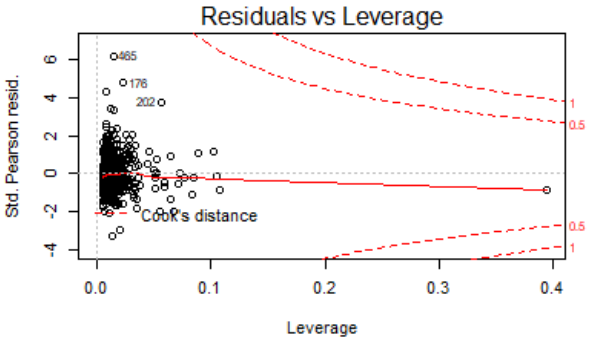


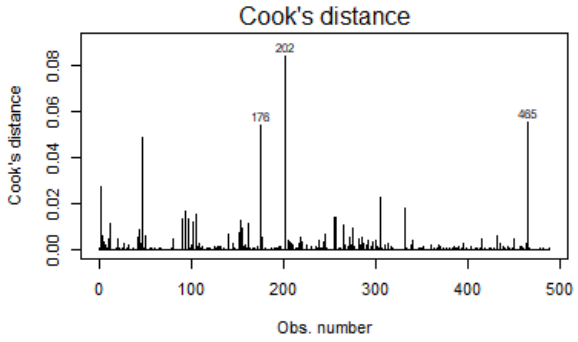
d) Mass ~ HB*SW*Group, Gamma family (inverse link)









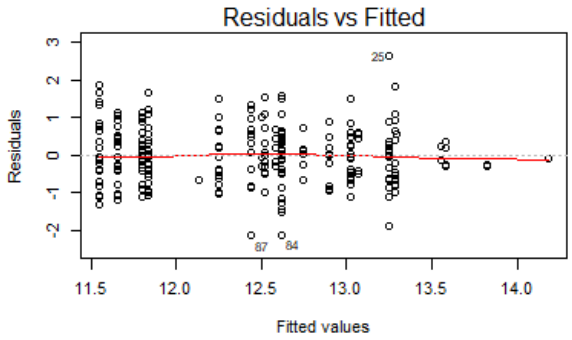


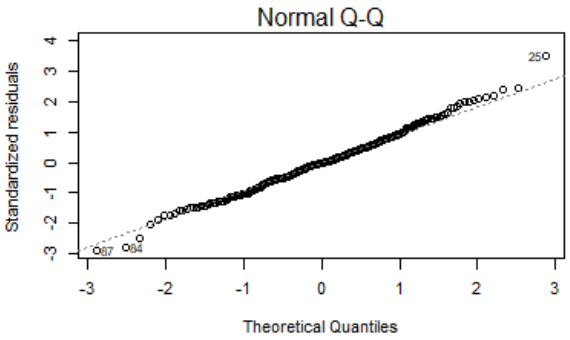
Appendix 4. Model-averaged beta coefficients for male body mass of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

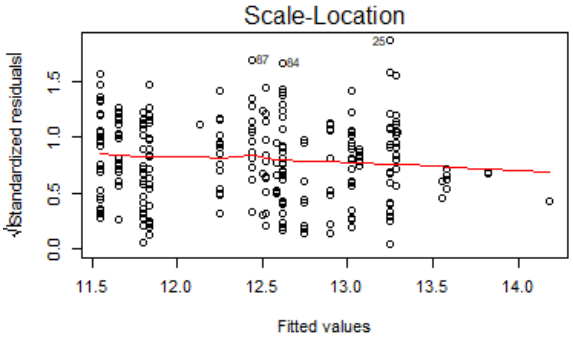
Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	-21.39	8.22	-37.55	-5.24
HB	0.38	0.10	0.19	0.56
Group 2	114.41	34.47	46.67	182.14
SW	4.42	1.81	0.87	7.97
HB*Group 2	-1.21	0.34	-1.88	-0.55
HB*SW	-0.04	0.02	-0.08	0.00
Group 2*SW	-14.08	3.23	-20.43	-7.73
HB*Group 2*SW	0.15	0.03	0.08	0.21

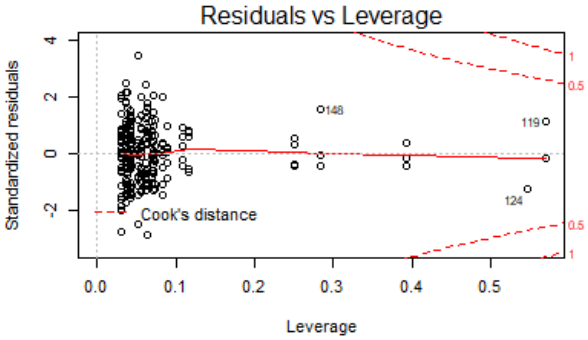
Appendix 5. Diagnostic plots of the generalized linear model for the scrotal width (SW) of mature males of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The investigated models were: i) linear; ii) linear with the response variable transformed to natural logarithm; iii) generalized linear using gamma family and log link function; iv) and generalized linear using gamma family and inverse link function. The effects in each model were: month adapted to the life cycle of the individuals (M), generation (Gen), grid, and the interactions between month and generation (M*Gen), between month and grid (M*Grid) and between generation and grid (Gen*Grid). Graphics for each model in clockwise direction: residuals vs fitted plot, normal QQ plot, residuals vs leverage plot, cook's distances plot and scale-location or spread-location plot. Labeled points represent possible outliers, high-leverage and/or influential points, and were investigated. Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points.

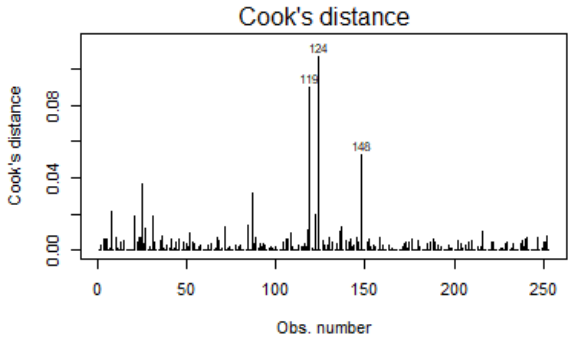
a) SW ~ M + Gen + Grid + M*Gen + M*Grid + Gen*Grid



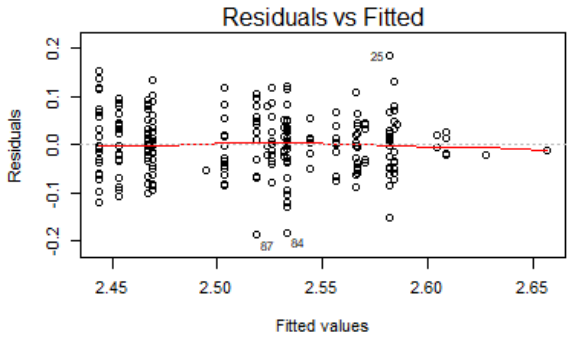


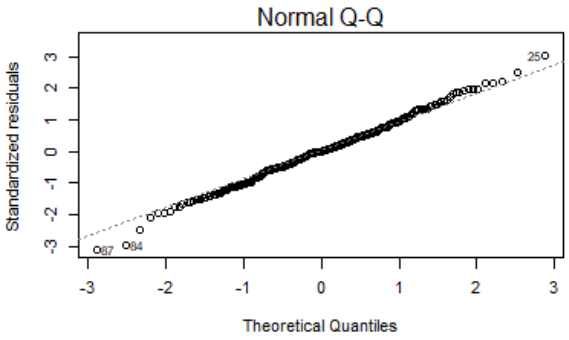


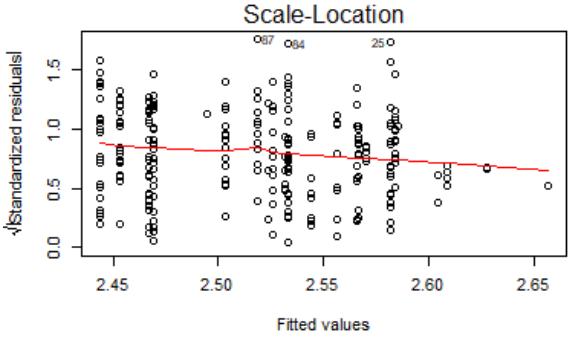


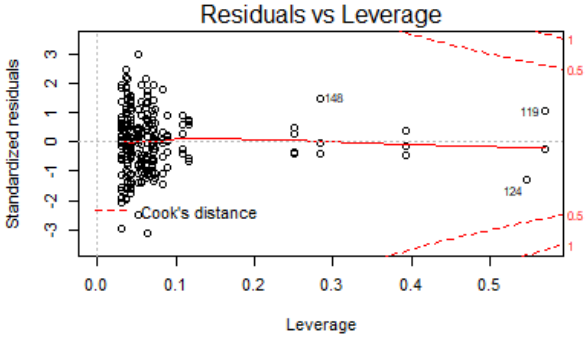


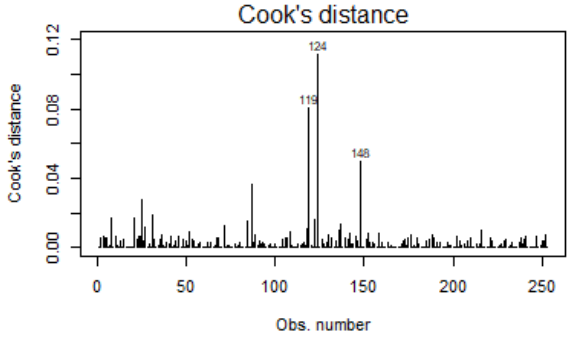
b) ln(SW) ~ M + Gen + Grid + M*Gen + M*Grid + Gen*Grid



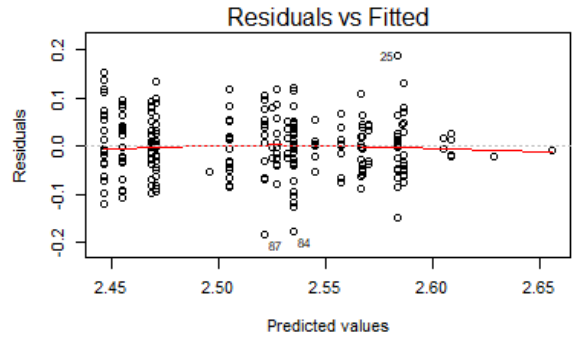


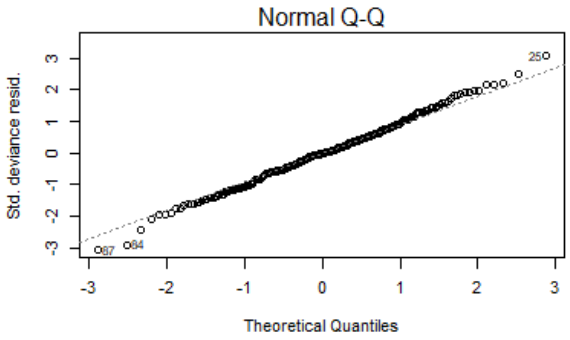


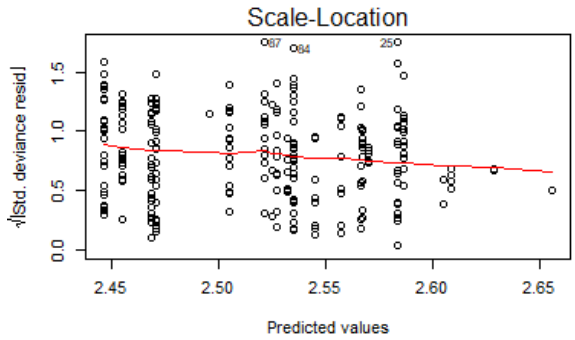


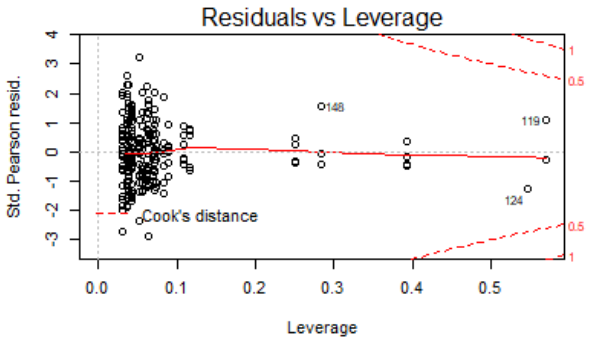


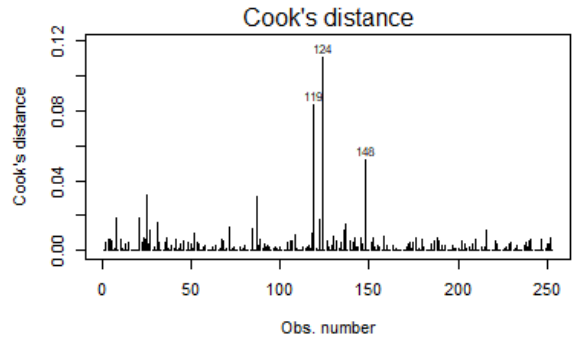
c) SW ~ M + Gen + Grid + M*Gen + M*Grid + Gen*Grid, Gamma family (log link)



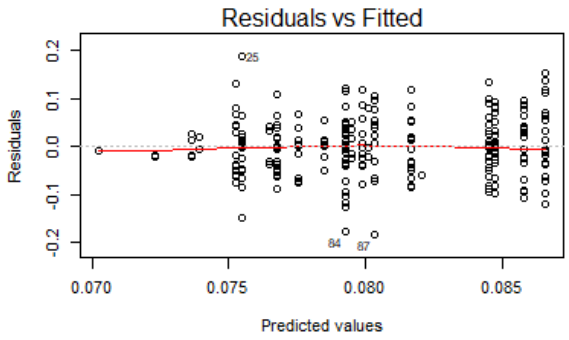


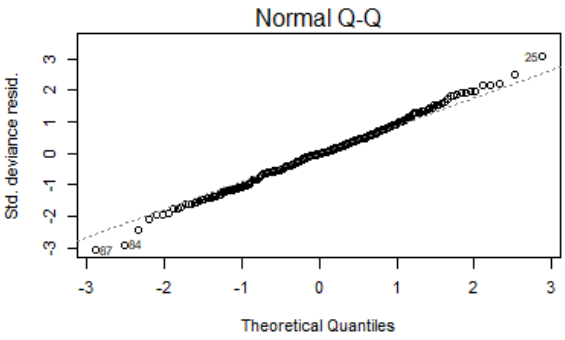


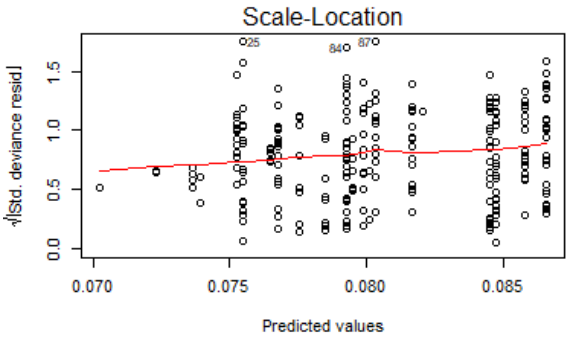


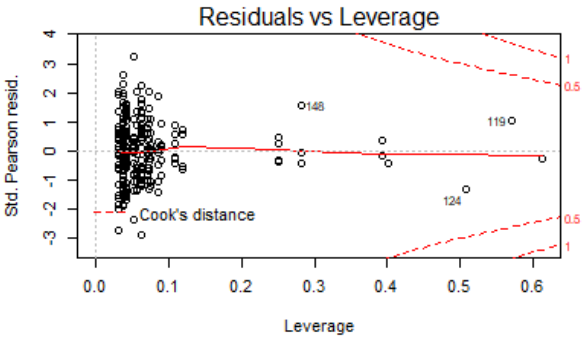


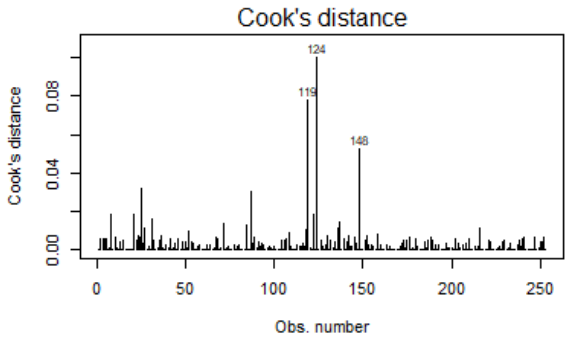
d) SW ~ M + Gen + Grid + M*Gen + M*Grid + Gen*Grid, Gamma family (inverse link)











Appendix 6. Model-averaged beta coefficients for the scrotal width of mature males of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	12.32	0.13	12.08	12.57
Sep	0.71	0.16	0.40	1.03
2.Dec	0.75	0.47	-0.17	1.68
2016	-0.72	0.15	-1.01	-0.44
Suppl	0.24	0.12	0.00	0.48
2016*Sep	0.35	0.25	-0.15	0.85
2016*2.Dec	0.82	0.56	-0.29	1.93
2016*Suppl	0.01	0.09	-0.18	0.19
Sep*Suppl	0.00	0.07	-0.14	0.15
2.Dec*Suppl	0.06	0.22	-0.37	0.49

Appendix 7. Model selection for the capture histories of *Gracilinanus agilis* for each of the four patches of "cerradão", two with food supplementation experiment and two controls. Models may have apparent survival (φ) and recapture (p) probabilities varying as a function of sex, time (t), climatic season (seas: dry and wet), food supplementation experiment (suppl), interaction between factors (*) or no effect (.). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, L is the model likelihood and Dev is the deviance. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	-2logL	Dev
	FAL (control)						
1	φ(sex+t) p(sex*seas)	34	854.81	0.00	0.58	782.41	260.77
2	φ(sex+t) p(sex)	32	857.23	2.42	0.17	789.34	267.70
3	φ(sex+t) p(.)	31	858.02	3.21	0.12	792.37	270.73
4	φ(sex+t) p(sex+seas)	33	858.97	4.16	0.07	788.83	267.19
5	φ(sex+t) p(seas)	32	859.52	4.71	0.06	791.63	269.99
6	φ(sex+seas) p(.)	4	878.44	23.63	0.00	870.37	348.73
7	φ(sex+seas) p(seas)	5	878.54	23.73	0.00	868.43	346.79
8	φ(sex*seas) p(.)	5	879.72	24.91	0.00	869.61	347.97
9	φ(sex*seas) p(seas)	6	879.92	25.11	0.00	867.77	346.13
10	φ(sex+seas) p(sex)	5	880.31	25.50	0.00	870.20	348.56
11	φ(sex+seas) p(sex*seas)	7	880.45	25.64	0.00	866.25	344.61
12	φ(sex+seas) p(sex+seas)	6	880.50	25.69	0.00	868.35	346.71
13	φ(sex*seas) p(sex)	6	881.73	26.92	0.00	869.58	347.94
14	φ(sex*seas) p(sex+seas)	7	881.94	27.13	0.00	867.74	346.11
15	φ(sex*seas) p(sex*seas)	8	882.44	27.63	0.00	866.19	344.55
16	φ(sex+seas) p(t)	32	882.59	27.78	0.00	814.70	293.06
17	φ(sex*seas) p(t)	33	883.52	28.71	0.00	813.38	291.74
18	φ(sex+seas) p(sex+t)	33	883.79	28.98	0.00	813.65	292.01
19	φ(sex*seas) p(sex+t)	34	884.13	29.32	0.00	811.73	290.09
20	φ(t) p(.)	30	886.32	31.52	0.00	822.91	301.27
21	φ(sex+t) p(t)	58	886.65	31.84	0.00	757.41	235.77
22	φ(t) p(sex*seas)	33	887.12	32.32	0.00	816.98	295.35
23	φ(t) p(seas)	31	887.59	32.79	0.00	821.95	300.31
24	φ(sex+t) p(sex+t)	59	887.65	32.85	0.00	755.93	234.29
25	φ(t) p(sex)	31	888.39	33.58	0.00	822.74	301.10
26	φ(t) p(sex+seas)	32	889.41	34.60	0.00	821.52	299.88
27	φ(sex) p(sex*seas)	6	892.74	37.93	0.00	880.59	358.95
28	φ(seas) p(sex+t)	32	895.12	40.31	0.00	827.23	305.59
29	φ(sex) p(seas)	4	897.78	42.97	0.00	889.71	368.07

30	φ(seas) p(sex*seas)	6	898.56	43.75	0.00	886.41	364.77
31	φ(seas) p(sex+seas)	5	899.06	44.25	0.00	888.96	367.32
32	φ(sex) p(sex+seas)	5	899.81	45.00	0.00	889.70	368.06
33	φ(sex*t) p(sex*seas)	62	899.83	45.02	0.00	760.60	238.96
34	φ(seas) p(sex)	4	900.29	45.48	0.00	892.22	370.58
35	φ(seas) p(.)	3	901.39	46.58	0.00	895.34	373.70
36	φ(seas) p(seas)	4	901.41	46.60	0.00	893.34	371.70
37	φ(sex*t) p(sex)	60	901.54	46.74	0.00	767.33	245.69
38	φ(sex*t) p(.)	59	902.09	47.28	0.00	770.37	248.73
39	φ(sex*t) p(sex+seas)	61	902.41	47.60	0.00	765.69	244.06
40	φ(seas) p(t)	31	902.41	47.60	0.00	836.76	315.12
41	φ(sex) p(t)	31	902.57	47.77	0.00	836.93	315.29
42	φ(sex) p(sex+t)	32	902.70	47.89	0.00	834.81	313.17
43	φ(sex*t) p(seas)	60	902.77	47.96	0.00	768.56	246.92
44	φ(.) p(sex*seas)	5	909.73	54.92	0.00	899.62	377.98
45	φ(sex) p(.)	3	911.59	56.78	0.00	905.54	383.91
46	φ(t) p(sex+t)	58	912.45	57.64	0.00	783.21	261.57
47	φ(sex) p(sex)	4	912.54	57.73	0.00	904.47	382.83
48	φ(.) p(sex+t)	31	913.10	58.29	0.00	847.45	325.81
49	φ(t) p(t)	57	914.81	60.00	0.00	788.05	266.41
50	φ(.) p(sex+seas)	4	914.93	60.12	0.00	906.86	385.22
51	φ(.) p(seas)	3	918.12	63.31	0.00	912.08	390.44
52	φ(.) p(t)	30	921.24	66.43	0.00	857.83	336.19
53	φ(sex+seas) p(sex*t)	61	926.44	71.63	0.00	789.72	268.08
54	φ(sex*seas) p(sex*t)	62	928.37	73.56	0.00	789.14	267.50
55	φ(seas) p(sex*t)	60	932.71	77.90	0.00	798.49	276.85
56	φ(.) p(.)	2	932.75	77.94	0.00	928.73	407.09
57	φ(.) p(sex)	3	933.62	78.81	0.00	927.58	405.94
58	φ(sex*t) p(t)	86	935.28	80.47	0.00	732.68	211.04
59	φ(sex*t) p(sex+t)	87	936.39	81.59	0.00	731.02	209.38
60	φ(sex) p(sex*t)	60	941.23	86.42	0.00	807.01	285.38
61	φ(.) p(sex*t)	59	947.72	92.91	0.00	816.00	294.36
62	φ(sex+t) p(sex*t)	87	948.54	93.73	0.00	743.16	221.52
63	φ(t) p(sex*t)	86	958.92	104.11	0.00	756.32	234.68
64	φ(sex*t) p(sex*t)	114	1011.21	156.40	0.00	726.33	204.69
	JB1 (control)						
1	φ(sex+t) p(sex)	33	1132.72	0.00	0.53	1063.66	313.70
2	φ(sex+t) p(sex+seas)	34	1133.89	1.16	0.29	1062.64	312.68
3	φ(sex+t) p(sex*seas)	35	1136.05	3.32	0.10	1062.60	312.64
4	φ(sex+t) p(.)	32	1137.20	4.47	0.06	1070.32	320.36
5	φ(sex+t) p(seas)	33	1138.97	6.25	0.02	1069.91	319.95
6	φ(sex*seas) p(sex+seas)	7	1157.78	25.06	0.00	1143.64	393.67
7	φ(sex*seas) p(sex)	6	1158.85	26.13	0.00	1146.74	396.78

8	φ(sex+seas) p(sex+seas)	6	1159.15	26.42	0.00	1147.04	397.08
9	φ(sex*seas) p(sex*seas)	8	1159.52	26.80	0.00	1143.33	393.37
10	φ(sex*t) p(sex)	62	1159.97	27.25	0.00	1024.88	274.91
11	φ(sex*seas) p(seas)	6	1161.11	28.39	0.00	1149.00	399.04
12	φ(sex+seas) p(sex*seas)	7	1161.15	28.42	0.00	1147.00	397.04
13	φ(sex*t) p(sex+seas)	63	1161.29	28.57	0.00	1023.82	273.86
14	φ(sex+seas) p(sex)	5	1162.16	29.44	0.00	1152.08	402.12
15	φ(sex+seas) p(seas)	5	1162.55	29.82	0.00	1152.47	402.51
16	φ(sex*seas) p(.)	5	1162.83	30.10	0.00	1152.75	402.79
17	φ(sex) p(sex+seas)	5	1163.59	30.87	0.00	1153.51	403.55
18	φ(sex*t) p(sex*seas)	64	1163.67	30.95	0.00	1023.82	273.86
19	φ(sex*t) p(.)	61	1164.30	31.58	0.00	1031.57	281.61
20	φ(sex+seas) p(.)	4	1164.51	31.79	0.00	1156.46	406.50
21	φ(sex+t) p(sex+t)	61	1164.72	31.99	0.00	1031.99	282.03
22	φ(sex) p(sex*seas)	6	1165.44	32.71	0.00	1153.33	403.37
23	φ(sex*t) p(seas)	62	1166.05	33.32	0.00	1030.95	280.99
24	φ(sex) p(seas)	4	1166.99	34.27	0.00	1158.94	408.98
25	φ(sex*seas) p(t)	34	1167.29	34.57	0.00	1096.04	346.08
26	φ(sex+seas) p(t)	33	1168.91	36.19	0.00	1099.85	349.89
27	φ(sex*seas) p(sex+t)	35	1169.20	36.47	0.00	1095.75	345.79
28	φ(sex+seas) p(sex+t)	34	1170.24	37.51	0.00	1098.98	349.02
29	φ(sex+t) p(t)	60	1170.83	38.10	0.00	1040.46	290.50
30	φ(sex) p(sex)	4	1173.36	40.64	0.00	1165.31	415.35
31	φ(sex) p(t)	32	1175.89	43.17	0.00	1109.01	359.05
32	φ(t) p(.)	31	1176.61	43.88	0.00	1111.91	361.95
33	φ(sex) p(.)	3	1177.63	44.91	0.00	1171.60	421.64
34	φ(sex) p(sex+t)	33	1178.07	45.35	0.00	1109.01	359.05
35	φ(t) p(seas)	32	1178.43	45.70	0.00	1111.55	361.59
36	φ(t) p(sex)	32	1178.59	45.86	0.00	1111.71	361.75
37	φ(t) p(sex*seas)	34	1180.19	47.47	0.00	1108.94	358.98
38	φ(t) p(sex+seas)	33	1180.53	47.81	0.00	1111.47	361.51
39	φ(seas) p(sex+t)	33	1184.61	51.88	0.00	1115.54	365.58
40	φ(sex+seas) p(sex*t)	63	1186.78	54.05	0.00	1049.31	299.35
41	φ(sex*seas) p(sex*t)	64	1189.03	56.30	0.00	1049.17	299.21
42	φ(seas) p(seas)	4	1190.55	57.83	0.00	1182.50	432.54
43	φ(.) p(seas)	3	1191.84	59.11	0.00	1185.80	435.84
44	φ(seas) p(sex+seas)	5	1192.10	59.37	0.00	1182.02	432.06
45	φ(seas) p(.)	3	1192.61	59.89	0.00	1186.58	436.62
46	φ(seas) p(sex*seas)	6	1193.70	60.97	0.00	1181.59	431.62
47	φ(.) p(sex+seas)	4	1193.73	61.00	0.00	1185.67	435.71
48	φ(seas) p(sex)	4	1193.77	61.05	0.00	1185.72	435.76
49	φ(seas) p(t)	32	1194.20	61.47	0.00	1127.32	377.36
50	φ(seas) p(sex*t)	62	1194.30	61.57	0.00	1059.20	309.24
51	φ(.) p(sex+t)	32	1195.37	62.64	0.00	1128.49	378.53

52	φ(.) p(sex*seas)	5	1195.73	63.01	0.00	1185.65	435.69
53	φ(sex*t) p(sex+t)	90	1198.36	65.64	0.00	994.13	244.17
54	φ(sex) p(sex*t)	62	1198.49	65.76	0.00	1063.39	313.43
55	φ(.) p(t)	31	1198.90	66.18	0.00	1134.20	384.24
56	φ(.) p(.)	2	1200.82	68.09	0.00	1196.80	446.84
57	φ(.) p(sex)	3	1202.83	70.11	0.00	1196.80	446.84
58	φ(sex*t) p(t)	89	1203.48	70.75	0.00	1001.81	251.85
59	φ(t) p(sex+t)	60	1204.75	72.03	0.00	1074.38	324.42
60	φ(sex+t) p(sex*t)	90	1206.26	73.54	0.00	1002.03	252.07
61	φ(.) p(sex*t)	61	1206.92	74.20	0.00	1074.19	324.23
62	φ(t) p(t)	59	1209.51	76.78	0.00	1081.49	331.53
63	φ(t) p(sex*t)	89	1221.24	88.51	0.00	1019.58	269.61
64	φ(sex*t) p(sex*t)	118	1263.90	131.18	0.00	984.57	234.60
	JB2 (experiment)						
1	φ(sex+t) p(t)	58	1310.89	0.00	0.73	1185.84	350.50
2	φ(sex+t) p(sex+t)	59	1312.85	1.96	0.27	1185.47	350.14
3	φ(sex+suppl) p(t)	32	1330.57	19.68	0.00	1263.86	428.53
4	φ(sex*suppl) p(t)	33	1332.08	21.19	0.00	1263.20	427.87
5	φ(sex+suppl) p(sex+t)	33	1332.35	21.46	0.00	1263.48	428.15
6	φ(sex+seas) p(t)	32	1332.55	21.66	0.00	1265.85	430.51
7	φ(sex) p(t)	31	1332.87	21.98	0.00	1268.33	433.00
8	φ(sex*seas) p(t)	33	1333.50	22.61	0.00	1264.62	429.29
9	φ(sex*suppl) p(sex+t)	34	1333.82	22.93	0.00	1262.77	427.43
10	φ(sex+seas) p(sex+t)	33	1334.20	23.31	0.00	1265.33	429.99
11	φ(sex) p(sex+t)	32	1334.56	23.67	0.00	1267.86	432.53
12	φ(sex*seas) p(sex+t)	34	1334.72	23.83	0.00	1263.67	428.34
13	φ(sex+t) p(suppl)	32	1336.74	25.85	0.00	1270.04	434.70
14	φ(t) p(t)	57	1337.32	26.43	0.00	1214.59	379.26
15	φ(sex+t) p(sex*seas)	34	1337.53	26.64	0.00	1266.48	431.15
16	φ(t) p(sex+t)	58	1337.66	26.77	0.00	1212.61	377.28
17	φ(sex+t) p(sex+suppl)	33	1338.06	27.17	0.00	1269.18	433.85
18	φ(sex+t) p(sex*suppl)	34	1340.23	29.34	0.00	1269.18	433.85
19	φ(sex+t) p(seas)	32	1341.16	30.27	0.00	1274.46	439.13
20	φ(sex+t) p(.)	31	1342.51	31.62	0.00	1277.97	442.64
21	φ(sex*t) p(t)	86	1342.52	31.63	0.00	1149.97	314.63
22	φ(sex+t) p(sex+seas)	33	1343.18	32.29	0.00	1274.31	438.98
23	φ(sex+t) p(sex)	32	1344.06	33.17	0.00	1277.36	442.03
24	φ(sex*t) p(sex+t)	87	1345.03	34.14	0.00	1149.96	314.63
25	φ(suppl) p(sex+t)	32	1350.77	39.88	0.00	1284.07	448.74
26	φ(seas) p(sex+t)	32	1352.69	41.80	0.00	1285.99	450.66
27	φ(.) p(sex+t)	31	1352.82	41.93	0.00	1288.28	452.95
28	φ(sex+t) p(sex*t)	87	1354.22	43.33	0.00	1159.16	323.83
29	φ(sex+suppl) p(sex*t)	61	1355.55	44.66	0.00	1223.51	388.18

30	φ(suppl) p(t)	31	1355.91	45.02	0.00	1291.37	456.04
31	φ(.) p(t)	30	1357.39	46.50	0.00	1295.02	459.69
32	φ(sex*suppl) p(sex*t)	62	1357.40	46.51	0.00	1223.01	387.68
33	φ(sex) p(sex*t)	60	1358.05	47.16	0.00	1228.34	393.01
34	φ(seas) p(t)	31	1358.22	47.33	0.00	1293.68	458.35
35	φ(sex+seas) p(sex*t)	61	1359.14	48.25	0.00	1227.10	391.77
36	φ(sex*seas) p(sex*t)	62	1360.72	49.83	0.00	1226.33	391.00
37	φ(suppl) p(sex*t)	60	1361.51	50.62	0.00	1231.80	396.47
38	φ(.) p(sex*t)	59	1363.87	52.98	0.00	1236.49	401.16
39	φ(seas) p(sex*t)	60	1365.11	54.22	0.00	1235.40	400.07
40	φ(t) p(sex*seas)	33	1365.26	54.37	0.00	1296.38	461.05
41	φ(sex*t) p(suppl)	60	1365.62	54.73	0.00	1235.92	400.58
42	φ(t) p(suppl)	31	1365.90	55.01	0.00	1301.37	466.03
43	φ(t) p(sex*t)	86	1366.06	55.17	0.00	1173.50	338.17
44	φ(t) p(sex+suppl)	32	1367.12	56.23	0.00	1300.42	465.09
45	φ(sex*t) p(sex+suppl)	61	1367.63	56.74	0.00	1235.58	400.25
46	φ(sex*t) p(seas)	60	1368.31	57.42	0.00	1238.60	403.27
47	φ(t) p(seas)	31	1368.72	57.83	0.00	1304.19	468.85
48	φ(t) p(sex+seas)	32	1368.72	57.83	0.00	1302.02	466.69
49	φ(t) p(sex*suppl)	33	1369.25	58.37	0.00	1300.38	465.05
50	φ(sex*t) p(sex*suppl)	62	1369.90	59.01	0.00	1235.51	400.18
51	φ(sex*t) p(.)	59	1370.24	59.35	0.00	1242.86	407.53
52	φ(sex*t) p(sex*seas)	62	1370.39	59.50	0.00	1236.01	400.67
53	φ(sex*t) p(sex+seas)	61	1370.53	59.64	0.00	1238.48	403.15
54	φ(t) p(.)	30	1371.14	60.25	0.00	1308.77	473.44
55	φ(sex+suppl) p(sex*seas)	7	1371.21	60.32	0.00	1357.07	521.74
56	φ(t) p(sex)	31	1371.92	61.03	0.00	1307.38	472.05
57	φ(sex*t) p(sex)	60	1372.42	61.53	0.00	1242.71	407.38
58	φ(sex*suppl) p(sex*seas)	8	1372.97	62.08	0.00	1356.80	521.46
59	φ(sex+suppl) p(seas)	5	1373.92	63.03	0.00	1363.85	528.52
60	φ(sex*suppl) p(seas)	6	1375.71	64.82	0.00	1363.61	528.27
61	φ(sex+suppl) p(sex+seas)	6	1375.95	65.06	0.00	1363.85	528.52
62	φ(sex) p(sex*seas)	6	1377.62	66.73	0.00	1365.52	530.19
63	φ(sex*suppl) p(sex+seas)	7	1377.74	66.85	0.00	1363.60	528.27
64	φ(sex+seas) p(sex*seas)	7	1379.66	68.77	0.00	1365.52	530.19
65	φ(sex) p(seas)	4	1380.26	69.37	0.00	1372.21	536.88
66	φ(sex+suppl) p(suppl)	5	1380.62	69.73	0.00	1370.54	535.21
67	φ(sex*seas) p(sex*seas)	8	1381.69	70.80	0.00	1365.51	530.18
68	φ(sex+suppl) p(sex+suppl)	6	1381.90	71.01	0.00	1369.79	534.46
69	φ(sex+seas) p(suppl)	5	1382.07	71.18	0.00	1372.00	536.67
70	φ(sex+seas) p(seas)	5	1382.17	71.28	0.00	1372.09	536.76
71	φ(sex) p(sex+seas)	5	1382.28	71.39	0.00	1372.21	536.88
72	φ(sex*suppl) p(suppl)	6	1382.32	71.43	0.00	1370.22	534.88
73	φ(sex) p(suppl)	4	1382.87	71.98	0.00	1374.82	539.49

74	φ(sex*seas) p(suppl)	6	1382.91	72.02	0.00	1370.80	535.47
75	φ(sex*seas) p(seas)	6	1383.10	72.21	0.00	1370.99	535.66
76	φ(sex+seas) p(sex+suppl)	6	1383.56	72.67	0.00	1371.45	536.12
77	φ(sex*suppl) p(sex+suppl)	7	1383.69	72.80	0.00	1369.55	534.22
78	φ(sex+suppl) p(sex*suppl)	7	1383.93	73.04	0.00	1369.79	534.46
79	φ(sex+seas) p(sex+seas)	6	1384.19	73.30	0.00	1372.09	536.76
80	φ(sex) p(sex+suppl)	5	1384.24	73.35	0.00	1374.17	538.83
81	φ(sex*seas) p(sex+suppl)	7	1384.57	73.68	0.00	1370.43	535.10
82	φ(sex*seas) p(sex+seas)	7	1385.13	74.24	0.00	1370.99	535.66
83	φ(sex+seas) p(sex*suppl)	7	1385.55	74.66	0.00	1371.41	536.08
84	φ(sex*suppl) p(sex*suppl)	8	1385.72	74.83	0.00	1369.54	534.20
85	φ(sex+suppl) p(.)	4	1385.84	74.95	0.00	1377.79	542.46
86	φ(sex) p(sex*suppl)	6	1386.23	75.34	0.00	1374.13	538.80
87	φ(sex*seas) p(sex*suppl)	8	1386.59	75.70	0.00	1370.41	535.08
88	φ(sex+suppl) p(sex)	5	1387.34	76.45	0.00	1377.26	541.93
89	φ(sex*suppl) p(.)	5	1387.57	76.68	0.00	1377.50	542.17
90	φ(sex*suppl) p(sex)	6	1389.07	78.18	0.00	1376.97	541.63
91	φ(sex+seas) p(.)	4	1391.02	80.13	0.00	1382.97	547.63
92	φ(sex*seas) p(.)	5	1392.09	81.20	0.00	1382.02	546.69
93	φ(sex) p(.)	3	1392.50	81.61	0.00	1386.47	551.14
94	φ(sex+seas) p(sex)	5	1392.62	81.73	0.00	1382.55	547.21
95	φ(sex*seas) p(sex)	6	1393.88	82.99	0.00	1381.77	546.44
96	φ(sex) p(sex)	4	1394.00	83.11	0.00	1385.95	550.62
97	φ(suppl) p(sex*seas)	6	1395.19	84.30	0.00	1383.08	547.75
98	φ(suppl) p(sex+seas)	5	1398.86	87.97	0.00	1388.78	553.45
99	φ(sex*t) p(sex*t)	114	1399.87	88.98	0.00	1134.41	299.08
100	φ(suppl) p(seas)	4	1400.65	89.76	0.00	1392.60	557.27
101	φ(.) p(sex*seas)	5	1401.64	90.75	0.00	1391.56	556.23
102	φ(seas) p(sex*seas)	6	1403.11	92.22	0.00	1391.01	555.68
103	φ(.) p(sex+seas)	4	1405.20	94.31	0.00	1397.15	561.82
104	φ(.) p(seas)	3	1407.03	96.14	0.00	1401.00	565.67
105	φ(seas) p(sex+seas)	5	1407.16	96.27	0.00	1397.08	561.75
106	φ(suppl) p(suppl)	4	1407.19	96.31	0.00	1399.15	563.81
107	φ(suppl) p(sex+suppl)	5	1408.28	97.39	0.00	1398.21	562.87
108	φ(seas) p(seas)	4	1409.00	98.11	0.00	1400.95	565.62
109	φ(.) p(suppl)	3	1409.34	98.45	0.00	1403.31	567.97
110	φ(seas) p(suppl)	4	1409.91	99.02	0.00	1401.86	566.53
111	φ(.) p(sex+suppl)	4	1410.26	99.37	0.00	1402.21	566.87
112	φ(suppl) p(sex*suppl)	6	1410.28	99.40	0.00	1398.18	562.85
113	φ(seas) p(sex+suppl)	5	1410.51	99.62	0.00	1400.43	565.10
114	φ(.) p(sex*suppl)	5	1412.24	101.35	0.00	1402.17	566.83
115	φ(suppl) p(.)	3	1412.39	101.50	0.00	1406.36	571.03
116	φ(seas) p(sex*suppl)	6	1412.51	101.62	0.00	1400.41	565.08
117	φ(suppl) p(sex)	4	1413.07	102.18	0.00	1405.02	569.69

118	φ(.) p(.)	2	1419.11	108.22	0.00	1415.09	579.76
119	φ(seas) p(.)	3	1419.20	108.31	0.00	1413.17	577.84
120	φ(seas) p(sex)	4	1419.37	108.49	0.00	1411.33	575.99
121	φ(.) p(sex)	3	1419.76	108.87	0.00	1413.73	578.40
	JB4 (experiment)						
1	φ(sex*t) p(sex)	38	974.70	0.00	0.45	898.70	313.50
2	φ(sex*t) p(sex+suppl)	39	976.17	1.47	0.21	898.17	312.97
3	φ(sex*t) p(sex+seas)	39	976.70	2.00	0.16	898.70	313.50
4	φ(sex*t) p(sex*suppl)	40	978.17	3.47	0.08	898.17	312.97
5	φ(sex*t) p(sex*seas)	40	978.70	4.00	0.06	898.70	313.50
6	φ(sex*t) p(.)	37	980.83	6.13	0.02	906.83	321.63
7	φ(sex*t) p(suppl)	38	982.40	7.70	0.01	906.40	321.20
8	φ(sex*t) p(seas)	38	983.13	8.42	0.01	907.13	321.93
9	φ(sex*t) p(sex+t)	54	991.75	17.05	0.00	883.75	298.55
10	φ(sex*t) p(t)	53	997.42	22.71	0.00	891.41	306.21
11	φ(sex*t) p(sex*t)	70	1023.76	49.05	0.00	883.75	298.55
12	φ(sex+t) p(sex+t)	37	1063.91	89.20	0.00	989.91	404.71
13	φ(sex+t) p(sex+suppl)	22	1065.50	90.80	0.00	1021.50	436.30
14	φ(sex+t) p(sex*suppl)	23	1067.50	92.80	0.00	1021.50	436.30
15	φ(sex+t) p(sex)	21	1070.23	95.52	0.00	1028.23	443.03
16	φ(sex+t) p(sex+seas)	22	1072.23	97.52	0.00	1028.22	443.02
17	φ(sex+t) p(sex*seas)	23	1074.23	99.52	0.00	1028.23	443.03
18	φ(sex+t) p(t)	36	1080.91	106.21	0.00	1008.91	423.71
19	φ(sex+t) p(suppl)	21	1095.53	120.82	0.00	1053.53	468.33
20	φ(sex+t) p(sex*t)	54	1096.68	121.97	0.00	988.67	403.47
21	φ(sex+t) p(seas)	21	1098.34	123.64	0.00	1056.34	471.14
22	φ(sex+t) p(.)	20	1098.96	124.25	0.00	1058.96	473.76
23	φ(t) p(.)	19	1230.04	255.34	0.00	1192.04	606.84
24	φ(t) p(seas)	20	1231.10	256.40	0.00	1191.10	605.90
25	φ(t) p(sex)	20	1231.40	256.70	0.00	1191.40	606.20
26	φ(t) p(suppl)	20	1231.42	256.72	0.00	1191.42	606.22
27	φ(t) p(sex+suppl)	21	1232.76	258.05	0.00	1190.76	605.56
28	φ(t) p(sex+seas)	21	1233.38	258.67	0.00	1191.38	606.18
29	φ(t) p(sex*suppl)	22	1234.73	260.03	0.00	1190.73	605.53
30	φ(t) p(sex*seas)	22	1235.38	260.68	0.00	1191.38	606.18
31	φ(t) p(t)	35	1245.06	270.35	0.00	1175.05	589.85
32	φ(t) p(sex+t)	36	1248.49	273.79	0.00	1176.49	591.29
33	φ(t) p(sex*t)	53	1269.67	294.96	0.00	1163.66	578.46
34	φ(sex) p(sex+t)	21	1350.05	375.34	0.00	1308.05	722.85
35	φ(sex*suppl) p(sex+t)	23	1351.32	376.62	0.00	1305.32	720.12
36	φ(.) p(sex*t)	37	1395.06	420.35	0.00	1321.06	735.86
37	φ(sex*seas) p(t)	22	1420.63	445.92	0.00	1376.63	791.42
38	φ(sex+seas) p(t)	21	1423.12	448.42	0.00	1381.12	795.92

39	φ(sex) p(t)	20	1426.27	451.57	0.00	1386.27	801.07
40	φ(sex*suppl) p(t)	22	1426.38	451.68	0.00	1382.38	797.18
41	φ(sex+suppl) p(t)	21	1428.53	453.83	0.00	1386.53	801.33
42	φ(sex) p(sex*t)	38	1490.08	515.38	0.00	1414.08	828.88
43	φ(sex+suppl) p(sex*t)	39	1490.80	516.09	0.00	1412.79	827.59
44	φ(.) p(sex+t)	20	1518.45	543.74	0.00	1478.45	893.25
45	φ(sex*seas) p(sex)	6	1573.02	598.32	0.00	1561.02	975.82
46	φ(sex*seas) p(sex+suppl)	7	1574.78	600.08	0.00	1560.78	975.58
47	φ(sex*seas) p(sex+seas)	7	1574.93	600.22	0.00	1560.93	975.72
48	φ(sex*seas) p(sex*suppl)	8	1575.87	601.16	0.00	1559.87	974.66
49	φ(sex*seas) p(sex*seas)	8	1576.93	602.23	0.00	1560.93	975.73
50	φ(sex*seas) p(.)	5	1580.80	606.09	0.00	1570.80	985.60
51	φ(sex*seas) p(seas)	6	1581.85	607.14	0.00	1569.85	984.65
52	φ(sex*seas) p(sex+t)	23	1587.10	612.39	0.00	1541.10	955.90
53	φ(sex*seas) p(sex*t)	40	1607.07	632.36	0.00	1527.06	941.86
54	φ(sex*seas) p(suppl)	6	1636.41	661.70	0.00	1624.41	1039.21
55	φ(sex+seas) p(sex+seas)	6	1666.01	691.31	0.00	1654.01	1068.81
56	φ(sex+seas) p(sex*seas)	7	1668.03	693.33	0.00	1654.03	1068.83
57	φ(sex+seas) p(sex+t)	22	1678.70	703.99	0.00	1634.69	1049.49
58	φ(sex+seas) p(seas)	5	1692.31	717.61	0.00	1682.31	1097.11
59	φ(sex+seas) p(sex+suppl)	6	1692.57	717.87	0.00	1680.57	1095.37
60	φ(sex+seas) p(sex)	5	1696.73	722.03	0.00	1686.73	1101.53
61	φ(sex+seas) p(sex*t)	39	1701.30	726.59	0.00	1623.29	1038.09
62	φ(sex+seas) p(suppl)	5	1726.28	751.58	0.00	1716.28	1131.08
63	φ(sex+seas) p(.)	4	1730.01	755.31	0.00	1722.01	1136.81
64	φ(seas) p(t)	20	1886.31	911.60	0.00	1846.30	1261.10
65	φ(sex+suppl) p(sex*seas)	7	1891.71	917.00	0.00	1877.71	1292.51
66	φ(sex+seas) p(sex*suppl)	7	1946.43	971.72	0.00	1932.43	1347.23
67	φ(suppl) p(sex+t)	21	1955.48	980.78	0.00	1913.48	1328.28
68	φ(sex*suppl) p(sex)	6	1982.22	1007.51	0.00	1970.22	1385.02
69	φ(sex*suppl) p(sex+suppl)	7	1983.91	1009.20	0.00	1969.91	1384.71
70	φ(sex*suppl) p(sex+seas)	7	1984.04	1009.34	0.00	1970.04	1384.84
71	φ(sex*suppl) p(seas)	6	1985.83	1011.13	0.00	1973.83	1388.63
72	φ(sex*suppl) p(sex*suppl)	8	1985.91	1011.21	0.00	1969.91	1384.71
73	φ(sex*suppl) p(.)	5	1985.94	1011.24	0.00	1975.94	1390.74
74	φ(sex*suppl) p(sex*seas)	8	1986.01	1011.30	0.00	1970.01	1384.81
75	φ(sex*suppl) p(suppl)	6	1987.73	1013.02	0.00	1975.73	1390.53
76	φ(sex) p(sex)	4	2002.53	1027.83	0.00	1994.53	1409.33
77	φ(sex+suppl) p(sex)	5	2002.69	1027.99	0.00	1992.69	1407.49
78	φ(sex) p(sex+suppl)	5	2004.33	1029.62	0.00	1994.33	1409.13
79	φ(sex) p(sex+seas)	5	2004.35	1029.64	0.00	1994.35	1409.15
80	φ(sex+suppl) p(sex+seas)	6	2004.46	1029.76	0.00	1992.46	1407.26
81	φ(sex+suppl) p(sex+suppl)	6	2004.70	1029.99	0.00	1992.70	1407.50
82	φ(sex) p(seas)	4	2005.90	1031.20	0.00	1997.90	1412.70

83	φ(sex+suppl) p(seas)	5	2006.26	1031.55	0.00	1996.26	1411.06
84	φ(sex) p(.)	3	2006.58	1031.88	0.00	2000.58	1415.38
85	φ(sex+suppl) p(sex*suppl)	7	2006.70	1032.00	0.00	1992.70	1407.50
86	φ(sex+suppl) p(.)	4	2006.77	1032.07	0.00	1998.77	1413.57
87	φ(sex) p(suppl)	4	2008.05	1033.35	0.00	2000.05	1414.85
88	φ(sex+suppl) p(suppl)	5	2008.59	1033.88	0.00	1998.59	1413.39
89	φ(sex+suppl) p(sex+t)	22	2018.06	1043.36	0.00	1974.06	1388.86
90	φ(sex*suppl) p(sex*t)	40	2032.41	1057.70	0.00	1952.41	1367.20
91	φ(seas) p(sex+suppl)	5	2342.14	1367.43	0.00	2332.14	1746.94
92	φ(.) p(sex+suppl)	4	2351.28	1376.57	0.00	2343.28	1758.08
93	φ(seas) p(sex+seas)	5	2380.28	1405.57	0.00	2370.28	1785.08
94	φ(suppl) p(sex)	4	2390.34	1415.63	0.00	2382.34	1797.13
95	φ(.) p(sex)	3	2393.28	1418.58	0.00	2387.28	1802.08
96	φ(.) p(sex+seas)	4	2394.04	1419.34	0.00	2386.04	1800.84
97	φ(.) p(sex*seas)	5	2395.36	1420.65	0.00	2385.36	1800.16
98	φ(seas) p(sex*t)	38	2407.28	1432.58	0.00	2331.28	1746.08
99	φ(suppl) p(sex+suppl)	5	2477.08	1502.37	0.00	2467.08	1881.88
100	φ(suppl) p(sex+seas)	5	2556.41	1581.71	0.00	2546.41	1961.21
101	φ(seas) p(seas)	4	2567.61	1592.90	0.00	2559.61	1974.40
102	φ(seas) p(suppl)	4	2571.45	1596.75	0.00	2563.45	1978.25
103	φ(seas) p(sex*suppl)	6	2576.39	1601.68	0.00	2564.39	1979.19
104	φ(seas) p(sex)	4	2577.40	1602.70	0.00	2569.40	1984.20
105	φ(seas) p(sex*seas)	6	2579.48	1604.77	0.00	2567.48	1982.28
106	φ(seas) p(sex+t)	21	2594.34	1619.64	0.00	2552.34	1967.14
107	φ(seas) p(.)	3	2821.02	1846.32	0.00	2815.02	2229.82
108	φ(suppl) p(seas)	4	3304.16	2329.46	0.00	3296.16	2710.96
109	φ(suppl) p(.)	3	3714.51	2739.80	0.00	3708.51	3123.30
110	φ(suppl) p(suppl)	4	3714.64	2739.94	0.00	3706.64	3121.44
111	φ(.) p(t)	19	3840.14	2865.44	0.00	3802.14	3216.94
112	φ(.) p(suppl)	3	3902.83	2928.13	0.00	3896.83	3311.63
113	φ(.) p(.)	2	3921.69	2946.99	0.00	3917.69	3332.49
114	φ(.) p(seas)	3	14403.24	13428.53	0.00	14397.24	13812.04

Appendix 8. Model selection for the capture histories of the cohorts 2015 and 2016 of *Gracilinanus agilis* in FAL, one of the control areas. Comark-Jolly-Seber (CJS) models may have apparent survival (φ) probabilities varying as a function of sex, time (t), reproductive season (pre-reproductive, reproductive and post-reproductive), interaction between factors (*) or no effect (.), and recapture (p) probabilities varying as a function of sex, climatic season (seas: dry and wet), reproductive season, interaction between factors or no effect. Pradel models have φ and p varying according to the selected CJS models and recruitment (*f*) as a function of sex, time (t), reproductive season, climatic season, and interactions. POPAN models have φ, p and probability of entrance (pent) varying according to the selected Pradel models and super-population size varying between sexes or constant. The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, L is the model likelihood and Dev is the deviance. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	-2logL	Dev
	Cohort 2015						
	CJS models						
1	φ(sex*rep) p(seas)	6	66.93	0.00	0.25	1.00	52.88
2	φ(sex*rep) p(.)	5	67.13	0.19	0.23	0.91	55.70
3	φ(sex*rep) p(rep)	6	68.99	2.06	0.09	0.36	54.94
4	φ(sex*rep) p(sex)	6	69.26	2.33	0.08	0.31	55.21
5	φ(sex*rep) p(sex+seas)	7	69.64	2.71	0.06	0.26	52.84
6	φ(.) p(sex+rep)	4	71.62	4.69	0.02	0.10	62.69
7	φ(sex*rep) p(sex+rep)	7	71.74	4.81	0.02	0.09	54.94
8	φ(.) p(sex*rep)	5	71.90	4.97	0.02	0.08	60.47
9	φ(.) p(.)	2	71.94	5.01	0.02	0.08	67.68
10	φ(.) p(seas)	3	72.34	5.41	0.02	0.07	65.79
11	φ(rep) p(.)	3	72.35	5.41	0.02	0.07	65.80
12	φ(sex*rep) p(sex*seas)	8	72.54	5.61	0.02	0.06	52.85
13	φ(.) p(rep)	3	72.86	5.93	0.01	0.05	66.32
14	φ(.) p(sex+seas)	4	72.93	6.00	0.01	0.05	64.00
15	φ(sex+rep) p(.)	4	73.61	6.67	0.01	0.04	64.67
16	φ(sex) p(sex+rep)	5	73.67	6.73	0.01	0.03	62.24
17	φ(rep) p(seas)	4	73.74	6.81	0.01	0.03	64.81
18	φ(rep) p(sex+rep)	5	73.98	7.05	0.01	0.03	62.55
19	φ(.) p(sex)	3	74.04	7.11	0.01	0.03	67.50
20	φ(sex) p(.)	3	74.07	7.14	0.01	0.03	67.53

21	φ(rep) p(sex*rep)	6	74.50	7.57	0.01	0.02	60.45
22	φ(rep) p(sex)	4	74.61	7.68	0.01	0.02	65.68
23	φ(sex+rep) p(sex*rep)	7	74.65	7.72	0.01	0.02	57.85
24	φ(sex) p(seas)	4	74.66	7.72	0.01	0.02	65.73
25	φ(rep) p(rep)	4	74.73	7.80	0.01	0.02	65.80
26	φ(sex+rep) p(sex+rep)	6	74.75	7.81	0.01	0.02	60.70
27	φ(rep) p(sex+seas)	5	74.77	7.83	0.01	0.02	63.34
28	φ(.) p(sex*seas)	5	74.83	7.90	0.00	0.02	63.40
29	φ(sex) p(rep)	4	75.14	8.21	0.00	0.02	66.21
30	φ(rep) p(sex*rep)	6	75.15	8.22	0.00	0.02	61.10
31	φ(sex+rep) p(sex)	5	75.25	8.32	0.00	0.02	63.82
32	φ(sex) p(sex+seas)	5	75.40	8.46	0.00	0.01	63.97
33	φ(sex+rep) p(seas)	5	75.46	8.52	0.00	0.01	64.03
34	φ(sex+rep) p(rep)	5	76.07	9.14	0.00	0.01	64.64
35	φ(sex) p(sex)	4	76.40	9.47	0.00	0.01	67.47
36	φ(sex*rep) p(sex*rep)	8	76.49	9.55	0.00	0.01	56.79
37	φ(rep) p(sex*seas)	6	76.71	9.77	0.00	0.01	62.66
38	φ(sex+rep) p(sex+seas)	6	77.10	10.17	0.00	0.01	63.06
39	φ(sex) p(sex*seas)	6	77.45	10.52	0.00	0.01	63.40
40	φ(t) p(.)	6	77.89	10.95	0.00	0.00	63.84
41	φ(t) p(seas)	7	78.24	11.31	0.00	0.00	61.44
42	φ(sex+rep) p(sex*seas)	7	78.34	11.40	0.00	0.00	61.54
43	φ(t) p(sex+seas)	8	79.27	12.33	0.00	0.00	59.57
44	φ(sex+t) p(.)	7	79.65	12.71	0.00	0.00	62.85
45	φ(t) p(rep)	7	80.17	13.23	0.00	0.00	63.37
46	φ(t) p(sex)	7	80.32	13.39	0.00	0.00	63.52
47	φ(sex+t) p(seas)	8	80.68	13.75	0.00	0.00	60.99
48	φ(sex+t) p(sex+rep)	9	81.34	14.40	0.00	0.00	58.60
49	φ(t) p(sex*rep)	9	81.34	14.40	0.00	0.00	58.60
50	φ(sex+t) p(sex)	8	81.34	14.41	0.00	0.00	61.65
51	φ(t) p(sex+rep)	8	81.41	14.47	0.00	0.00	61.71
52	φ(sex+t) p(rep)	8	81.96	15.02	0.00	0.00	62.27
53	φ(sex+t) p(sex+seas)	9	82.29	15.36	0.00	0.00	59.55
54	φ(t) p(sex*seas)	9	82.31	15.38	0.00	0.00	59.57
55	φ(sex*t) p(.)	11	82.86	15.93	0.00	0.00	53.53
56	φ(sex*t) p(seas)	12	84.14	17.21	0.00	0.00	51.23
57	φ(sex+t) p(sex*rep)	10	84.54	17.61	0.00	0.00	58.60
58	φ(sex+t) p(sex*seas)	10	85.43	18.49	0.00	0.00	59.48
59	φ(sex*t) p(sex)	12	85.93	19.00	0.00	0.00	53.02
60	φ(sex*t) p(rep)	12	85.93	19.00	0.00	0.00	53.02
61	φ(sex*t) p(sex+seas)	13	87.91	20.97	0.00	0.00	51.20
62	φ(sex*t) p(sex+rep)	13	89.72	22.79	0.00	0.00	53.02
63	φ(sex*t) p(sex*seas)	14	91.93	25.00	0.00	0.00	51.20
64	φ(sex*t) p(sex*rep)	14	93.75	26.81	0.00	0.00	53.02

	Pradel models						
1	φ(sex*rep) p(.) f(sex*rep)	9	191.70	0.00	0.35	1.00	169.20
2	φ(sex*rep) p(rep) f(sex*rep)	10	192.82	1.12	0.20	0.57	167.18
3	φ(sex*rep) p(seas) f(sex*rep)	10	194.47	2.77	0.09	0.25	168.83
4	φ(sex*rep) p(.) f(t)	10	194.93	3.22	0.07	0.20	169.29
5	φ(sex*rep) p(.) f(rep)	7	195.47	3.76	0.05	0.15	178.80
6	φ(sex*rep) p(.) f(sex+rep)	8	195.88	4.18	0.04	0.12	176.37
7	φ(sex*rep) p(.) f(sex+t)	11	195.90	4.20	0.04	0.12	166.96
8	φ(sex*rep) p(seas) f(rep)	8	196.95	5.25	0.03	0.07	177.44
9	φ(sex*rep) p(seas) f(sex+rep)	9	196.97	5.27	0.02	0.07	174.47
10	φ(sex*rep) p(seas) f(t)	11	197.17	5.47	0.02	0.07	168.22
11	φ(sex*rep) p(rep) f(sex+rep)	9	197.39	5.69	0.02	0.06	174.89
12	φ(sex*rep) p(rep) f(rep)	8	197.54	5.83	0.02	0.05	178.02
13	φ(sex*rep) p(seas) f(sex+t)	12	198.02	6.31	0.01	0.04	165.58
14	φ(sex*rep) p(rep) f(t)	11	198.17	6.47	0.01	0.04	169.23
15	φ(sex*rep) p(rep) f(sex+t)	12	199.23	7.53	0.01	0.02	166.80
16	φ(sex*rep) p(.) f(seas)	7	199.73	8.03	0.01	0.02	183.06
17	φ(sex*rep) p(seas) f(seas)	8	202.20	10.50	0.00	0.01	182.69
18	φ(sex*rep) p(rep) f(seas)	8	202.28	10.58	0.00	0.01	182.77
19	φ(sex*rep) p(.) f(sex*t)	15	202.44	10.74	0.00	0.00	158.32
20	φ(sex*rep) p(.) f(sex+seas)	8	202.55	10.85	0.00	0.00	183.04
21	φ(sex*rep) p(.) f(sex*seas)	9	202.97	11.27	0.00	0.00	180.47
22	φ(sex*rep) p(seas) f(sex+seas)	9	205.19	13.48	0.00	0.00	182.69
23	φ(sex*rep) p(rep) f(sex+seas)	9	205.25	13.55	0.00	0.00	182.75
24	φ(sex*rep) p(seas) f(sex*seas)	10	205.41	13.71	0.00	0.00	179.77
25	φ(sex*rep) p(rep) f(sex*seas)	10	205.48	13.78	0.00	0.00	179.84
26	φ(sex*rep) p(rep) f(sex*t)	16	205.85	14.14	0.00	0.00	157.36
27	φ(sex*rep) p(seas) f(sex*t)	16	206.21	14.50	0.00	0.00	157.72
	POPAN models						
1	φ(sex*rep) p(.) pent(sex*rep) N(.)	10	110.91	0.00	0.65	1.00	85.27
2	φ(sex*rep) p(rep) pent(sex*rep) N(.)	11	113.33	2.42	0.19	0.30	84.38
3	φ(sex*rep) p(.) pent(sex*rep) N(sex)	11	114.21	3.30	0.12	0.19	85.27
4	φ(sex*rep) p(rep) pent(sex*rep) N(sex)	12	116.81	5.90	0.03	0.05	84.38
	Cohort 2016						
	CJS models						
1	φ(.) p(sex*rep)	5	71.85	0.00	0.15	1.00	60.57
2	φ(.) p(rep)	3	72.86	1.01	0.09	0.60	66.37
3	φ(.) p(sex+rep)	4	73.61	1.76	0.06	0.41	64.78
4	φ(sex+rep) p(sex)	5	74.05	2.20	0.05	0.33	62.77
5	φ(sex) p(rep)	4	74.19	2.34	0.05	0.31	65.35

6	φ(sex) p(sex*rep)	6	74.28	2.43	0.04	0.30	60.45
7	φ(rep) p(sex*rep)	6	74.39	2.54	0.04	0.28	60.56
8	φ(sex+rep) p(.)	4	74.40	2.55	0.04	0.28	65.57
9	φ(sex+rep) p(sex+rep)	6	74.80	2.95	0.03	0.23	60.98
10	φ(sex+rep) p(rep)	5	74.88	3.02	0.03	0.22	63.60
11	φ(sex*rep) p(.)	5	74.98	3.13	0.03	0.21	63.70
12	φ(rep) p(rep)	4	75.15	3.30	0.03	0.19	66.32
13	φ(sex*rep) p(sex)	6	75.59	3.74	0.02	0.15	61.77
14	φ(rep) p(.)	3	75.61	3.76	0.02	0.15	69.12
15	φ(t) p(rep)	6	75.71	3.86	0.02	0.15	61.88
16	φ(sex*rep) p(rep)	6	75.77	3.92	0.02	0.14	61.95
17	φ(t) p(.)	5	75.88	4.03	0.02	0.13	64.60
18	φ(rep) p(sex+rep)	5	75.96	4.11	0.02	0.13	64.69
19	φ(sex) p(sex+rep)	5	75.97	4.12	0.02	0.13	64.69
20	φ(sex+rep) p(sex+seas)	6	75.99	4.14	0.02	0.13	62.17
21	φ(sex+t) p(.)	6	76.13	4.27	0.02	0.12	62.30
22	φ(t) p(sex*rep)	8	76.16	4.31	0.02	0.12	56.89
23	φ(sex+t) p(sex)	7	76.47	4.62	0.01	0.10	59.98
24	φ(sex+rep) p(seas)	5	76.50	4.65	0.01	0.10	65.23
25	φ(t) p(sex+rep)	7	76.94	5.09	0.01	0.08	60.45
26	φ(sex*rep) p(sex+rep)	7	77.07	5.22	0.01	0.07	60.58
27	φ(rep) p(sex)	4	77.08	5.23	0.01	0.07	68.25
28	φ(sex+rep) p(sex*rep)	7	77.32	5.47	0.01	0.07	60.83
29	φ(sex*rep) p(seas)	6	77.38	5.53	0.01	0.06	63.56
30	φ(t) p(sex)	6	77.39	5.54	0.01	0.06	63.56
31	φ(sex+t) p(rep)	7	77.54	5.69	0.01	0.06	61.05
32	φ(rep) p(seas)	4	77.68	5.83	0.01	0.05	68.85
33	φ(t) p(seas)	6	77.88	6.02	0.01	0.05	64.05
34	φ(sex+t) p(sex+rep)	8	77.88	6.03	0.01	0.05	58.61
35	φ(sex*rep) p(sex+seas)	7	77.97	6.12	0.01	0.05	61.48
36	φ(sex+t) p(seas)	7	78.01	6.16	0.01	0.05	61.52
37	φ(sex+rep) p(sex*seas)	7	78.66	6.80	0.00	0.03	62.17
38	φ(sex+t) p(sex+seas)	8	78.73	6.88	0.00	0.03	59.46
39	φ(rep) p(sex+seas)	5	78.86	7.01	0.00	0.03	67.58
40	φ(sex+t) p(sex*rep)	9	79.07	7.22	0.00	0.03	56.88
41	φ(t) p(sex+seas)	7	79.39	7.54	0.00	0.02	62.90
42	φ(sex*rep) p(sex*rep)	8	79.85	8.00	0.00	0.02	60.58
43	φ(sex*rep) p(sex*seas)	8	80.75	8.90	0.00	0.01	61.48
44	φ(rep) p(sex*seas)	6	81.41	9.56	0.00	0.01	67.58
45	φ(sex+t) p(sex*seas)	9	81.64	9.79	0.00	0.01	59.46
46	φ(sex*t) p(.)	9	81.75	9.90	0.00	0.01	59.57
47	φ(t) p(sex*seas)	8	82.17	10.32	0.00	0.01	62.90
48	φ(sex*t) p(rep)	10	82.80	10.95	0.00	0.00	57.56
49	φ(sex*t) p(sex)	10	83.18	11.33	0.00	0.00	57.94

50	φ(sex*t) p(seas)	10	84.25	12.40	0.00	0.00	59.02
51	φ(.) p(.)	2	84.95	13.09	0.00	0.00	80.71
52	φ(.) p(seas)	3	85.20	13.35	0.00	0.00	78.71
53	φ(sex*t) p(sex+rep)	11	85.32	13.47	0.00	0.00	56.88
54	φ(sex) p(.)	3	85.69	13.84	0.00	0.00	79.20
55	φ(sex) p(seas)	4	86.17	14.32	0.00	0.00	77.34
56	φ(sex*t) p(sex+seas)	11	86.38	14.53	0.00	0.00	57.94
57	φ(sex) p(sex)	4	86.44	14.59	0.00	0.00	77.61
58	φ(.) p(sex)	3	86.52	14.67	0.00	0.00	80.03
59	φ(.) p(sex+seas)	4	87.45	15.60	0.00	0.00	78.62
60	φ(.) p(sex*seas)	5	88.34	16.48	0.00	0.00	77.06
61	φ(sex) p(sex+seas)	5	88.37	16.52	0.00	0.00	77.10
62	φ(sex*t) p(sex*rep)	12	88.68	16.83	0.00	0.00	56.88
63	φ(sex) p(sex*seas)	6	89.34	17.49	0.00	0.00	75.51
64	φ(sex*t) p(sex*seas)	12	89.74	17.89	0.00	0.00	57.94
	Pradel models						
1	φ(.) p(rep) f(t)	7	182.01	0.00	0.25	1.00	165.77
2	φ(.) p(rep) f(seas)	5	182.21	0.20	0.23	0.90	171.06
3	φ(.) p(sex+rep) f(seas)	6	184.04	2.03	0.09	0.36	170.39
4	φ(.) p(sex+rep) f(t)	8	184.30	2.29	0.08	0.32	165.36
5	φ(.) p(rep) f(sex+t)	8	184.67	2.67	0.07	0.26	165.73
6	φ(.) p(rep) f(sex+seas)	6	184.67	2.67	0.07	0.26	171.03
7	φ(.) p(rep) f(sex*t)	11	185.98	3.97	0.03	0.14	158.24
8	φ(.) p(rep) f(rep)	5	186.08	4.07	0.03	0.13	174.92
9	φ(.) p(rep) f(sex*seas)	7	186.31	4.30	0.03	0.12	170.07
10	φ(.) p(sex+rep) f(sex+seas)	7	186.38	4.37	0.03	0.11	170.14
11	φ(.) p(sex+rep) f(sex+t)	9	186.99	4.98	0.02	0.08	165.24
12	φ(.) p(sex+rep) f(sex*t)	12	187.56	5.55	0.02	0.06	156.62
13	φ(.) p(sex+rep) f(rep)	6	187.80	5.79	0.01	0.06	174.15
14	φ(.) p(sex+rep) f(sex*seas)	8	188.28	6.27	0.01	0.04	169.34
15	φ(.) p(rep) f(sex+rep)	6	188.54	6.53	0.01	0.04	174.90
16	φ(.) p(sex+rep) f(sex+rep)	7	190.35	8.34	0.00	0.02	174.11
17	φ(.) p(rep) f(sex*rep)	7	190.41	8.40	0.00	0.02	174.17
18	φ(.) p(sex+rep) f(sex*rep)	8	191.71	9.70	0.00	0.01	172.77
19	φ(.) p(sex*rep) f(t)	9	199.81	17.81	0.00	0.00	178.06
20	φ(.) p(sex*rep) f(rep)	7	202.58	20.58	0.00	0.00	186.34
21	φ(.) p(sex*rep) f(sex+t)	10	202.74	20.73	0.00	0.00	178.06
22	φ(.) p(sex*rep) f(sex+rep)	8	205.25	23.24	0.00	0.00	186.31
23	φ(.) p(sex*rep) f(sex*t)	13	205.49	23.49	0.00	0.00	171.22
24	φ(.) p(sex*rep) f(sex*rep)	9	207.17	25.16	0.00	0.00	185.42
25	φ(.) p(sex*rep) f(seas)	7	216.37	34.36	0.00	0.00	200.13
26	φ(.) p(sex*rep) f(sex+seas)	8	218.76	36.75	0.00	0.00	199.82
27	φ(.) p(sex*rep) f(sex*seas)	9	219.21	37.20	0.00	0.00	197.46

	POPAN models						
1	φ(.) p(rep) pent(t) N(.)	8	137.57	0.00	0.44	1.00	118.63
2	φ(.) p(rep) pent(t) N(sex)	9	139.04	1.47	0.21	0.48	117.29
3	φ(.) p(rep) pent(seas) N(sex)	7	139.99	2.42	0.13	0.30	123.75
4	φ(.) p(rep) pent(seas) N(.)	6	140.15	2.58	0.12	0.27	126.50
5	φ(.) p(sex+rep) pent(seas) N(sex)	8	141.28	3.71	0.07	0.16	122.34
6	φ(.) p(sex+rep) pent(seas) N(.)	7	142.74	5.18	0.03	0.08	126.50

Appendix 9. Model selection for the capture histories of the cohorts 2015 and 2016 of *Gracilinanus agilis* in JB1, one of the control areas. Comark-Jolly-Seber (CJS) models may have apparent survival (φ) probabilities varying as a function of sex, time (t), reproductive season (pre-reproductive, reproductive and post-reproductive), interaction between factors (*) or no effect (.), and recapture (p) probabilities varying as a function of sex, climatic season (seas: dry and wet), reproductive season, interaction between factors or no effect. Pradel models have φ and p varying according to the selected CJS models and recruitment (*f*) as a function of sex, time (t), reproductive season, climatic season, and interactions. POPAN models have φ, p and probability of entrance (pent) varying according to the selected Pradel models and super-population size varying between sexes or constant. The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, L is the model likelihood and Dev is the deviance. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	-2logL	Dev
	Cohort 2015						
	CJS models						
1	φ(sex) p(.)	3	176.16	0.00	0.09	1.00	169.96
2	φ(sex) p(seas)	4	176.18	0.02	0.09	0.99	167.84
3	φ(sex+rep) p(.)	4	176.45	0.29	0.08	0.87	168.11
4	φ(sex+rep) p(seas)	5	176.71	0.54	0.07	0.76	166.19
5	φ(sex+rep) p(rep)	5	177.76	1.60	0.04	0.45	167.24
6	φ(sex) p(rep)	4	177.76	1.60	0.04	0.45	169.42
7	φ(sex) p(sex)	4	177.76	1.60	0.04	0.45	169.43
8	φ(sex*rep) p(seas)	6	177.80	1.64	0.04	0.44	165.07
9	φ(sex) p(sex+seas)	5	178.03	1.87	0.04	0.39	167.52
10	φ(sex+rep) p(sex)	5	178.10	1.93	0.03	0.38	167.58
11	φ(.) p(sex*rep)	5	178.19	2.03	0.03	0.36	167.68
12	φ(sex+rep) p(sex+seas)	6	178.53	2.37	0.03	0.31	165.81
13	φ(.) p(.)	2	178.91	2.74	0.02	0.25	174.81
14	φ(sex) p(sex+rep)	5	178.98	2.82	0.02	0.24	168.47
15	φ(rep) p(.)	3	179.00	2.84	0.02	0.24	172.80
16	φ(sex+rep) p(sex+rep)	6	179.01	2.85	0.02	0.24	166.29
17	φ(sex+t) p(sex+rep)	9	179.07	2.91	0.02	0.23	159.48
18	φ(sex) p(sex*rep)	6	179.14	2.98	0.02	0.23	166.42
19	φ(sex*rep) p(sex)	6	179.21	3.05	0.02	0.22	166.49
20	φ(rep) p(sex+seas)	4	179.39	3.23	0.02	0.20	171.05

21	φ(rep) p(seas)	4	179.43	3.27	0.02	0.20	171.09
22	φ(sex*rep) p(sex+seas)	7	179.60	3.44	0.02	0.18	164.63
23	φ(.) p(sex+rep)	4	180.09	3.93	0.01	0.14	171.75
24	φ(sex*rep) p(rep)	5	180.18	4.02	0.01	0.13	169.67
25	φ(rep) p(sex*rep)	6	180.24	4.08	0.01	0.13	167.51
26	φ(sex) p(sex*seas)	6	180.25	4.09	0.01	0.13	167.52
27	φ(sex*rep) p(sex+rep)	7	180.35	4.19	0.01	0.12	165.37
28	φ(rep) p(rep)	4	180.45	4.28	0.01	0.12	172.11
29	φ(sex+t) p(.)	9	180.46	4.30	0.01	0.12	160.87
30	φ(.) p(rep)	3	180.62	4.46	0.01	0.11	174.42
31	φ(sex+rep) p(sex*seas)	7	180.78	4.62	0.01	0.10	165.81
32	φ(.) p(sex)	3	181.00	4.84	0.01	0.09	174.80
33	φ(rep) p(sex)	4	181.06	4.90	0.01	0.09	172.72
34	φ(.) p(sex+seas)	4	181.07	4.91	0.01	0.09	172.73
35	φ(sex+rep) p(sex*rep)	7	181.26	5.10	0.01	0.08	166.29
36	φ(sex+t) p(seas)	10	181.74	5.58	0.01	0.06	159.78
37	φ(sex*rep) p(sex*seas)	8	181.89	5.73	0.01	0.06	164.63
38	φ(rep) p(sex+rep)	5	182.19	6.03	0.00	0.05	171.67
39	φ(t) p(.)	8	182.25	6.08	0.00	0.05	164.98
40	φ(t) p(.)	8	182.25	6.08	0.00	0.05	164.98
41	φ(sex+t) p(rep)	10	182.35	6.19	0.00	0.05	160.39
42	φ(sex+t) p(sex)	10	182.46	6.30	0.00	0.04	160.50
43	φ(sex*rep) p(sex*rep)	8	182.64	6.48	0.00	0.04	165.37
44	φ(t) p(sex*rep)	11	182.94	6.78	0.00	0.03	158.56
45	φ(.) p(sex*seas)	5	183.24	7.08	0.00	0.03	172.73
46	φ(sex+t) p(sex+seas)	11	183.60	7.44	0.00	0.02	159.22
47	φ(t) p(seas)	9	183.62	7.46	0.00	0.02	164.03
48	φ(rep) p(sex*seas)	6	183.69	7.53	0.00	0.02	170.97
49	φ(t) p(rep)	9	184.23	8.07	0.00	0.02	164.64
50	φ(t) p(sex)	9	184.49	8.33	0.00	0.02	164.90
51	φ(t) p(sex+rep)	10	184.51	8.35	0.00	0.02	162.55
52	φ(sex+t) p(sex*rep)	12	185.37	9.21	0.00	0.01	158.54
53	φ(t) p(sex+seas)	10	185.71	9.55	0.00	0.01	163.75
54	φ(sex+t) p(sex*seas)	12	186.06	9.90	0.00	0.01	159.22
55	φ(t) p(sex*seas)	11	187.01	10.85	0.00	0.00	162.63
56	φ(sex*rep) p(.)	4	187.07	10.91	0.00	0.00	178.73
57	φ(sex*t) p(.)	15	188.64	12.48	0.00	0.00	154.16
58	φ(sex*t) p(seas)	16	190.20	14.04	0.00	0.00	153.07
59	φ(sex*t) p(sex)	16	190.88	14.72	0.00	0.00	153.75
60	φ(sex*t) p(rep)	16	190.95	14.79	0.00	0.00	153.82
61	φ(sex*t) p(sex+seas)	17	192.48	16.31	0.00	0.00	152.65
62	φ(sex*t) p(sex+rep)	17	193.19	17.03	0.00	0.00	153.37
63	φ(sex*t) p(sex*seas)	18	195.22	19.06	0.00	0.00	152.65
64	φ(sex*t) p(sex*rep)	18	195.94	19.78	0.00	0.00	153.37

	Pradel models						
1	φ(sex*rep) p(seas) f(sex+rep)	9	426.43	0.00	0.12	1.00	406.85
2	φ(sex) p(seas) f(sex+rep)	7	426.99	0.56	0.09	0.76	412.03
3	φ(sex+rep) p(seas) f(sex+rep)	8	427.36	0.93	0.07	0.63	410.11
4	φ(sex) p(.) f(sex+rep)	6	427.74	1.31	0.06	0.52	415.02
5	φ(sex) p(seas) f(sex*rep)	8	427.80	1.37	0.06	0.50	410.55
6	φ(sex+rep) p(.) f(sex+rep)	7	427.95	1.51	0.05	0.47	412.98
7	φ(sex+rep) p(seas) f(sex*rep)	9	428.11	1.68	0.05	0.43	408.54
8	φ(sex*rep) p(seas) f(sex*rep)	10	428.47	2.04	0.04	0.36	406.52
9	φ(sex+rep) p(rep) f(sex+rep)	8	428.55	2.12	0.04	0.35	411.30
10	φ(sex) p(.) f(sex*rep)	7	428.56	2.12	0.04	0.35	413.59
11	φ(sex*rep) p(seas) f(sex+seas)	8	428.66	2.23	0.04	0.33	411.41
12	φ(sex+rep) p(.) f(sex*rep)	8	428.75	2.32	0.04	0.31	411.50
13	φ(sex+rep) p(rep) f(sex*rep)	9	428.90	2.47	0.03	0.29	409.32
14	φ(sex) p(rep) f(sex+rep)	7	428.91	2.48	0.03	0.29	413.95
15	φ(sex) p(sex+seas) f(sex+rep)	8	428.99	2.56	0.03	0.28	411.74
16	φ(sex) p(sex) f(sex+rep)	7	429.09	2.65	0.03	0.27	414.12
17	φ(sex+rep) p(sex) f(sex+rep)	8	429.19	2.76	0.03	0.25	411.94
18	φ(sex) p(sex+seas) f(sex*rep)	9	429.32	2.89	0.03	0.24	409.74
19	φ(sex) p(rep) f(sex*rep)	8	429.40	2.97	0.03	0.23	412.15
20	φ(sex) p(sex) f(sex*rep)	8	429.96	3.52	0.02	0.17	412.70
21	φ(sex+rep) p(sex) f(sex*rep)	9	429.98	3.55	0.02	0.17	410.40
22	φ(sex) p(seas) f(sex+t)	12	432.47	6.04	0.01	0.05	405.66
23	φ(sex*rep) p(seas) f(rep)	8	432.50	6.06	0.01	0.05	415.24
24	φ(sex*rep) p(seas) f(sex+t)	14	432.82	6.39	0.00	0.04	400.97
25	φ(sex+rep) p(seas) f(sex+seas)	7	432.89	6.45	0.00	0.04	417.92
26	φ(sex) p(.) f(sex+t)	11	432.91	6.48	0.00	0.04	408.55
27	φ(sex+rep) p(seas) f(sex+t)	13	433.17	6.74	0.00	0.03	403.86
28	φ(sex+rep) p(.) f(sex+t)	12	433.35	6.91	0.00	0.03	406.53
29	φ(sex*rep) p(seas) f(sex*seas)	10	433.36	6.92	0.00	0.03	411.41
30	φ(sex) p(rep) f(sex+t)	12	434.58	8.15	0.00	0.02	407.77
31	φ(sex+rep) p(rep) f(sex+t)	13	434.66	8.23	0.00	0.02	405.36
32	φ(sex) p(sex) f(sex+t)	12	434.77	8.34	0.00	0.02	407.96
33	φ(sex) p(sex+seas) f(sex+t)	13	434.99	8.56	0.00	0.01	405.68
34	φ(sex+rep) p(sex) f(sex+t)	13	435.25	8.82	0.00	0.01	405.94
35	φ(sex) p(.) f(sex*t)	17	436.68	10.24	0.00	0.01	396.90
36	φ(sex) p(seas) f(sex*t)	18	437.05	10.62	0.00	0.00	394.53
37	φ(sex+rep) p(seas) f(sex*seas)	9	437.49	11.05	0.00	0.00	417.91
38	φ(sex+rep) p(.) f(sex*t)	18	437.49	11.06	0.00	0.00	394.98
39	φ(sex) p(seas) f(rep)	6	437.95	11.52	0.00	0.00	425.23
40	φ(sex) p(sex+seas) f(rep)	7	437.98	11.55	0.00	0.00	423.02
41	φ(sex+rep) p(.) f(rep)	6	438.11	11.68	0.00	0.00	425.40
42	φ(sex+rep) p(seas) f(sex*t)	19	438.15	11.72	0.00	0.00	392.85

43	φ(sex) p(.) f(rep)	5	438.16	11.73	0.00	0.00	427.65
44	φ(sex+rep) p(seas) f(rep)	7	438.17	11.74	0.00	0.00	423.20
45	φ(sex*rep) p(seas) f(seas)	8	438.29	11.85	0.00	0.00	421.03
46	φ(sex*rep) p(seas) f(t)	13	438.43	12.00	0.00	0.00	409.12
47	φ(sex+rep) p(rep) f(sex+seas)	8	438.45	12.01	0.00	0.00	421.19
48	φ(sex) p(rep) f(sex*t)	18	438.51	12.08	0.00	0.00	395.99
49	φ(sex+rep) p(.) f(sex+seas)	7	438.68	12.25	0.00	0.00	423.71
50	φ(sex) p(sex) f(sex*t)	18	438.79	12.36	0.00	0.00	396.27
51	φ(sex+rep) p(rep) f(rep)	7	438.88	12.45	0.00	0.00	423.92
52	φ(sex+rep) p(rep) f(sex*t)	19	439.12	12.69	0.00	0.00	393.81
53	φ(sex) p(rep) f(rep)	6	439.33	12.90	0.00	0.00	426.62
54	φ(sex+rep) p(sex) f(sex+seas)	8	439.36	12.92	0.00	0.00	422.10
55	φ(sex) p(sex+seas) f(sex*t)	19	439.55	13.11	0.00	0.00	394.24
56	φ(sex+rep) p(sex) f(sex*t)	19	439.69	13.26	0.00	0.00	394.38
57	φ(sex*rep) p(seas) f(sex*t)	20	439.90	13.47	0.00	0.00	391.74
58	φ(sex+rep) p(sex) f(rep)	7	440.21	13.78	0.00	0.00	425.25
59	φ(sex) p(sex) f(rep)	6	440.26	13.83	0.00	0.00	427.55
60	φ(sex+rep) p(rep) f(sex*seas)	9	440.66	14.23	0.00	0.00	421.08
61	φ(sex+rep) p(.) f(sex*seas)	8	440.67	14.24	0.00	0.00	423.42
62	φ(sex) p(sex+seas) f(t)	12	441.19	14.76	0.00	0.00	414.38
63	φ(sex+rep) p(sex) f(sex*seas)	9	441.50	15.07	0.00	0.00	421.92
64	φ(sex) p(.) f(t)	10	442.92	16.49	0.00	0.00	420.98
65	φ(sex) p(seas) f(t)	11	443.04	16.61	0.00	0.00	418.68
66	φ(sex+rep) p(.) f(t)	11	443.26	16.83	0.00	0.00	418.90
67	φ(sex+rep) p(seas) f(t)	12	443.70	17.27	0.00	0.00	416.89
68	φ(sex) p(rep) f(t)	11	443.98	17.55	0.00	0.00	419.62
69	φ(sex+rep) p(rep) f(t)	12	444.16	17.73	0.00	0.00	417.35
70	φ(sex) p(sex) f(t)	11	444.56	18.13	0.00	0.00	420.21
71	φ(sex+rep) p(seas) f(seas)	7	444.65	18.22	0.00	0.00	429.68
72	φ(sex+rep) p(sex) f(t)	12	445.08	18.65	0.00	0.00	418.27
73	φ(sex+rep) p(rep) f(seas)	7	445.48	19.05	0.00	0.00	430.52
74	φ(sex) p(seas) f(sex+seas)	7	445.98	19.55	0.00	0.00	431.02
75	φ(sex+rep) p(.) f(seas)	6	446.36	19.93	0.00	0.00	433.65
76	φ(sex) p(sex+seas) f(sex+seas)	8	446.48	20.05	0.00	0.00	429.23
77	φ(sex+rep) p(sex) f(seas)	7	446.79	20.36	0.00	0.00	431.83
78	φ(sex) p(sex+seas) f(seas)	7	447.85	21.41	0.00	0.00	432.88
79	φ(sex) p(seas) f(sex*seas)	8	448.24	21.81	0.00	0.00	430.99
80	φ(sex) p(sex+seas) f(sex*seas)	9	448.77	22.34	0.00	0.00	429.19
81	φ(sex) p(.) f(sex+seas)	6	453.09	26.65	0.00	0.00	440.37
82	φ(sex) p(sex) f(sex+seas)	7	453.30	26.87	0.00	0.00	438.33
83	φ(sex) p(rep) f(sex+seas)	7	453.37	26.94	0.00	0.00	438.41
84	φ(sex) p(seas) f(seas)	6	454.24	27.81	0.00	0.00	441.52
85	φ(sex) p(.) f(sex*seas)	7	455.11	28.68	0.00	0.00	440.15
86	φ(sex) p(sex) f(sex*seas)	8	455.41	28.97	0.00	0.00	438.15

87	φ(sex) p(rep) f(sex*seas)	8	455.50	29.07	0.00	0.00	438.25
88	φ(sex) p(rep) f(seas)	6	457.36	30.93	0.00	0.00	444.64
89	φ(sex) p(sex) f(seas)	6	457.83	31.40	0.00	0.00	445.11
90	φ(sex) p(.) f(seas)	5	458.98	32.54	0.00	0.00	448.47
	POPAN models						
1	φ(sex) p(.) pent(sex+rep) N(.)	7	242.12	0.00	0.22	1.00	227.15
2	φ(sex+rep) p(.) pent(sex+rep) N(.)	8	242.61	0.49	0.18	0.78	225.36
3	φ(sex) p(seas) pent(sex+rep) N(.)	8	243.20	1.08	0.13	0.58	225.95
4	φ(sex+rep) p(seas) pent(sex+rep) N(.)	9	243.71	1.59	0.10	0.45	224.13
5	φ(sex) p(.) pent(sex+rep) N(sex)	8	244.41	2.29	0.07	0.32	227.15
6	φ(sex*rep) p(seas) pent(sex+rep) N(.)	10	244.87	2.75	0.06	0.25	222.93
7	φ(sex+rep) p(.) pent(sex+rep) N(sex)	9	244.94	2.82	0.05	0.24	225.36
8	φ(sex) p(seas) pent(sex*rep) N(.)	9	245.44	3.32	0.04	0.19	225.86
9	φ(sex) p(seas) pent(sex+rep) N(sex)	9	245.53	3.41	0.04	0.18	225.95
10	φ(sex+rep) p(seas) pent(sex*rep) N(.)	10	245.99	3.87	0.03	0.14	224.04
11	φ(sex+rep) p(seas) pent(sex+rep) N(sex)	10	246.08	3.96	0.03	0.14	224.13
12	φ(sex*rep) p(seas) pent(sex+rep) N(sex)	11	247.28	5.16	0.02	0.08	222.93
13	φ(sex) p(seas) pent(sex*rep) N(sex)	10	247.81	5.69	0.01	0.06	225.86
14	φ(sex+rep) p(seas) pent(sex*rep) N(sex)	11	248.40	6.28	0.01	0.04	224.04
	Cohort 2016						
	CJS models						
1	φ(sex*rep) p(.)	5	188.39	0.00	0.14	1.00	177.91
2	φ(.) p(sex*rep)	5	189.02	0.64	0.10	0.73	178.54
3	φ(rep) p(sex*rep)	6	189.37	0.98	0.09	0.61	176.69
4	φ(sex*rep) p(sex)	6	190.01	1.63	0.06	0.44	177.34
5	φ(sex*rep) p(rep)	6	190.02	1.63	0.06	0.44	177.34
6	φ(sex+rep) p(.)	4	190.28	1.90	0.06	0.39	181.97
7	φ(sex*rep) p(seas)	6	190.50	2.12	0.05	0.35	177.83
8	φ(rep) p(.)	3	191.03	2.64	0.04	0.27	184.84
9	φ(sex) p(sex*rep)	6	191.17	2.78	0.04	0.25	178.49
10	φ(sex+rep) p(sex)	5	191.31	2.93	0.03	0.23	180.83
11	φ(sex+rep) p(sex*rep)	7	191.45	3.06	0.03	0.22	176.54
12	φ(sex*rep) p(sex+rep)	7	191.49	3.10	0.03	0.21	176.58
13	φ(sex*rep) p(sex+seas)	7	192.13	3.74	0.02	0.15	177.22
14	φ(sex+rep) p(rep)	5	192.31	3.92	0.02	0.14	181.83
15	φ(sex+rep) p(sex+rep)	6	192.37	3.98	0.02	0.14	179.69
16	φ(sex+rep) p(seas)	5	192.41	4.03	0.02	0.13	181.93
17	φ(rep) p(sex)	4	193.05	4.67	0.01	0.10	184.74
18	φ(rep) p(rep)	4	193.08	4.69	0.01	0.10	184.76
19	φ(rep) p(seas)	4	193.11	4.73	0.01	0.09	184.80
20	φ(.) p(sex+rep)	4	193.31	4.92	0.01	0.09	184.99

21	φ(sex+rep) p(sex+seas)	6	193.51	5.12	0.01	0.08	180.83
22	φ(sex*rep) p(sex*rep)	8	193.76	5.37	0.01	0.07	176.58
23	φ(sex*rep) p(sex*seas)	8	193.77	5.38	0.01	0.07	176.59
24	φ(t) p(sex*rep)	8	193.83	5.44	0.01	0.07	176.65
25	φ(sex+t) p(.)	6	193.90	5.52	0.01	0.06	181.23
26	φ(.) p(rep)	3	194.10	5.72	0.01	0.06	187.92
27	φ(rep) p(sex+rep)	5	194.13	5.75	0.01	0.06	183.65
28	φ(sex+rep) p(sex*seas)	7	194.40	6.01	0.01	0.05	179.49
29	φ(t) p(.)	5	194.43	6.04	0.01	0.05	183.95
30	φ(rep) p(sex*seas)	5	194.75	6.36	0.01	0.04	184.27
31	φ(sex) p(rep)	4	194.90	6.51	0.01	0.04	186.58
32	φ(sex+t) p(sex)	7	195.00	6.61	0.01	0.04	180.09
33	φ(rep) p(sex+seas)	5	195.16	6.77	0.00	0.03	184.68
34	φ(sex+t) p(sex+rep)	8	195.43	7.04	0.00	0.03	178.25
35	φ(sex) p(sex+rep)	5	195.43	7.04	0.00	0.03	184.95
36	φ(sex+t) p(rep)	7	195.46	7.07	0.00	0.03	180.55
37	φ(sex+t) p(sex*rep)	9	195.89	7.51	0.00	0.02	176.41
38	φ(t) p(rep)	6	196.02	7.64	0.00	0.02	183.35
39	φ(sex+t) p(seas)	7	196.06	7.67	0.00	0.02	181.15
40	φ(t) p(seas)	6	196.44	8.06	0.00	0.02	183.77
41	φ(t) p(sex)	6	196.52	8.13	0.00	0.02	183.84
42	φ(sex*t) p(.)	9	197.01	8.62	0.00	0.01	177.52
43	φ(t) p(sex+rep)	7	197.15	8.77	0.00	0.01	182.24
44	φ(sex+t) p(sex+seas)	8	197.25	8.86	0.00	0.01	180.07
45	φ(sex+t) p(sex*seas)	9	198.34	9.95	0.00	0.01	178.85
46	φ(t) p(sex+seas)	7	198.53	10.14	0.00	0.01	183.62
47	φ(sex*t) p(rep)	10	198.77	10.38	0.00	0.01	176.93
48	φ(sex*t) p(sex)	10	198.77	10.38	0.00	0.01	176.94
49	φ(sex*t) p(seas)	10	199.24	10.85	0.00	0.00	177.41
50	φ(t) p(sex*seas)	8	200.14	11.75	0.00	0.00	182.96
51	φ(sex*t) p(sex+rep)	11	200.22	11.83	0.00	0.00	176.00
52	φ(sex*t) p(sex+seas)	11	200.89	12.50	0.00	0.00	176.67
53	φ(sex*t) p(sex*rep)	12	202.65	14.26	0.00	0.00	176.00
54	φ(sex*t) p(sex*seas)	12	202.74	14.36	0.00	0.00	176.10
55	φ(.) p(.)	2	205.33	16.94	0.00	0.00	201.24
56	φ(.) p(seas)	3	205.91	17.52	0.00	0.00	199.72
57	φ(.) p(sex)	3	206.87	18.48	0.00	0.00	200.68
58	φ(sex) p(.)	3	206.87	18.48	0.00	0.00	200.68
59	φ(sex) p(seas)	4	207.32	18.93	0.00	0.00	199.00
60	φ(.) p(sex+seas)	4	207.53	19.14	0.00	0.00	199.21
61	φ(sex) p(sex)	4	207.80	19.42	0.00	0.00	199.49
62	φ(sex) p(sex+seas)	5	208.35	19.96	0.00	0.00	197.87
63	φ(.) p(sex*seas)	5	208.77	20.39	0.00	0.00	198.29
64	φ(sex) p(sex*seas)	6	209.57	21.18	0.00	0.00	196.89

	Pradel models						
1	φ(sex*rep) p(.) f(sex*seas)	9	423.30	0.00	0.15	1.00	403.89
2	φ(sex*rep) p(.) f(seas)	7	424.19	0.90	0.09	0.64	409.33
3	φ(sex+rep) p(.) f(seas)	6	424.29	0.99	0.09	0.61	411.65
4	φ(sex*rep) p(sex) f(sex*seas)	10	424.63	1.33	0.08	0.51	402.89
5	φ(sex+rep) p(.) f(sex*seas)	8	424.63	1.34	0.07	0.51	407.52
6	φ(sex*rep) p(rep) f(sex*seas)	10	425.08	1.79	0.06	0.41	403.35
7	φ(sex*rep) p(sex) f(seas)	8	425.21	1.92	0.06	0.38	408.10
8	φ(rep) p(sex*rep) f(seas)	8	425.38	2.08	0.05	0.35	408.26
9	φ(rep) p(sex*rep) f(sex*seas)	10	425.48	2.18	0.05	0.34	403.74
10	φ(sex*rep) p(rep) f(seas)	8	425.63	2.34	0.05	0.31	408.52
11	φ(sex*rep) p(.) f(sex+seas)	8	426.41	3.12	0.03	0.21	409.30
12	φ(sex+rep) p(.) f(sex+seas)	7	426.50	3.20	0.03	0.20	411.63
13	φ(sex*rep) p(.) f(t)	9	427.03	3.73	0.02	0.15	407.62
14	φ(sex+rep) p(.) f(t)	8	427.24	3.95	0.02	0.14	410.13
15	φ(sex*rep) p(sex) f(sex+seas)	9	427.38	4.08	0.02	0.13	407.97
16	φ(sex*rep) p(sex) f(t)	10	427.64	4.34	0.02	0.11	405.90
17	φ(rep) p(sex*rep) f(sex+seas)	9	427.65	4.36	0.02	0.11	408.25
18	φ(sex*rep) p(rep) f(sex+seas)	9	427.89	4.60	0.01	0.10	408.49
19	φ(rep) p(sex*rep) f(t)	10	427.95	4.66	0.01	0.10	406.22
20	φ(sex*rep) p(rep) f(t)	10	429.02	5.73	0.01	0.06	407.29
21	φ(sex*rep) p(.) f(sex+t)	10	429.31	6.01	0.01	0.05	407.58
22	φ(sex*rep) p(.) f(sex*t)	13	429.50	6.21	0.01	0.04	400.57
23	φ(sex+rep) p(.) f(sex+t)	9	429.51	6.22	0.01	0.04	410.10
24	φ(sex*rep) p(sex) f(sex+t)	11	429.78	6.49	0.01	0.04	405.69
25	φ(rep) p(sex*rep) f(sex+t)	11	430.19	6.90	0.00	0.03	406.10
26	φ(.) p(sex*rep) f(sex*seas)	9	430.22	6.92	0.00	0.03	410.81
27	φ(sex*rep) p(.) f(rep)	7	430.71	7.41	0.00	0.02	415.84
28	φ(sex+rep) p(.) f(sex*t)	12	430.84	7.55	0.00	0.02	404.35
29	φ(rep) p(sex*rep) f(sex*t)	14	430.96	7.67	0.00	0.02	399.55
30	φ(sex+rep) p(.) f(rep)	6	431.30	8.00	0.00	0.02	418.65
31	φ(sex*rep) p(rep) f(sex+t)	11	431.36	8.06	0.00	0.02	407.26
32	φ(sex*rep) p(sex) f(sex*t)	14	431.41	8.11	0.00	0.02	399.99
33	φ(sex*rep) p(rep) f(sex*t)	14	431.49	8.19	0.00	0.02	400.07
34	φ(.) p(sex*rep) f(seas)	7	432.16	8.87	0.00	0.01	417.30
35	φ(rep) p(sex*rep) f(rep)	8	432.52	9.22	0.00	0.01	415.40
36	φ(sex*rep) p(.) f(sex+rep)	8	432.76	9.46	0.00	0.01	415.64
37	φ(.) p(sex*rep) f(t)	9	432.76	9.47	0.00	0.01	413.36
38	φ(sex*rep) p(rep) f(rep)	8	432.86	9.57	0.00	0.01	415.75
39	φ(sex+rep) p(.) f(sex+rep)	7	433.43	10.13	0.00	0.01	418.57
40	φ(.) p(sex*rep) f(sex+seas)	8	433.77	10.48	0.00	0.01	416.66
41	φ(.) p(sex*rep) f(sex*t)	13	434.43	11.13	0.00	0.00	405.49
42	φ(sex*rep) p(.) f(sex*rep)	9	434.66	11.36	0.00	0.00	415.25

43	φ(rep) p(sex*rep) f(sex+rep)	9	434.72	11.42	0.00	0.00	415.31
44	φ(sex*rep) p(rep) f(sex+rep)	9	434.96	11.66	0.00	0.00	415.55
45	φ(.) p(sex*rep) f(sex+t)	10	435.00	11.71	0.00	0.00	413.27
46	φ(sex*rep) p(sex) f(sex+rep)	9	435.00	11.71	0.00	0.00	415.60
47	φ(sex*rep) p(sex) f(rep)	8	435.35	12.05	0.00	0.00	418.23
48	φ(sex+rep) p(.) f(sex*rep)	8	435.56	12.27	0.00	0.00	418.45
49	φ(rep) p(sex*rep) f(sex*rep)	10	436.38	13.08	0.00	0.00	414.64
50	φ(.) p(sex*rep) f(rep)	7	436.86	13.56	0.00	0.00	421.99
51	φ(sex*rep) p(rep) f(sex*rep)	10	436.87	13.57	0.00	0.00	415.13
52	φ(sex*rep) p(sex) f(sex*rep)	10	436.98	13.69	0.00	0.00	415.25
53	φ(.) p(sex*rep) f(sex+rep)	8	439.10	15.81	0.00	0.00	421.99
54	φ(.) p(sex*rep) f(sex*rep)	9	440.09	16.79	0.00	0.00	420.68
55	φ(sex*t) p(sex*t) f(sex*t)	24	456.57	33.28	0.00	0.00	397.95
56	φ(sex*rep) p(.) f(sex*seas)	9	423.30	0.00	0.15	1.00	403.89
57	φ(sex*rep) p(.) f(seas)	7	424.19	0.90	0.09	0.64	409.33
	POPAN models						
1	φ(sex*rep) p(.) pent(seas) N(.)	8	252.65	0.00	0.19	1.00	235.53
2	φ(sex*rep) p(.) pent(sex*seas) N(.)	10	252.70	0.05	0.19	0.98	230.97
3	φ(sex*rep) p(.) pent(seas) N(sex)	9	253.81	1.16	0.11	0.56	234.40
4	φ(sex*rep) p(sex) pent(seas) N(.)	9	254.48	1.83	0.08	0.40	235.07
5	φ(sex*rep) p(.) pent(sex*seas) N(sex)	11	254.54	1.89	0.07	0.39	230.44
6	φ(sex*rep) p(rep) pent(sex*seas) N(.)	11	254.60	1.95	0.07	0.38	230.51
7	φ(sex*rep) p(sex) pent(sex*seas) N(.)	11	255.01	2.36	0.06	0.31	230.91
8	φ(sex+rep) p(.) pent(sex*seas) N(.)	9	255.55	2.91	0.04	0.23	236.15
9	φ(sex*rep) p(sex) pent(sex*seas) N(sex)	12	255.76	3.11	0.04	0.21	229.26
10	φ(sex+rep) p(.) pent(seas) N(.)	7	255.92	3.27	0.04	0.20	241.06
11	φ(sex*rep) p(sex) pent(seas) N(sex)	10	256.05	3.40	0.03	0.18	234.32
12	φ(sex+rep) p(.) pent(seas) N(sex)	8	256.28	3.63	0.03	0.16	239.16
13	φ(sex*rep) p(rep) pent(sex*seas) N(sex)	12	256.61	3.96	0.03	0.14	230.11
14	φ(sex+rep) p(.) pent(sex*seas) N(sex)	10	256.81	4.16	0.02	0.13	235.08

Appendix 10. Model selection for the capture histories of the cohorts 2015 and 2016 of *Gracilinanus agilis* in JB2, one of the food supplemented areas. Comark-Jolly-Seber (CJS) models may have apparent survival (φ) and recapture (p) probabilities varying as a function of sex, time (t), reproductive season (pre-reproductive, reproductive and post-reproductive), interaction between factors (*) or no effect (.). Pradel models have φ and p varying according to the selected CJS models and recruitment (*f*) as a function of sex, time (t), reproductive season, climatic season, and interactions. POPAN models have φ, p and probability of entrance (pent) varying according to the selected Pradel models and super-population size varying between sexes or constant. The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, L is the model likelihood and Dev is the deviance. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	-2logL	Dev
	Cohort 2015						
	CJS models						
1	φ(sex+t) p(.)	9	278.59	0.00	0.29	1.00	259.41
2	φ(t) p(sex*rep)	11	280.62	2.02	0.10	0.36	256.87
3	φ(sex+t) p(sex)	10	280.74	2.15	0.10	0.34	259.29
4	φ(sex+t) p(rep)	10	280.78	2.19	0.10	0.33	259.33
5	φ(sex*rep) p(t)	11	281.95	3.36	0.05	0.19	258.20
6	φ(sex+t) p(sex*rep)	12	282.72	4.13	0.04	0.13	256.64
7	φ(sex+t) p(t)	14	282.96	4.37	0.03	0.11	252.12
8	φ(sex+t) p(sex+rep)	11	283.01	4.42	0.03	0.11	259.27
9	φ(t) p(rep)	15	283.08	4.49	0.03	0.11	249.82
10	φ(t) p(.)	8	283.30	4.71	0.03	0.09	266.37
11	φ(sex*t) p(.)	15	283.32	4.72	0.03	0.09	250.05
12	φ(sex*rep) p(sex+t)	12	283.70	5.10	0.02	0.08	257.62
13	φ(sex+rep) p(t)	10	283.82	5.23	0.02	0.07	262.37
14	φ(sex*rep) p(.)	5	284.41	5.82	0.02	0.05	274.03
15	φ(sex+t) p(sex+t)	15	284.88	6.29	0.01	0.04	251.61
16	φ(sex+rep) p(sex+t)	11	285.33	6.74	0.01	0.03	261.59
17	φ(t) p(sex)	9	285.42	6.83	0.01	0.03	266.24
18	φ(sex*t) p(rep)	16	285.54	6.95	0.01	0.03	249.82
19	φ(sex*t) p(sex)	16	285.62	7.03	0.01	0.03	249.90
20	φ(t) p(sex+rep)	10	285.71	7.12	0.01	0.03	264.26
21	φ(sex*rep) p(sex)	6	286.26	7.67	0.01	0.02	273.72
22	φ(sex+rep) p(.)	4	286.43	7.84	0.01	0.02	278.18
23	φ(sex*rep) p(rep)	6	286.54	7.95	0.01	0.02	274.00

24	φ(t) p(t)	13	287.49	8.90	0.00	0.01	259.05
25	φ(sex*t) p(t)	20	287.77	9.18	0.00	0.01	241.86
26	φ(rep) p(t)	9	287.79	9.20	0.00	0.01	268.62
27	φ(sex*t) p(sex+rep)	17	287.97	9.38	0.00	0.01	249.75
28	φ(sex+rep) p(sex)	5	288.11	9.52	0.00	0.01	277.72
29	φ(sex*rep) p(sex+rep)	7	288.45	9.86	0.00	0.01	273.72
30	φ(sex+rep) p(rep)	5	288.53	9.94	0.00	0.01	278.15
31	φ(.) p(sex*rep)	5	288.59	9.99	0.00	0.01	278.20
32	φ(.) p(sex+t)	9	288.66	10.07	0.00	0.01	269.49
33	φ(sex) p(t)	9	288.87	10.28	0.00	0.01	269.70
34	φ(.) p(sex*t)	15	289.19	10.60	0.00	0.01	255.92
35	φ(rep) p(sex*rep)	6	289.31	10.71	0.00	0.00	276.77
36	φ(sex*rep) p(sex*rep)	8	289.37	10.77	0.00	0.00	272.43
37	φ(t) p(sex*t)	20	289.44	10.85	0.00	0.00	243.52
38	φ(t) p(sex+t)	14	289.78	11.19	0.00	0.00	258.95
39	φ(sex) p(sex+t)	10	289.80	11.20	0.00	0.00	268.35
40	φ(sex*t) p(sex*rep)	18	289.85	11.26	0.00	0.00	249.10
41	φ(rep) p(sex+t)	10	290.02	11.43	0.00	0.00	268.57
42	φ(sex+rep) p(sex+rep)	6	290.24	11.65	0.00	0.00	277.71
43	φ(sex*t) p(sex+t)	21	290.29	11.70	0.00	0.00	241.74
44	φ(.) p(t)	8	290.55	11.96	0.00	0.00	273.61
45	φ(rep) p(.)	3	290.56	11.96	0.00	0.00	284.40
46	φ(sex) p(sex*rep)	6	290.70	12.11	0.00	0.00	278.16
47	φ(sex+rep) p(sex*rep)	7	290.89	12.30	0.00	0.00	276.17
48	φ(rep) p(sex*t)	16	290.93	12.34	0.00	0.00	255.21
49	φ(sex+t) p(sex*t)	21	291.38	12.79	0.00	0.00	242.83
50	φ(sex) p(sex*t)	16	291.42	12.83	0.00	0.00	255.69
51	φ(rep) p(rep)	4	292.55	13.96	0.00	0.00	284.30
52	φ(sex+rep) p(sex*t)	17	292.60	14.01	0.00	0.00	254.38
53	φ(rep) p(sex)	4	292.66	14.06	0.00	0.00	284.40
54	φ(.) p(sex+rep)	4	293.89	15.30	0.00	0.00	285.64
55	φ(sex) p(rep)	4	294.26	15.66	0.00	0.00	286.00
56	φ(rep) p(sex+rep)	5	294.40	15.81	0.00	0.00	284.02
57	φ(sex*rep) p(sex*t)	18	295.00	16.41	0.00	0.00	254.25
58	φ(sex) p(sex+rep)	5	295.08	16.49	0.00	0.00	284.70
59	φ(.) p(rep)	3	295.81	17.22	0.00	0.00	289.66
60	φ(sex) p(.)	3	297.40	18.80	0.00	0.00	291.25
61	φ(.) p(.)	2	298.59	19.99	0.00	0.00	294.51
62	φ(sex) p(sex)	4	299.09	20.50	0.00	0.00	290.84
63	φ(.) p(sex)	3	300.63	22.04	0.00	0.00	294.48
64	φ(sex*t) p(sex*t)	26	301.27	22.68	0.00	0.00	238.95
	Pradel models						
1	φ(sex+t) p(.) f(t)	16	529.45	0.00	0.61	1.00	493.77

2	φ(sex+t) p(.) f(sex+t)	17	530.43	0.98	0.38	0.61	492.27
3	φ(t) p(sex*rep) f(t)	18	537.97	8.52	0.01	0.01	497.29
4	φ(t) p(sex*rep) f(sex+t)	19	540.53	11.08	0.00	0.00	497.28
5	φ(sex+t) p(.) f(sex*t)	23	543.70	14.25	0.00	0.00	489.87
6	φ(t) p(sex*rep) f(sex*t)	25	554.19	24.74	0.00	0.00	494.84
7	φ(sex+t) p(.) f(sex+rep)	12	556.97	27.53	0.00	0.00	530.92
8	φ(sex+t) p(.) f(rep)	11	557.29	27.84	0.00	0.00	533.56
9	φ(sex+t) p(.) f(sex*rep)	13	559.29	29.85	0.00	0.00	530.88
10	φ(t) p(sex*rep) f(rep)	13	564.06	34.62	0.00	0.00	535.65
11	φ(sex+t) p(.) f(sex+seas)	12	565.95	36.51	0.00	0.00	539.90
12	φ(t) p(sex*rep) f(sex+rep)	14	566.43	36.98	0.00	0.00	535.63
13	φ(sex+t) p(.) f(sex*seas)	13	567.37	37.93	0.00	0.00	538.96
14	φ(sex+t) p(.) f(seas)	11	567.89	38.45	0.00	0.00	544.17
15	φ(t) p(sex*rep) f(sex*rep)	15	568.31	38.86	0.00	0.00	535.09
16	φ(t) p(sex*rep) f(seas)	13	573.80	44.36	0.00	0.00	545.39
17	φ(t) p(sex*rep) f(sex+seas)	14	575.91	46.47	0.00	0.00	545.11
18	φ(t) p(sex*rep) f(sex*seas)	15	576.82	47.37	0.00	0.00	543.59
	POPAN models						
1	φ(sex+t) p(.) pent(t) N(.)	17	336.40	0.00	0.58	1.00	298.24
2	φ(sex+t) p(.) pent(t) N(sex)	18	338.61	2.21	0.19	0.33	297.93
3	φ(sex+t) p(.) pent(sex+t) N(.)	18	338.87	2.47	0.17	0.29	298.19
4	φ(sex+t) p(.) pent(sex+t) N(sex)	19	341.13	4.73	0.05	0.09	297.89
	Cohort 2016						
	CJS models						
1	φ(sex+rep) p(sex+t)	8	218.37	0.00	0.11	1.00	201.30
2	φ(sex+t) p(sex+t)	9	218.51	0.14	0.10	0.93	199.15
3	φ(sex*t) p(t)	11	218.94	0.57	0.08	0.75	194.92
4	φ(sex*t) p(.)	9	219.09	0.71	0.08	0.70	199.73
5	φ(sex+rep) p(t)	7	219.79	1.42	0.05	0.49	204.96
6	φ(sex*rep) p(sex+t)	9	219.80	1.43	0.05	0.49	200.45
7	φ(sex+t) p(t)	8	220.15	1.78	0.05	0.41	203.08
8	φ(sex*t) p(sex+t)	12	220.19	1.81	0.04	0.40	193.79
9	φ(sex*t) p(sex)	10	220.55	2.18	0.04	0.34	198.88
10	φ(sex*rep) p(t)	8	220.73	2.35	0.03	0.31	203.65
11	φ(sex*t) p(rep)	10	220.92	2.55	0.03	0.28	199.26
12	φ(sex*rep) p(.)	5	221.36	2.99	0.02	0.22	210.92
13	φ(sex+rep) p(.)	4	221.81	3.44	0.02	0.18	213.52
14	φ(sex) p(t)	6	221.88	3.51	0.02	0.17	209.26
15	φ(sex+t) p(.)	6	222.29	3.92	0.02	0.14	209.67
16	φ(sex) p(sex*rep)	6	222.33	3.96	0.02	0.14	209.72
17	φ(sex*t) p(sex+rep)	11	222.57	4.20	0.01	0.12	198.56

18	φ(sex*rep) p(sex)	6	222.58	4.21	0.01	0.12	209.97
19	φ(sex) p(sex+t)	7	222.66	4.29	0.01	0.12	207.83
20	φ(sex+rep) p(sex+rep)	5	222.74	4.37	0.01	0.11	212.30
21	φ(sex+rep) p(sex)	5	222.75	4.37	0.01	0.11	212.31
22	φ(sex) p(sex*t)	10	222.81	4.44	0.01	0.11	201.15
23	φ(sex+t) p(sex*t)	12	222.94	4.57	0.01	0.10	196.54
24	φ(sex) p(.)	3	223.14	4.77	0.01	0.09	216.97
25	φ(sex+rep) p(sex*t)	11	223.23	4.85	0.01	0.09	199.21
26	φ(.) p(sex*t)	9	223.29	4.92	0.01	0.09	203.94
27	φ(sex+t) p(sex*rep)	9	223.33	4.95	0.01	0.08	203.97
28	φ(sex+t) p(sex)	7	223.41	5.04	0.01	0.08	208.58
29	φ(sex*rep) p(rep)	6	223.44	5.06	0.01	0.08	210.82
30	φ(.) p(sex*rep)	5	223.86	5.48	0.01	0.06	213.42
31	φ(sex+rep) p(rep)	5	223.89	5.52	0.01	0.06	213.45
32	φ(sex) p(rep)	4	223.98	5.61	0.01	0.06	215.69
33	φ(sex) p(sex)	4	224.18	5.81	0.01	0.05	215.89
34	φ(sex+rep) p(sex*rep)	7	224.31	5.94	0.01	0.05	209.48
35	φ(t) p(sex*t)	11	224.35	5.98	0.01	0.05	200.34
36	φ(rep) p(sex*t)	10	224.44	6.06	0.01	0.05	202.77
37	φ(sex+t) p(rep)	7	224.49	6.12	0.01	0.05	209.67
38	φ(sex*rep) p(sex+rep)	7	224.73	6.36	0.00	0.04	209.90
39	φ(sex*t) p(sex*rep)	12	224.96	6.58	0.00	0.04	198.56
40	φ(sex*t) p(sex*t)	14	225.07	6.70	0.00	0.04	193.79
41	φ(sex+t) p(sex+rep)	8	225.60	7.23	0.00	0.03	208.52
42	φ(sex*rep) p(sex*t)	12	225.97	7.60	0.00	0.02	199.57
43	φ(sex) p(sex+rep)	5	226.01	7.64	0.00	0.02	215.57
44	φ(rep) p(sex*rep)	6	226.03	7.66	0.00	0.02	213.41
45	φ(t) p(sex*rep)	8	226.46	8.09	0.00	0.02	209.38
46	φ(sex*rep) p(sex*rep)	8	226.97	8.60	0.00	0.01	209.90
47	φ(t) p(sex+rep)	7	227.02	8.65	0.00	0.01	212.19
48	φ(.) p(sex+rep)	4	227.14	8.77	0.00	0.01	218.85
49	φ(t) p(sex)	6	228.87	10.50	0.00	0.01	216.26
50	φ(t) p(sex+t)	8	229.04	10.67	0.00	0.00	211.97
51	φ(.) p(sex+t)	6	229.13	10.76	0.00	0.00	216.51
52	φ(rep) p(sex+rep)	5	229.27	10.90	0.00	0.00	218.83
53	φ(t) p(t)	7	230.86	12.49	0.00	0.00	216.04
54	φ(rep) p(sex)	4	231.08	12.71	0.00	0.00	222.79
55	φ(rep) p(sex+t)	7	231.32	12.95	0.00	0.00	216.49
56	φ(t) p(.)	5	231.42	13.05	0.00	0.00	220.98
57	φ(.) p(sex)	3	231.44	13.07	0.00	0.00	225.27
58	φ(rep) p(t)	6	231.88	13.51	0.00	0.00	219.26
59	φ(.) p(t)	5	232.65	14.28	0.00	0.00	222.21
60	φ(t) p(rep)	6	233.30	14.93	0.00	0.00	220.69
61	φ(rep) p(.)	3	234.58	16.20	0.00	0.00	228.40

62	φ(.) p(.)	2	235.37	17.00	0.00	0.00	231.29
63	φ(.) p(rep)	3	235.60	17.23	0.00	0.00	229.43
64	φ(rep) p(rep)	4	236.44	18.07	0.00	0.00	228.15
	Pradel models						
1	φ(sex+t) p(sex+t) f(sex+t)	14	452.24	0.00	0.13	1.00	421.20
2	φ(sex+t) p(t) f(sex+rep)	12	453.04	0.80	0.09	0.67	426.81
3	φ(sex+t) p(sex+t) f(sex+rep)	13	453.07	0.83	0.08	0.66	424.45
4	φ(sex+rep) p(sex+t) f(sex+t)	13	453.14	0.90	0.08	0.64	424.52
5	φ(sex+rep) p(sex+t) f(sex+rep)	12	453.24	1.00	0.08	0.61	427.01
6	φ(sex+t) p(t) f(sex*rep)	13	453.96	1.71	0.05	0.42	425.34
7	φ(sex*t) p(t) f(sex*rep)	16	454.44	2.20	0.04	0.33	418.44
8	φ(sex*rep) p(sex+t) f(sex+t)	14	454.58	2.34	0.04	0.31	423.54
9	φ(sex+rep) p(t) f(sex+rep)	11	454.71	2.47	0.04	0.29	430.84
10	φ(sex+rep) p(t) f(sex*rep)	12	454.81	2.56	0.04	0.28	428.58
11	φ(sex*t) p(sex+t) f(sex+t)	17	454.82	2.58	0.04	0.28	416.28
12	φ(sex+t) p(sex+t) f(sex*rep)	14	454.84	2.60	0.03	0.27	423.80
13	φ(sex*rep) p(sex+t) f(sex+rep)	13	454.91	2.67	0.03	0.26	426.29
14	φ(sex+rep) p(sex+t) f(sex*rep)	13	455.03	2.79	0.03	0.25	426.41
15	φ(sex+t) p(t) f(sex+t)	13	455.33	3.08	0.03	0.21	426.71
16	φ(sex*t) p(t) f(sex+rep)	15	455.46	3.21	0.03	0.20	421.95
17	φ(sex*t) p(t) f(sex+t)	16	455.72	3.48	0.02	0.18	419.72
18	φ(sex*t) p(.) f(sex+t)	14	456.22	3.98	0.02	0.14	425.18
19	φ(sex*t) p(sex+t) f(sex+rep)	16	456.33	4.09	0.02	0.13	420.33
20	φ(sex+rep) p(t) f(sex+t)	12	456.52	4.28	0.02	0.12	430.29
21	φ(sex*rep) p(sex+t) f(sex*rep)	14	456.65	4.41	0.01	0.11	425.61
22	φ(sex*t) p(sex+t) f(sex*rep)	17	457.77	5.53	0.01	0.06	419.24
23	φ(sex*t) p(.) f(sex*t)	17	458.43	6.19	0.01	0.05	419.90
24	φ(sex+t) p(sex+t) f(sex*t)	17	458.69	6.45	0.01	0.04	420.16
25	φ(sex+rep) p(sex+t) f(sex*t)	16	458.90	6.66	0.00	0.04	422.90
26	φ(sex+t) p(sex+t) f(t)	13	459.17	6.93	0.00	0.03	430.55
27	φ(sex*t) p(t) f(sex*t)	19	459.24	7.00	0.00	0.03	415.53
28	φ(sex+t) p(t) f(sex*t)	16	459.62	7.38	0.00	0.03	423.62
29	φ(sex+rep) p(t) f(sex*t)	15	459.70	7.46	0.00	0.02	426.20
30	φ(sex*t) p(.) f(sex+rep)	12	459.91	7.67	0.00	0.02	433.69
31	φ(sex*t) p(.) f(sex*rep)	13	459.98	7.74	0.00	0.02	431.36
32	φ(sex*rep) p(sex+t) f(t)	13	460.51	8.27	0.00	0.02	431.89
33	φ(sex*rep) p(sex+t) f(sex*t)	17	460.53	8.29	0.00	0.02	422.00
34	φ(sex*t) p(sex+t) f(sex*t)	20	460.75	8.51	0.00	0.01	414.39
35	φ(sex+rep) p(sex+t) f(t)	12	461.49	9.25	0.00	0.01	435.26
36	φ(sex+t) p(sex+t) f(rep)	12	461.84	9.60	0.00	0.01	435.61
37	φ(sex*t) p(t) f(sex*seas)	16	462.69	10.45	0.00	0.01	426.69
38	φ(sex*t) p(sex+t) f(t)	16	463.02	10.78	0.00	0.00	427.02
39	φ(sex*t) p(t) f(seas)	11	463.03	10.79	0.00	0.00	439.16

40	φ(sex*rep) p(sex+t) f(rep)	12	463.25	11.01	0.00	0.00	437.02
41	φ(sex+rep) p(sex+t) f(rep)	11	463.70	11.46	0.00	0.00	439.83
42	φ(sex*rep) p(sex+t) f(sex+seas)	13	463.98	11.74	0.00	0.00	435.36
43	φ(sex*rep) p(sex+t) f(sex*seas)	14	464.34	12.10	0.00	0.00	433.30
44	φ(sex*t) p(sex+t) f(sex*seas)	17	464.51	12.27	0.00	0.00	425.97
45	φ(sex*t) p(.) f(t)	13	464.91	12.67	0.00	0.00	436.29
46	φ(sex+t) p(t) f(t)	12	465.14	12.90	0.00	0.00	438.91
47	φ(sex*t) p(t) f(t)	15	465.29	13.05	0.00	0.00	431.78
48	φ(sex+t) p(t) f(sex*seas)	13	465.71	13.47	0.00	0.00	437.09
49	φ(sex+t) p(t) f(sex+seas)	12	465.74	13.50	0.00	0.00	439.51
50	φ(sex+t) p(sex+t) f(sex*seas)	14	465.81	13.57	0.00	0.00	434.77
51	φ(sex*t) p(sex+t) f(sex+seas)	16	465.84	13.60	0.00	0.00	429.84
52	φ(sex+rep) p(t) f(rep)	10	465.90	13.66	0.00	0.00	444.35
53	φ(sex+t) p(t) f(rep)	11	466.18	13.94	0.00	0.00	442.31
54	φ(sex+rep) p(t) f(sex*seas)	12	466.39	14.15	0.00	0.00	440.17
55	φ(sex+rep) p(sex+t) f(sex+seas)	12	466.58	14.34	0.00	0.00	440.35
56	φ(sex+rep) p(t) f(sex+seas)	11	466.76	14.51	0.00	0.00	442.88
57	φ(sex+rep) p(t) f(t)	11	467.08	14.84	0.00	0.00	443.21
58	φ(sex+t) p(sex+t) f(sex+seas)	13	467.13	14.89	0.00	0.00	438.51
59	φ(sex*t) p(t) f(sex+seas)	15	467.23	14.99	0.00	0.00	433.73
60	φ(sex*t) p(t) f(rep)	14	467.27	15.03	0.00	0.00	436.23
61	φ(sex*t) p(.) f(rep)	11	467.55	15.31	0.00	0.00	443.68
62	φ(sex*rep) p(sex+t) f(seas)	12	468.37	16.12	0.00	0.00	442.14
63	φ(sex+rep) p(sex+t) f(sex*seas)	13	468.46	16.22	0.00	0.00	439.85
64	φ(sex*t) p(sex+t) f(rep)	15	468.66	16.42	0.00	0.00	435.16
65	φ(sex*t) p(.) f(sex+seas)	12	469.92	17.68	0.00	0.00	443.70
66	φ(sex*t) p(.) f(sex*seas)	13	470.61	18.37	0.00	0.00	441.99
67	φ(sex+t) p(t) f(seas)	11	471.11	18.87	0.00	0.00	447.24
68	φ(sex+rep) p(t) f(seas)	10	472.53	20.29	0.00	0.00	450.98
69	φ(sex*t) p(.) f(seas)	11	483.06	30.82	0.00	0.00	459.19
70	φ(sex+t) p(sex+t) f(seas)	12	492.12	39.87	0.00	0.00	465.89
71	φ(sex*t) p(sex+t) f(seas)	15	493.26	41.01	0.00	0.00	459.75
72	φ(sex+rep) p(sex+t) f(seas)	11	498.22	45.98	0.00	0.00	474.35
	POPAN models						
1	φ(sex+t) p(sex+t) pent(sex+rep) N(sex)	15	261.50	0.00	0.31	1.00	228.00
2	φ(sex+rep) p(sex+t) pent(sex+rep) N(sex)	14	262.02	0.52	0.24	0.77	230.98
3	φ(sex+rep) p(sex+t) pent(sex+rep) N(.)	13	263.70	2.20	0.10	0.33	235.08
4	φ(sex+t) p(sex+t) pent(sex+rep) N(.)	14	263.85	2.34	0.10	0.31	232.80
5	φ(sex+rep) p(sex+t) pent(sex+t) N(sex)	15	264.02	2.52	0.09	0.28	230.52
6	φ(sex+rep) p(sex+t) pent(sex+t) N(.)	14	264.61	3.11	0.07	0.21	233.56
7	φ(sex+t) p(sex+t) pent(sex+t) N(.)	15	264.78	3.27	0.06	0.19	231.27
8	φ(sex+t) p(t) pent(sex+rep) N(.)	13	267.50	5.99	0.02	0.05	238.88

9	φ(sex+t) p(t) pent(sex*rep) N(.)	14	268.15	6.65	0.01	0.04	237.11
10	φ(sex+t) p(t) pent(sex+rep) N(sex)	14	269.57	8.07	0.01	0.02	238.53
11	φ(sex+t) p(t) pent(sex*rep) N(sex)	15	270.45	8.95	0.00	0.01	236.95
12	φ(sex+t) p(sex+t) pent(sex+t) N(sex)	16	281.52	20.01	0.00	0.00	245.52

Appendix 11. Model selection for the capture histories of the cohorts 2015 and 2016 of *Gracilinanus agilis* in JB4, one of the food supplemented areas. Comark-Jolly-Seber (CJS) models may have apparent survival (φ) probabilities varying as a function of sex, time (t), reproductive season (pre-reproductive, reproductive and post-reproductive), interaction between factors (*) or no effect (.), and recapture (p) probabilities varying as a function of sex, climatic season (seas: dry and wet), reproductive season, interaction between factors or no effect. Pradel models have φ and p varying according to the selected CJS models and recruitment (*f*) as a function of sex, time (t), reproductive season, climatic season, and interactions. POPAN models have φ, p and probability of entrance (pent) varying according to the selected Pradel models and super-population size varying between sexes or constant. The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, L is the model likelihood and Dev is the deviance. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	-2logL	Dev
	Cohort 2015						
	CJS models						
1	φ(t) p(sex*rep)	12	314.12	0.00	0.26	1.00	288.47
2	φ(.) p(sex*rep)	5	314.62	0.50	0.20	0.78	304.31
3	φ(sex+t) p(sex*rep)	13	315.17	1.05	0.16	0.59	287.24
4	φ(sex) p(sex*rep)	6	315.87	1.75	0.11	0.42	303.44
5	φ(rep) p(sex*rep)	6	316.23	2.11	0.09	0.35	303.80
6	φ(sex+rep) p(sex*rep)	7	316.50	2.38	0.08	0.30	301.93
7	φ(sex*rep) p(sex)	6	318.02	3.90	0.04	0.14	305.59
8	φ(sex*rep) p(sex+seas)	7	320.14	6.02	0.01	0.05	305.56
9	φ(sex*rep) p(sex+rep)	7	320.16	6.04	0.01	0.05	305.59
10	φ(sex+rep) p(sex)	5	321.49	7.37	0.01	0.03	311.19
11	φ(sex*rep) p(sex*seas)	8	322.31	8.18	0.00	0.02	305.56
12	φ(sex*rep) p(sex*rep)	8	322.33	8.21	0.00	0.02	305.59
13	φ(sex+t) p(sex)	11	322.52	8.39	0.00	0.02	299.13
14	φ(sex+t) p(sex+seas)	12	323.44	9.32	0.00	0.01	297.79
15	φ(sex+rep) p(sex+rep)	6	323.47	9.35	0.00	0.01	311.04
16	φ(sex+rep) p(sex+seas)	6	323.50	9.38	0.00	0.01	311.07
17	φ(sex+t) p(sex+rep)	12	324.54	10.42	0.00	0.01	298.89
18	φ(sex*rep) p(.)	5	325.00	10.88	0.00	0.00	314.70
19	φ(sex*t) p(sex)	18	325.64	11.51	0.00	0.00	285.90
20	φ(sex+rep) p(sex*seas)	7	325.65	11.52	0.00	0.00	311.07

21	φ(sex+t) p(sex*seas)	13	325.73	11.60	0.00	0.00	297.79
22	φ(sex*rep) p(rep)	6	326.40	12.28	0.00	0.00	313.97
23	φ(sex*rep) p(seas)	6	326.68	12.55	0.00	0.00	314.25
24	φ(sex*t) p(sex+rep)	19	328.02	13.89	0.00	0.00	285.84
25	φ(sex*t) p(sex+seas)	19	328.07	13.95	0.00	0.00	285.90
26	φ(sex+rep) p(.)	4	329.28	15.16	0.00	0.00	321.08
27	φ(sex+rep) p(rep)	5	330.40	16.28	0.00	0.00	320.10
28	φ(sex*t) p(sex*rep)	20	330.48	16.36	0.00	0.00	285.84
29	φ(sex*t) p(sex*seas)	20	330.54	16.42	0.00	0.00	285.90
30	φ(sex+t) p(.)	10	330.56	16.43	0.00	0.00	309.40
31	φ(sex+rep) p(seas)	5	330.94	16.82	0.00	0.00	320.63
32	φ(sex) p(sex)	4	331.75	17.62	0.00	0.00	323.54
33	φ(sex*t) p(.)	17	331.82	17.70	0.00	0.00	294.49
34	φ(sex+t) p(rep)	11	332.19	18.07	0.00	0.00	308.80
35	φ(sex+t) p(seas)	11	332.36	18.23	0.00	0.00	308.97
36	φ(sex) p(rep)	4	332.48	18.36	0.00	0.00	324.28
37	φ(sex) p(sex+rep)	5	333.14	19.02	0.00	0.00	322.84
38	φ(rep) p(sex)	4	333.26	19.14	0.00	0.00	325.06
39	φ(sex*t) p(rep)	18	333.27	19.15	0.00	0.00	293.53
40	φ(sex) p(sex+seas)	5	333.85	19.72	0.00	0.00	323.54
41	φ(sex*t) p(seas)	18	334.14	20.02	0.00	0.00	294.41
42	φ(t) p(sex)	10	334.69	20.56	0.00	0.00	313.53
43	φ(rep) p(sex+rep)	5	335.16	21.03	0.00	0.00	324.85
44	φ(rep) p(sex+seas)	5	335.31	21.19	0.00	0.00	325.00
45	φ(sex) p(sex*seas)	6	335.97	21.85	0.00	0.00	323.54
46	φ(rep) p(.)	3	336.02	21.90	0.00	0.00	329.90
47	φ(.) p(rep)	3	336.20	22.08	0.00	0.00	330.08
48	φ(t) p(sex+seas)	11	336.27	22.14	0.00	0.00	312.88
49	φ(rep) p(rep)	4	336.35	22.23	0.00	0.00	328.15
50	φ(rep) p(sex*seas)	6	336.43	22.31	0.00	0.00	324.00
51	φ(t) p(sex+rep)	11	336.53	22.41	0.00	0.00	313.14
52	φ(.) p(sex+rep)	4	336.99	22.86	0.00	0.00	328.78
53	φ(rep) p(seas)	4	337.51	23.39	0.00	0.00	329.31
54	φ(t) p(.)	9	337.98	23.85	0.00	0.00	319.04
55	φ(t) p(sex*seas)	12	338.53	24.41	0.00	0.00	312.88
56	φ(.) p(sex)	3	338.61	24.49	0.00	0.00	332.49
57	φ(sex) p(.)	3	338.82	24.70	0.00	0.00	332.70
58	φ(t) p(rep)	10	339.11	24.99	0.00	0.00	317.96
59	φ(sex) p(seas)	4	339.95	25.83	0.00	0.00	331.75
60	φ(t) p(seas)	10	340.06	25.93	0.00	0.00	318.90
61	φ(.) p(sex+seas)	4	340.69	26.57	0.00	0.00	332.49
62	φ(.) p(sex*seas)	5	341.81	27.68	0.00	0.00	331.50
63	φ(.) p(.)	2	342.49	28.37	0.00	0.00	338.43
64	φ(.) p(seas)	3	343.52	29.40	0.00	0.00	337.40

	Pradel models						
1	φ(.) p(sex*rep) f(sex+rep)	8	681.82	0.00	0.37	1.00	665.08
2	φ(.) p(sex*rep) f(sex*rep)	9	682.58	0.76	0.25	0.68	663.65
3	φ(sex) p(sex*rep) f(sex+rep)	9	683.10	1.28	0.20	0.53	664.17
4	φ(t) p(sex*rep) f(sex*rep)	16	683.36	1.54	0.17	0.46	648.44
5	φ(sex+t) p(sex*rep) f(sex+rep)	16	690.49	8.67	0.00	0.01	655.57
6	φ(sex+t) p(sex*rep) f(sex*rep)	17	691.92	10.10	0.00	0.01	654.61
7	φ(sex+t) p(sex*rep) f(sex+t)	22	696.98	15.16	0.00	0.00	647.36
8	φ(sex) p(sex*rep) f(sex*rep)	10	699.64	17.82	0.00	0.00	678.49
9	φ(.) p(sex*rep) f(sex+seas)	8	700.06	18.24	0.00	0.00	683.32
10	φ(sex+t) p(sex*rep) f(rep)	15	702.50	20.67	0.00	0.00	669.93
11	φ(t) p(sex*rep) f(sex+rep)	15	702.99	21.17	0.00	0.00	670.42
12	φ(sex) p(sex*rep) f(sex+t)	15	703.20	21.38	0.00	0.00	670.63
13	φ(sex+t) p(sex*rep) f(t)	21	705.74	23.92	0.00	0.00	658.64
14	φ(sex) p(sex*rep) f(rep)	8	706.28	24.46	0.00	0.00	689.54
15	φ(.) p(sex*rep) f(rep)	7	706.77	24.95	0.00	0.00	692.20
16	φ(t) p(sex*rep) f(sex+t)	21	707.04	25.22	0.00	0.00	659.93
17	φ(t) p(sex*rep) f(t)	20	707.98	26.15	0.00	0.00	663.36
18	φ(t) p(sex*rep) f(rep)	14	708.29	26.47	0.00	0.00	678.06
19	φ(.) p(sex*rep) f(sex+t)	14	709.08	27.26	0.00	0.00	678.85
20	φ(sex) p(sex*rep) f(t)	14	709.55	27.73	0.00	0.00	679.32
21	φ(.) p(sex*rep) f(t)	13	709.79	27.97	0.00	0.00	681.87
22	φ(sex+t) p(sex*rep) f(sex*t)	29	710.80	28.97	0.00	0.00	642.74
23	φ(sex+t) p(sex*rep) f(sex+seas)	16	712.79	30.97	0.00	0.00	677.87
24	φ(.) p(sex*rep) f(seas)	7	715.02	33.20	0.00	0.00	700.45
25	φ(sex) p(sex*rep) f(seas)	8	715.02	33.20	0.00	0.00	698.28
26	φ(sex+t) p(sex*rep) f(sex*seas)	17	715.10	33.28	0.00	0.00	677.80
27	φ(sex) p(sex*rep) f(sex*t)	22	716.69	34.87	0.00	0.00	667.07
28	φ(t) p(sex*rep) f(sex*t)	28	722.60	40.78	0.00	0.00	657.27
29	φ(.) p(sex*rep) f(sex*t)	21	723.55	41.73	0.00	0.00	676.45
30	φ(sex+t) p(sex*rep) f(seas)	15	733.25	51.43	0.00	0.00	700.68
31	φ(t) p(sex*rep) f(sex+seas)	15	736.64	54.82	0.00	0.00	704.07
32	φ(t) p(sex*rep) f(seas)	14	737.27	55.45	0.00	0.00	707.04
33	φ(t) p(sex*rep) f(sex*seas)	16	738.86	57.04	0.00	0.00	703.93
34	φ(sex) p(sex*rep) f(sex+seas)	9	750.30	68.48	0.00	0.00	731.37
35	φ(sex) p(sex*rep) f(sex*seas)	10	752.50	70.68	0.00	0.00	731.36
36	φ(.) p(sex*rep) f(sex*seas)	9	766.69	84.87	0.00	0.00	747.76
	POPAN models						
1	φ(.) p(sex*rep) pent(sex*rep) N(.)	10	376.31	0.00	0.23	1.00	355.16
2	φ(.) p(sex*rep) pent(sex+rep) N(.)	9	376.67	0.36	0.19	0.83	357.74
3	φ(sex) p(sex*rep) pent(sex+rep) N(.)	10	377.18	0.87	0.15	0.65	356.03
4	φ(t) p(sex*rep) pent(sex*rep) N(.)	17	377.25	0.94	0.14	0.62	339.94

5	φ(.) p(sex*rep) pent(sex*rep) N(sex)	11	377.94	1.63	0.10	0.44	354.56
6	φ(.) p(sex*rep) pent(sex+rep) N(sex)	10	378.69	2.39	0.07	0.30	357.55
7	φ(sex) p(sex*rep) pent(sex+rep) N(sex)	11	379.07	2.76	0.06	0.25	355.68
8	φ(t) p(sex*rep) pent(sex*rep) N(sex)	18	379.14	2.83	0.06	0.24	339.42
	Cohort 2016						
	CJS models						
1	φ(sex+t) p(.)	6	179.90	0.00	0.20	1.00	167.25
2	φ(sex+t) p(sex)	7	180.24	0.34	0.17	0.85	165.36
3	φ(sex+t) p(sex+rep)	8	180.99	1.09	0.12	0.58	163.86
4	φ(sex+t) p(rep)	7	181.21	1.31	0.11	0.52	166.34
5	φ(sex+t) p(seas)	7	182.09	2.19	0.07	0.34	167.21
6	φ(sex+t) p(sex+seas)	8	182.30	2.40	0.06	0.30	165.16
7	φ(t) p(.)	5	182.78	2.88	0.05	0.24	172.32
8	φ(sex+t) p(sex*rep)	9	183.29	3.39	0.04	0.18	163.86
9	φ(sex*t) p(.)	9	184.10	4.20	0.02	0.12	164.67
10	φ(t) p(rep)	6	184.25	4.35	0.02	0.11	171.60
11	φ(sex+t) p(sex*seas)	9	184.59	4.69	0.02	0.10	165.16
12	φ(t) p(seas)	6	184.86	4.96	0.02	0.08	172.21
13	φ(t) p(sex)	6	184.96	5.06	0.02	0.08	172.30
14	φ(sex*t) p(sex)	10	185.13	5.23	0.01	0.07	163.37
15	φ(sex*t) p(rep)	10	185.58	5.68	0.01	0.06	163.82
16	φ(t) p(sex*rep)	8	185.76	5.86	0.01	0.05	168.62
17	φ(sex*t) p(sex+rep)	11	186.36	6.46	0.01	0.04	162.23
18	φ(sex*t) p(seas)	10	186.38	6.47	0.01	0.04	164.62
19	φ(t) p(sex+seas)	7	186.47	6.57	0.01	0.04	171.60
20	φ(t) p(sex*seas)	8	186.76	6.86	0.01	0.03	169.63
21	φ(t) p(sex+rep)	7	186.95	7.05	0.01	0.03	172.08
22	φ(sex*t) p(sex+seas)	11	187.50	7.60	0.00	0.02	163.37
23	φ(sex*t) p(sex*rep)	12	188.76	8.86	0.00	0.01	162.23
24	φ(sex*t) p(sex*seas)	12	189.91	10.01	0.00	0.01	163.37
25	φ(sex+rep) p(.)	4	191.53	11.63	0.00	0.00	183.22
26	φ(sex+rep) p(seas)	5	191.55	11.64	0.00	0.00	181.08
27	φ(sex+rep) p(sex)	5	192.08	12.18	0.00	0.00	181.61
28	φ(rep) p(seas)	4	192.86	12.96	0.00	0.00	184.55
29	φ(sex*rep) p(.)	5	193.08	13.18	0.00	0.00	182.62
30	φ(rep) p(.)	3	193.14	13.24	0.00	0.00	186.96
31	φ(sex*rep) p(seas)	6	193.23	13.33	0.00	0.00	180.58
32	φ(rep) p(sex*seas)	6	193.41	13.51	0.00	0.00	180.76
33	φ(rep) p(sex+seas)	5	193.60	13.70	0.00	0.00	183.14
34	φ(sex+rep) p(rep)	5	193.69	13.78	0.00	0.00	183.22
35	φ(sex+rep) p(sex+seas)	6	193.74	13.83	0.00	0.00	181.08
36	φ(sex*rep) p(sex)	6	193.85	13.95	0.00	0.00	181.20

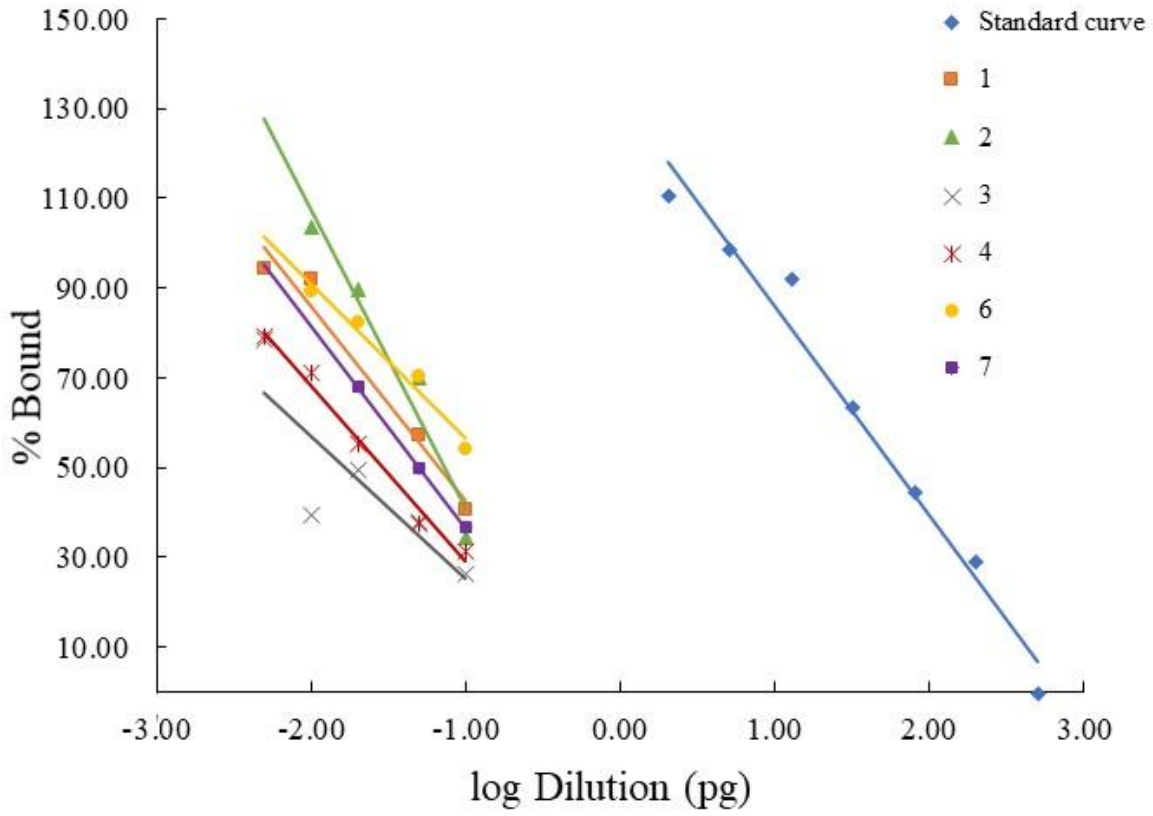
37	φ(sex+rep) p(sex*seas)	7	194.00	14.10	0.00	0.00	179.12
38	φ(sex+rep) p(sex+rep)	6	194.17	14.27	0.00	0.00	181.52
39	φ(sex*rep) p(sex*seas)	8	194.95	15.05	0.00	0.00	177.81
40	φ(rep) p(sex)	4	195.23	15.33	0.00	0.00	186.92
41	φ(rep) p(rep)	4	195.26	15.36	0.00	0.00	186.96
42	φ(sex*rep) p(rep)	6	195.27	15.37	0.00	0.00	182.62
43	φ(sex*rep) p(sex+seas)	7	195.31	15.41	0.00	0.00	180.43
44	φ(sex*rep) p(sex+rep)	7	196.03	16.13	0.00	0.00	181.15
45	φ(sex+rep) p(sex*rep)	7	196.40	16.49	0.00	0.00	181.52
46	φ(rep) p(sex*rep)	6	196.74	16.84	0.00	0.00	184.09
47	φ(rep) p(sex+rep)	5	197.27	17.36	0.00	0.00	186.80
48	φ(sex) p(rep)	4	198.00	18.10	0.00	0.00	189.69
49	φ(.) p(sex*rep)	5	198.22	18.32	0.00	0.00	187.76
50	φ(.) p(sex+rep)	4	198.24	18.34	0.00	0.00	189.94
51	φ(sex*rep) p(sex*rep)	8	198.29	18.38	0.00	0.00	181.15
52	φ(.) p(rep)	3	198.45	18.55	0.00	0.00	192.27
53	φ(sex) p(sex+rep)	5	199.97	20.07	0.00	0.00	189.51
54	φ(sex) p(sex*rep)	6	200.31	20.41	0.00	0.00	187.66
55	φ(sex) p(.)	3	201.64	21.74	0.00	0.00	195.46
56	φ(sex) p(sex)	4	202.26	22.36	0.00	0.00	193.96
57	φ(.) p(.)	2	202.34	22.44	0.00	0.00	198.25
58	φ(sex) p(seas)	4	203.61	23.71	0.00	0.00	195.31
59	φ(.) p(sex)	3	204.15	24.25	0.00	0.00	197.97
60	φ(.) p(seas)	3	204.25	24.34	0.00	0.00	198.06
61	φ(sex) p(sex+seas)	5	204.41	24.51	0.00	0.00	193.95
62	φ(.) p(sex+seas)	4	206.26	26.36	0.00	0.00	197.96
63	φ(sex) p(sex*seas)	6	206.54	26.64	0.00	0.00	193.89
64	φ(.) p(sex*seas)	5	207.35	27.45	0.00	0.00	196.89
	Pradel models						
1	φ(sex+t) p(.) f(sex+rep)	9	469.61	0.00	0.09	1.00	450.28
2	φ(sex+t) p(rep) f(sex+rep)	10	470.03	0.42	0.08	0.81	448.39
3	φ(sex+t) p(sex) f(sex+rep)	10	470.31	0.70	0.07	0.70	448.67
4	φ(sex+t) p(.) f(rep)	8	470.34	0.73	0.06	0.69	453.28
5	φ(sex+t) p(.) f(sex*rep)	10	470.51	0.90	0.06	0.64	448.87
6	φ(sex+t) p(rep) f(rep)	9	470.85	1.24	0.05	0.54	451.52
7	φ(sex+t) p(rep) f(sex*rep)	11	470.91	1.30	0.05	0.52	446.93
8	φ(sex+t) p(sex+rep) f(sex+rep)	11	470.98	1.37	0.05	0.50	447.00
9	φ(sex+t) p(sex) f(sex*rep)	11	471.00	1.39	0.05	0.50	447.01
10	φ(sex+t) p(.) f(sex+t)	11	471.10	1.49	0.04	0.47	447.11
11	φ(sex+t) p(sex+rep) f(sex*rep)	12	471.43	1.82	0.04	0.40	445.07
12	φ(sex+t) p(rep) f(sex+seas)	10	471.72	2.11	0.03	0.35	450.08
13	φ(sex+t) p(.) f(sex+seas)	9	471.78	2.17	0.03	0.34	452.45
14	φ(sex+t) p(sex) f(sex+t)	12	471.90	2.29	0.03	0.32	445.53

15	φ(sex+t) p(.) f(t)	10	471.98	2.37	0.03	0.31	450.34
16	φ(sex+t) p(sex) f(sex+seas)	10	472.18	2.57	0.03	0.28	450.54
17	φ(sex+t) p(sex+rep) f(sex+seas)	11	472.46	2.85	0.02	0.24	448.47
18	φ(sex+t) p(sex) f(rep)	9	472.49	2.88	0.02	0.24	453.16
19	φ(sex+t) p(rep) f(sex+t)	12	472.58	2.97	0.02	0.23	446.22
20	φ(sex+t) p(sex+rep) f(sex+t)	13	473.00	3.39	0.02	0.18	444.22
21	φ(sex+t) p(.) f(seas)	8	473.08	3.47	0.02	0.18	456.02
22	φ(sex+t) p(rep) f(seas)	9	473.14	3.53	0.02	0.17	453.81
23	φ(sex+t) p(sex+rep) f(sex*t)	14	473.25	3.64	0.02	0.16	442.02
24	φ(sex+t) p(rep) f(t)	11	473.56	3.95	0.01	0.14	449.58
25	φ(sex+t) p(sex+rep) f(rep)	10	473.74	4.13	0.01	0.13	452.10
26	φ(sex+t) p(rep) f(sex*seas)	11	474.06	4.45	0.01	0.11	450.08
27	φ(sex+t) p(.) f(sex*seas)	10	474.08	4.47	0.01	0.11	452.44
28	φ(sex+t) p(sex) f(t)	11	474.27	4.66	0.01	0.10	450.28
29	φ(sex+t) p(sex) f(sex*seas)	11	474.51	4.90	0.01	0.09	450.52
30	φ(sex+t) p(sex+rep) f(sex*seas)	12	474.81	5.20	0.01	0.07	448.45
31	φ(sex+t) p(sex) f(seas)	9	475.31	5.70	0.01	0.06	455.97
32	φ(sex+t) p(sex+rep) f(seas)	10	475.42	5.81	0.01	0.05	453.78
33	φ(sex+t) p(sex+rep) f(t)	12	475.90	6.29	0.00	0.04	449.54
34	φ(sex+t) p(.) f(sex*t)	14	476.64	7.03	0.00	0.03	445.41
35	φ(sex+t) p(sex) f(sex*t)	15	477.25	7.64	0.00	0.02	443.53
36	φ(sex+t) p(rep) f(sex*t)	15	478.22	8.61	0.00	0.01	444.50
	POPAN models						
1	φ(sex+t) p(.) pent(rep) N(.)	9	222.93	0.00	0.19	1.00	203.60
2	φ(sex+t) p(rep) pent(rep) N(.)	10	223.81	0.88	0.12	0.65	202.16
3	φ(sex+t) p(sex) pent(sex+rep) N(.)	11	224.52	1.59	0.09	0.45	200.54
4	φ(sex+t) p(.) pent(sex+rep) N(.)	10	224.87	1.94	0.07	0.38	203.23
5	φ(sex+t) p(.) pent(rep) N(sex)	10	225.16	2.23	0.06	0.33	203.52
6	φ(sex+t) p(sex) pent(sex+rep) N(sex)	12	225.25	2.32	0.06	0.31	198.89
7	φ(sex+t) p(sex+rep) pent(sex+rep) N(.)	12	225.55	2.62	0.05	0.27	199.19
8	φ(sex+t) p(rep) pent(sex+rep) N(.)	11	225.77	2.84	0.05	0.24	201.78
9	φ(sex+t) p(rep) pent(rep) N(sex)	11	226.03	3.10	0.04	0.21	202.05
10	φ(sex+t) p(sex+rep) pent(sex+rep) N(sex)	13	226.04	3.11	0.04	0.21	197.26
11	φ(sex+t) p(sex) pent(sex*rep) N(.)	12	226.27	3.34	0.04	0.19	199.90
12	φ(sex+t) p(.) pent(sex*rep) N(.)	11	226.60	3.67	0.03	0.16	202.61
13	φ(sex+t) p(sex) pent(sex*rep) N(sex)	13	227.05	4.12	0.02	0.13	198.27
14	φ(sex+t) p(.) pent(sex+rep) N(sex)	11	227.11	4.18	0.02	0.12	203.13
15	φ(sex+t) p(sex+rep) pent(sex*rep) N(.)	13	227.36	4.43	0.02	0.11	198.59
16	φ(sex+t) p(.) pent(sex+t) N(.)	12	227.46	4.53	0.02	0.10	201.10
17	φ(sex+t) p(rep) pent(sex*rep) N(.)	12	227.50	4.57	0.02	0.10	201.13
18	φ(sex+t) p(sex+rep) pent(sex*rep) N(sex)	14	227.57	4.64	0.02	0.10	196.34

19	φ(sex+t) p(rep) pent(sex+rep) N(sex)	12	228.00	5.07	0.02	0.08	201.64
20	φ(sex+t) p(.) pent(sex*rep) N(sex)	12	228.86	5.93	0.01	0.05	202.50
21	φ(sex+t) p(.) pent(sex+t) N(sex)	13	229.76	6.83	0.01	0.03	200.98
22	φ(sex+t) p(rep) pent(sex*rep) N(sex)	13	229.82	6.89	0.01	0.03	201.04
23	φ(sex+t) p(.) pent(rep) N(.)	9	222.93	0.00	0.19	1.00	203.60

SUPPLEMENTARY MATERIAL - CHAPTER 2

Appendix 1. Serial dilutions faecal extracts of *Gracilinanus agilis* showing parallelism with the standard curve (F = 1.85, P = 0.16).



Appendix 2. Steps of the following assays:

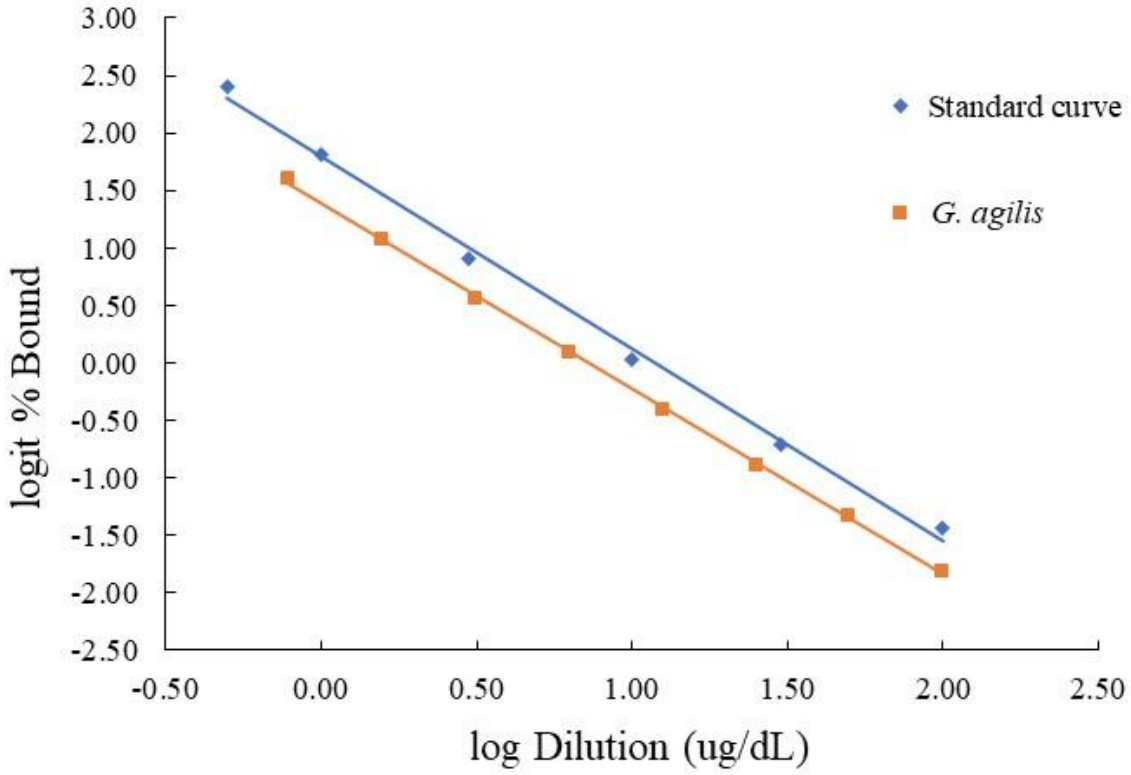
a) Enzimeimmunoassay (EIA)
   - the 96-well microplates previously coated with buffer containing Protein A;
   - wash coated plates (Bio-Tek ELx405RS Auto Plate Washer);
   - pipette 150 µL assay buffer to the non-specific binding (NSB) wells and 50 µL assay buffer to the zero binding (B0) wells;
   - add 50 µL of each standard, control and sample to each well (in duplicates);
   - add 100 µL of biotinylated steroid into each well;
   - add 100 µL antibody steroid into each well, except for the NSB wells;
   - incubate on a plate-shaker overnight at 4 °C;
   - wash plates;
   - add 250 µL streptavidin-peroxidase (POD solution) to each well (µFill, Bio-Tek);
   - incubate on a plate-shaker for 45 min at 4 °C;
   - wash plates;
   - add 250 µL tetramethylbenzedine (TMB) solution to each well with µFill;
   - incubate on a plate-shaker for 45 min at 4 °C;
   - add 50 µL of acid stop solution (2 mol/L H_2SO_4);
   - read the plates absorbance with an automated plate reader (VersaMax Microplate Reader, Molecular Devices, Sunnyvale, CA, USA). Optical density was measured at 450 nm with a 620 nm reference filter.

b) Radioimmunoassay (RIA)
   - pipette 25 µL of each standard, control and sample (in duplicates whenever possible) into its respective anti-cortisol coated tube;
   - add 40 µL double-distilled water and 20 µL ammonium hydroxide (NH_4OH) to each tube (to saponify triglycerides and stabilize measurements)
   - add 1.0 mL of ^{125}I-cortisol to all tubes;
   - vortex the tubes briefly;
   - incubating for 45 min at 37 °C;
   - decant the contents of the tubes;
   - count the tubes in the gamma counter.

c) Maximum corticosteroid-binding capacity (MCBC)

- strip (and dilute) plasma samples with DCC concentrate to remove endogenous steroids;
- use five test tubes for each sample: three TB tubes and two NSB tubes;
- add 50 µL plasma samples to all tubes;
- 50 µL phosphate buffer (PBS; pH 7) to the TB tubes;
- 50 µL unlabelled cortisol ('cold cort') to the NSB tubes;
- 50 µL a known specific activity of 3H-cortisol ('hot cort') to the TB tubes;
- 50 µL 3H-cortisol to two scintillation vials for a callibration of the amount of 'hot cort' used in the assay (total counts); add scintillation cocktail fluid (Biosafe II; Research Products International) to the vials, vortex and leave them in the dark;
- centrifuge samples briefly and incubate overnight at 4 °C;
- place the tube racks and the DCC in an ice slurry (~ 0 °C);
- set the timer for 16 min, and add quickly 300 µL DCC to all tubes (ideally within 1 minute);
- transfer the tubes to a refrigerated centrifuge (Beckman Coulter, Allegra 6R) wait the countdown to finish DCC exposure;
- centrifuge at 2500 g for 12 min;
- decant the supernatant into the scintillation vials;
- add scintillation cocktail fluid (Biosafe II; Research Products International) to the vials, vortex thoroughly and leave them in the dark for 4 h prior to reading in the scintillation counter (Tri-Carb 2900TR; Packard, Boston, MA, USA).

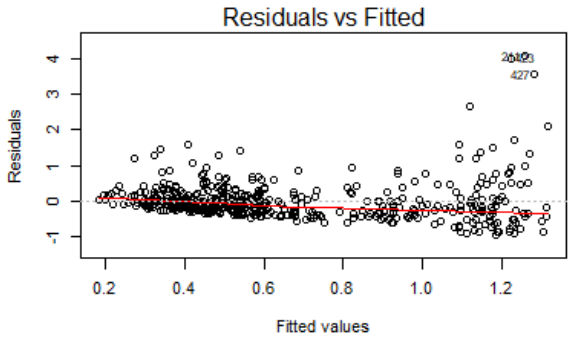
Appendix 3. Serial dilutions pooled plasma of *Gracilinanus agilis* showing parallelism with the standard curve for plasma total cortisol (F = 1.494, P = 0.25).

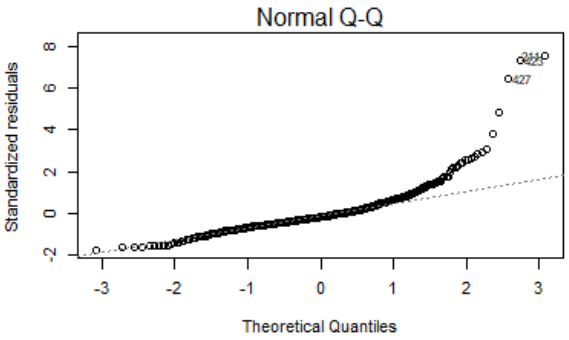


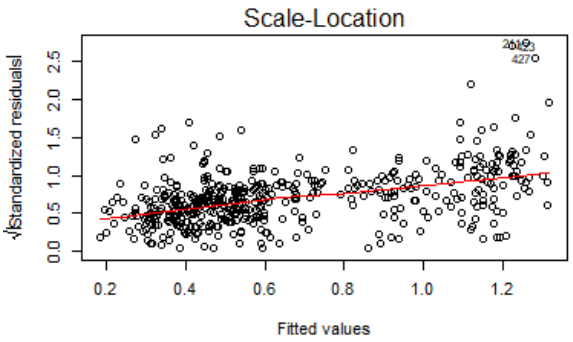
Appendix 4. Diagnostic plots of the global models for the physiological variables of the marsupial *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The studied physiological variables were a) neutrophil/lymphocyte ratio (N/L); b) body condition (SMI); c) haemoglobin concentration (Hb); d) glucose (Gl); e) faecal cortisol metabolites (FCM); f) total cortisol (CORT); g) maximum binding capacity (MCBC); and h) free cortisol (FREE). The investigated models were: i) linear; ii) linear with the response variable transformed to natural logarithm; iii) generalized linear using gamma family and log link function; iv) and generalized linear using gamma family and inverse link function. The effects in each model were: month adapted to the life cycle of the individuals (M), sex, reproductive status (Rep), grid, origin of blood sample (Blood), time inside trap (Time), time of blood collection (T.Blood), colour of plasma sample (Colour), and the interactions between sex and reproductive status (Sex*Rep) and between sex and grid (Sex*Grid). Graphics for each model in clockwise direction: residuals vs fitted plot, normal QQ plot, residuals vs leverage plot, cook's distances plot and scale-location or spread-location plot. Labeled points represent possible outliers, high-leverage and/or influential points, and were investigated. Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points.

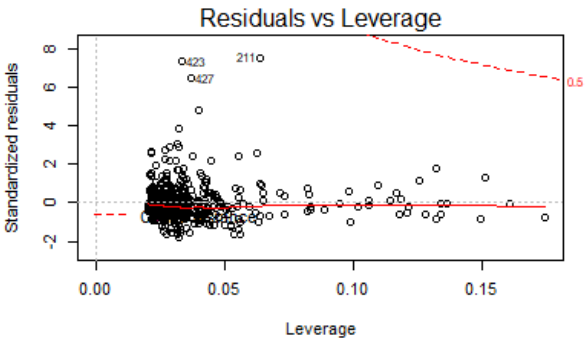
a) Neutrophil/lymphocyte ratio (N/L)

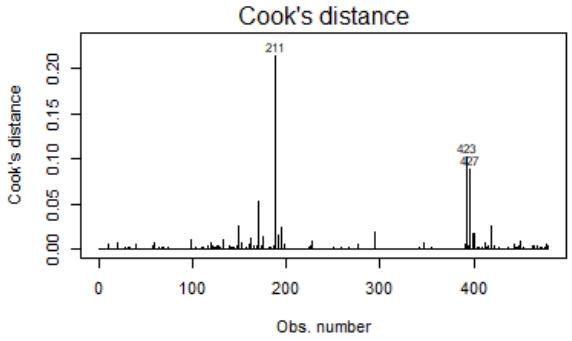
i) N/L ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



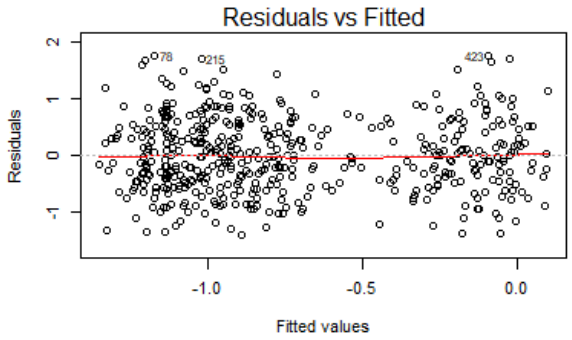


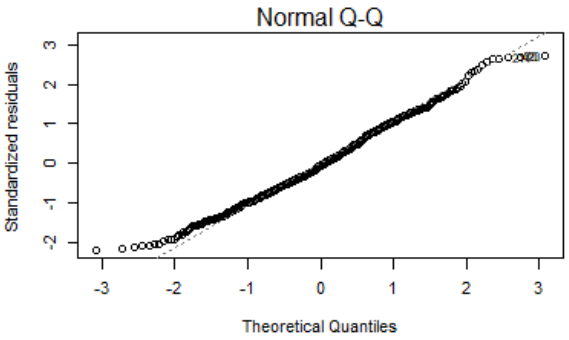


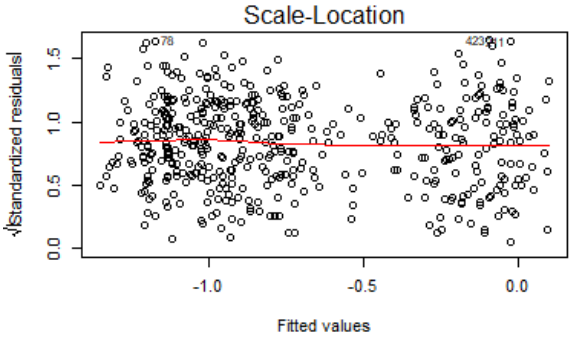


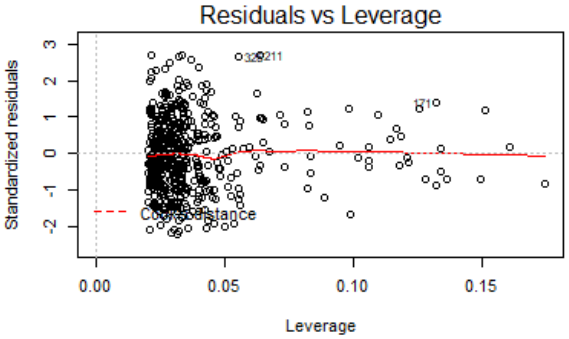


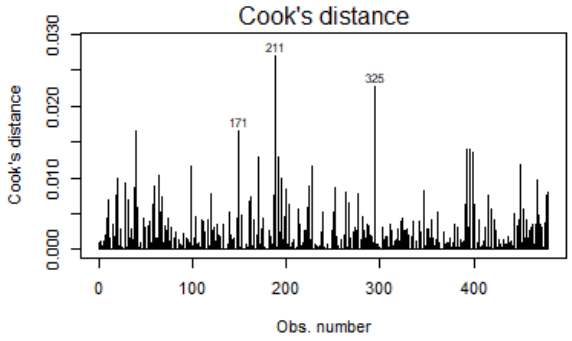
ii) ln (N/L) ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



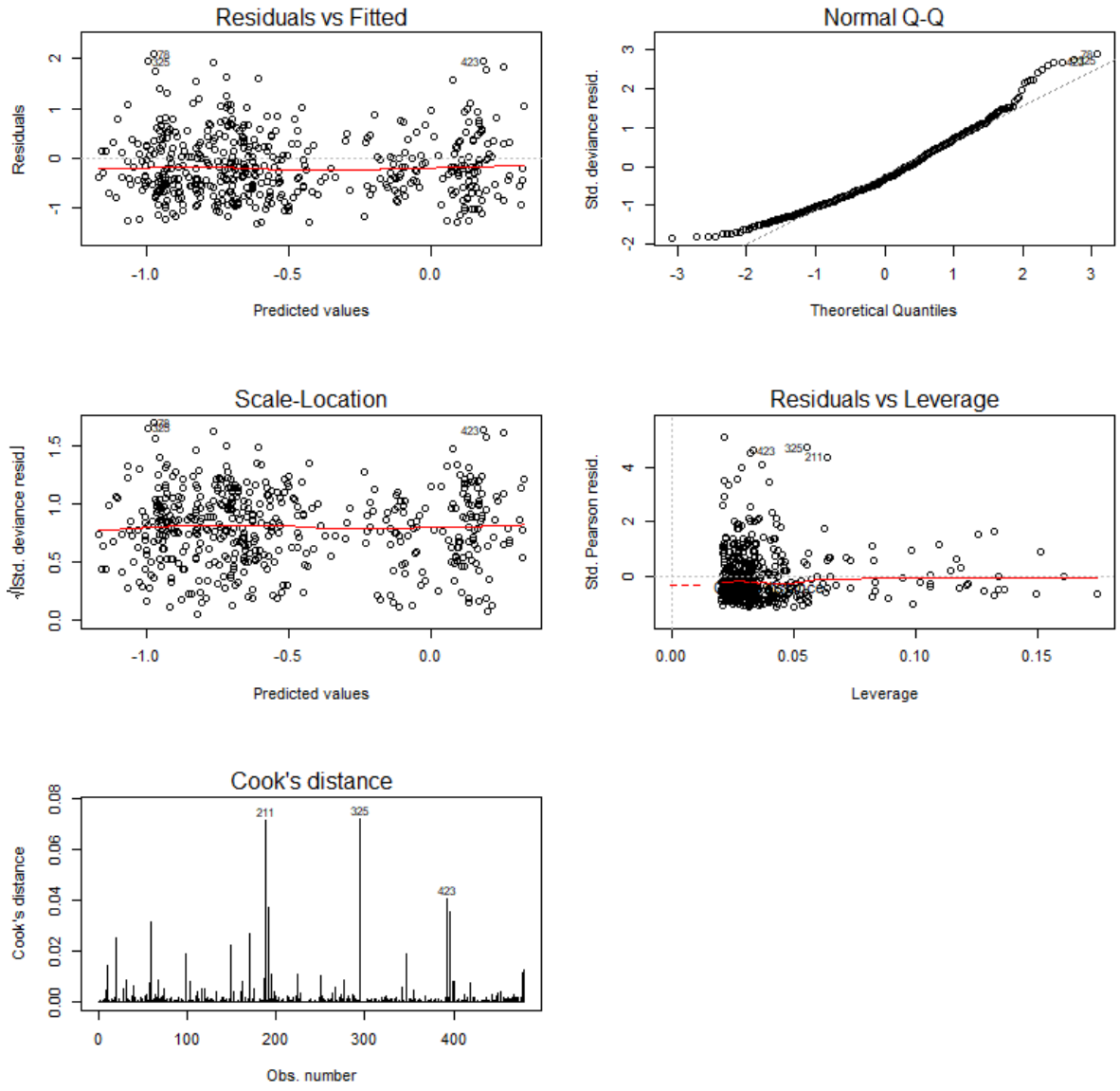




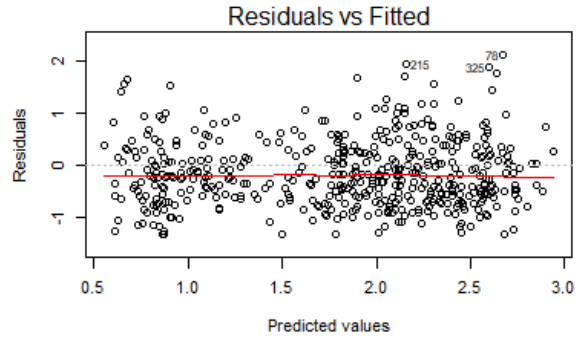


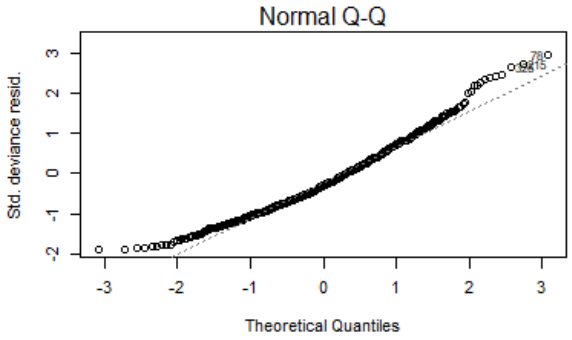


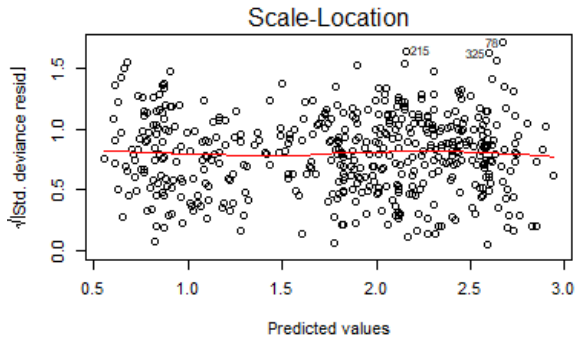
iii) N/L ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (log link)

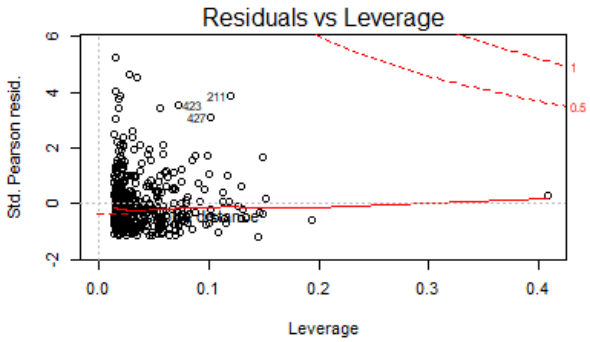


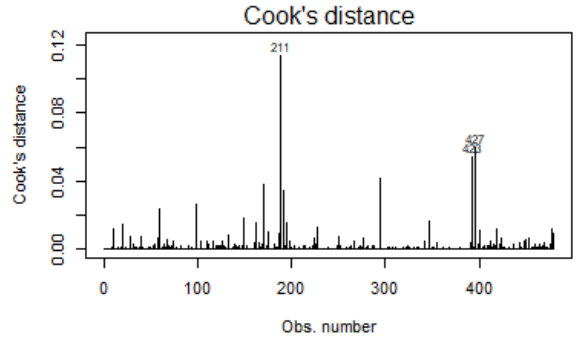
iv) N/L ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (inverse link)





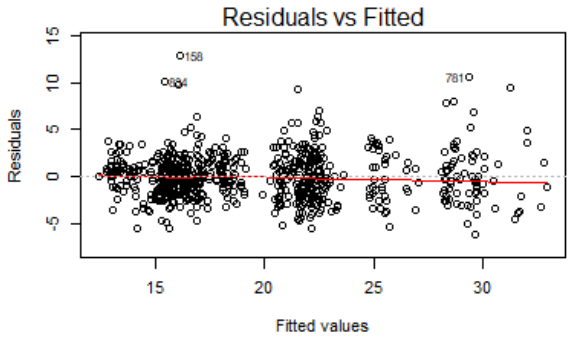


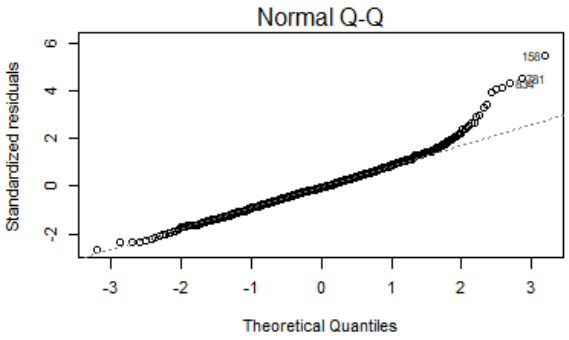


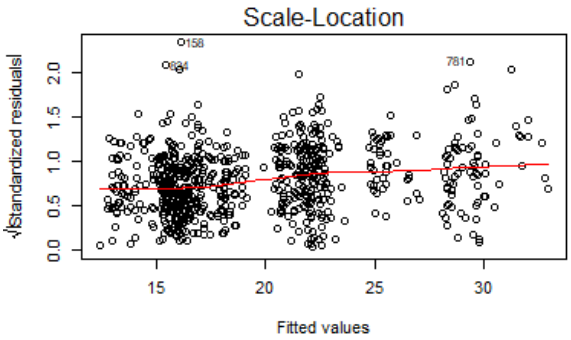


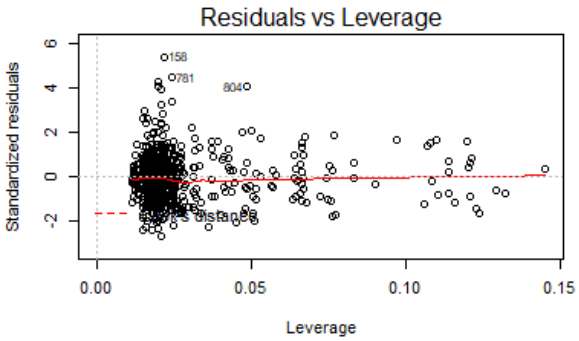
b) Body condition (SMI)

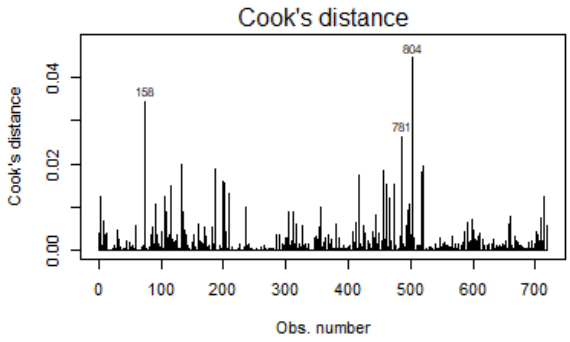
i) SMI ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



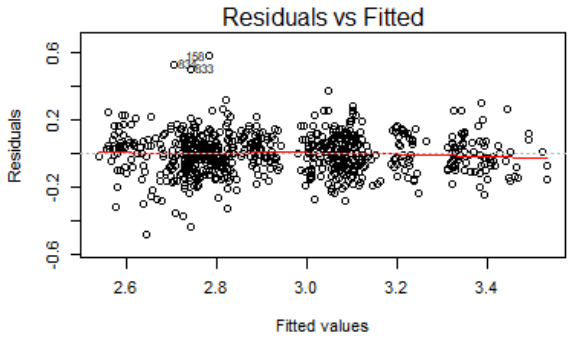


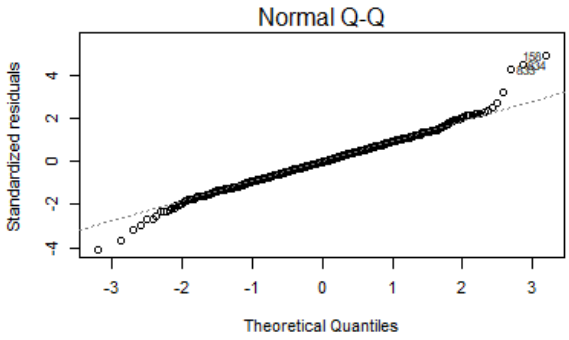


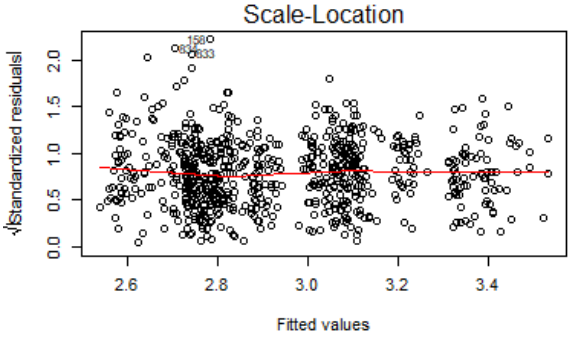


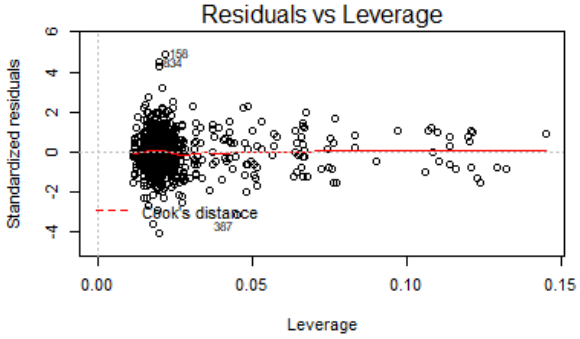


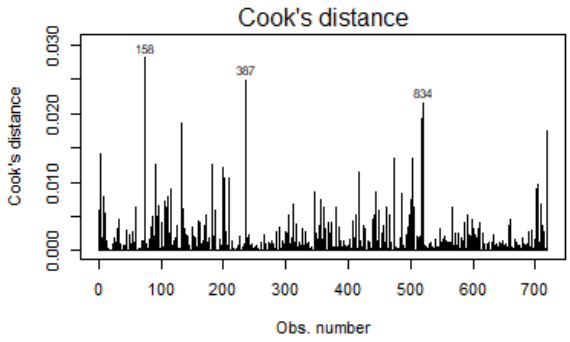
ii) ln (SMI) ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



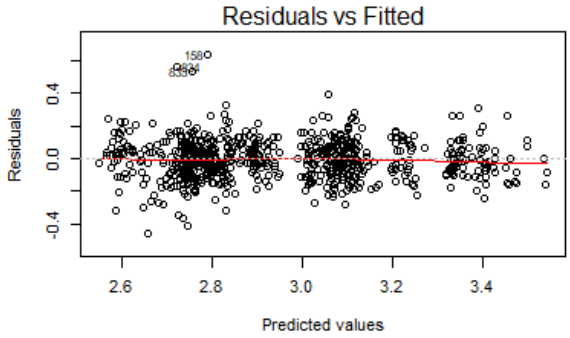


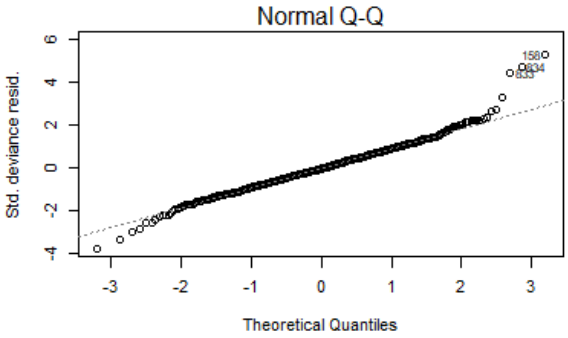


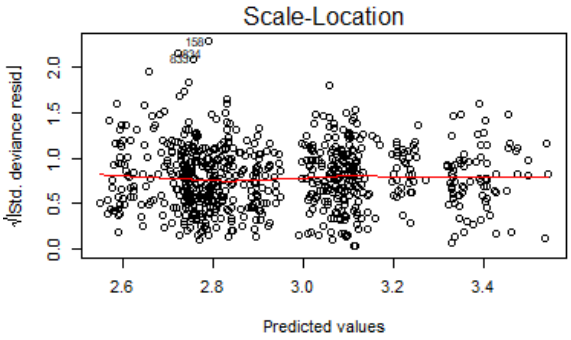


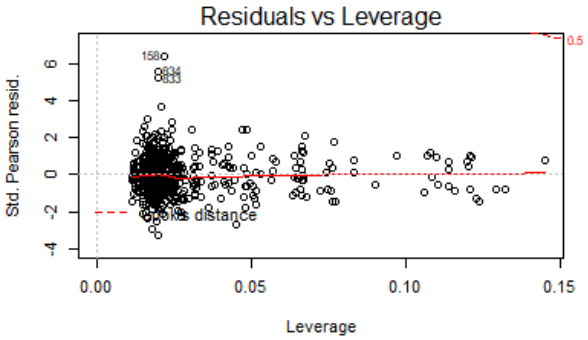


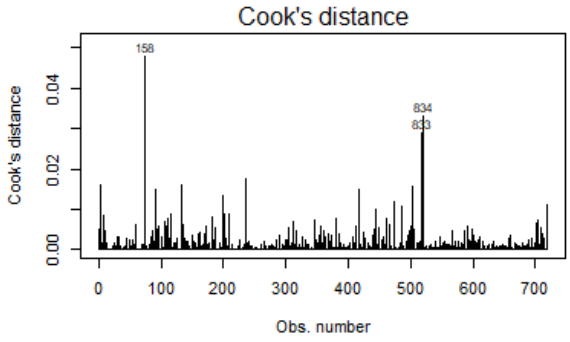
iii) SMI ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (log link)



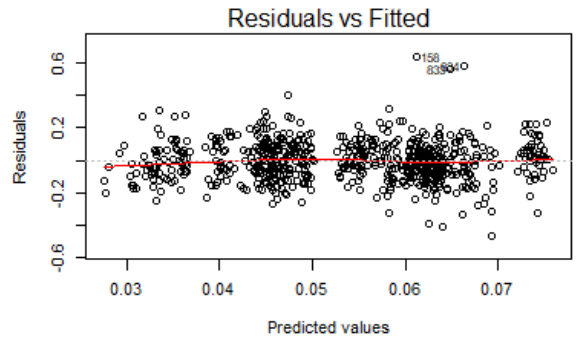


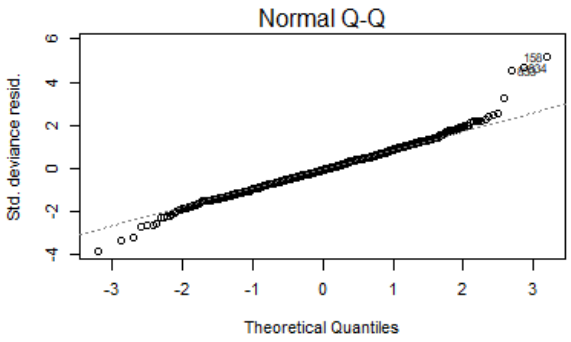


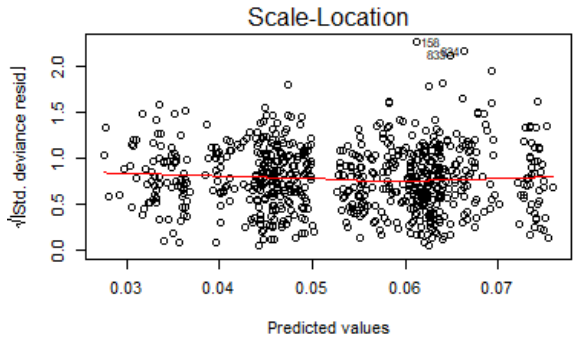


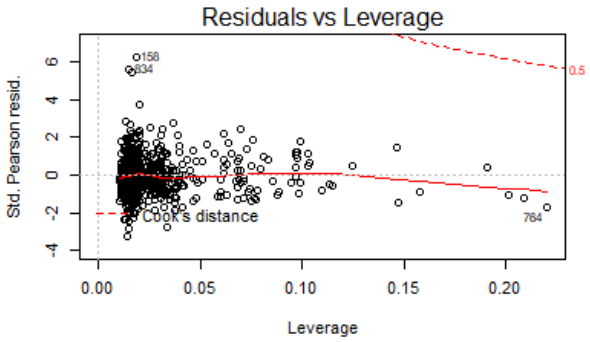


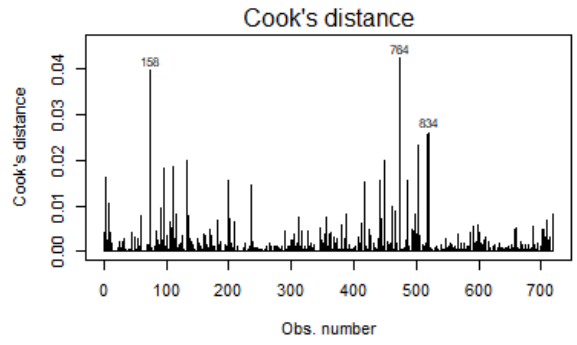
iv) SMI ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (inverse link)





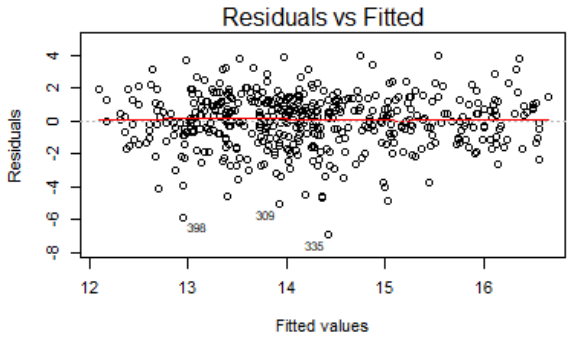


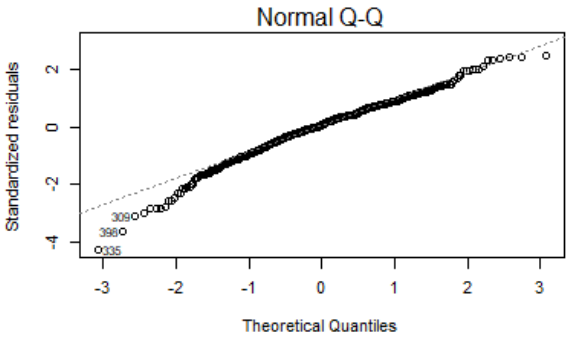


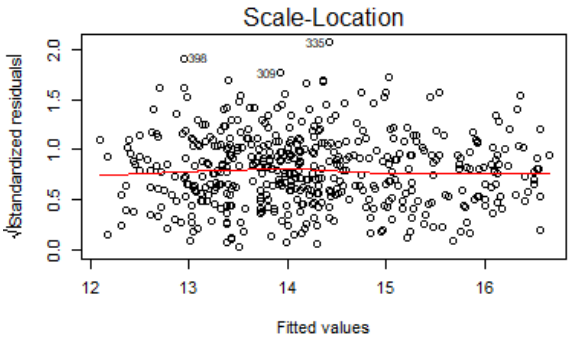


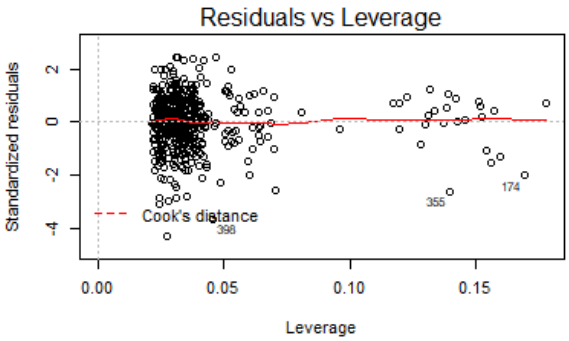
c) Haemoglobin concentration (Hb)

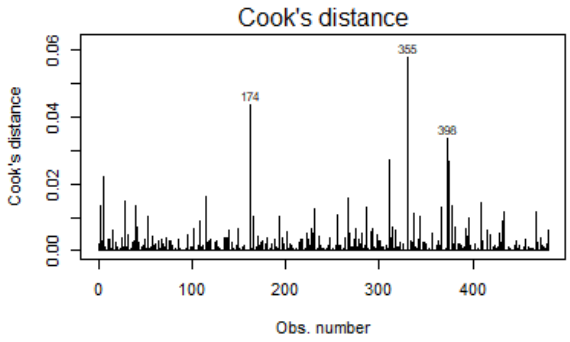
i) Hb ~ M + Sex + Rep + Grid + Blood + Time + Sex*Rep + Sex*Grid



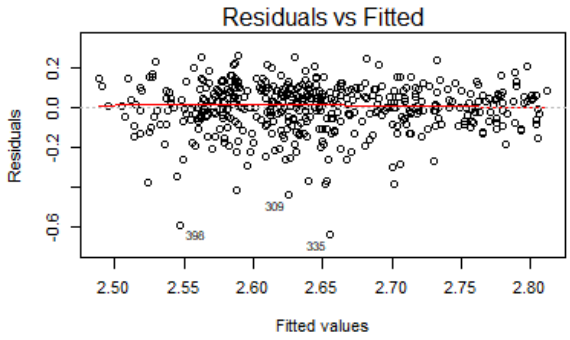


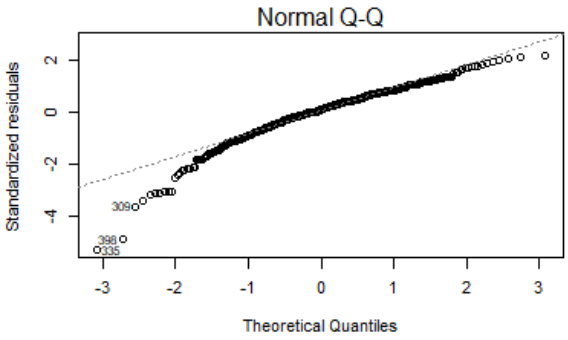


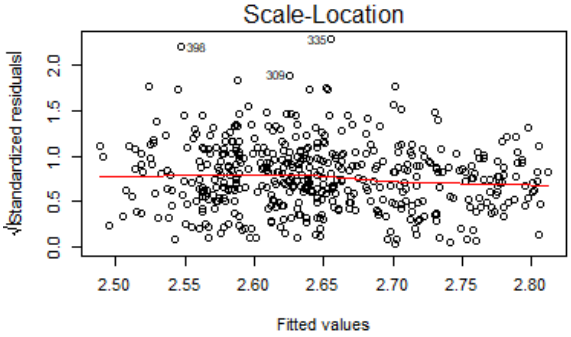


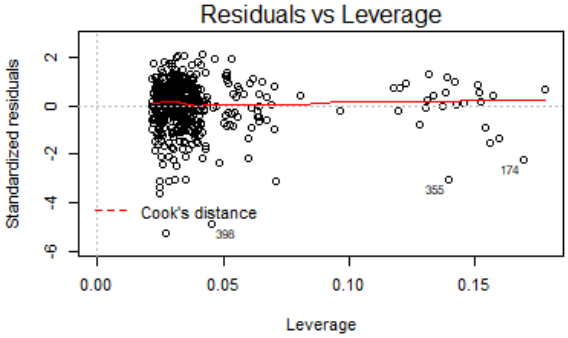


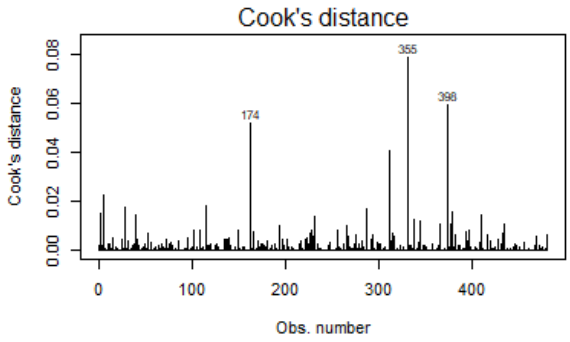
ii) ln (Hb) ~ M + Sex + Rep + Grid + Blood + Time + Sex*Rep + Sex*Grid



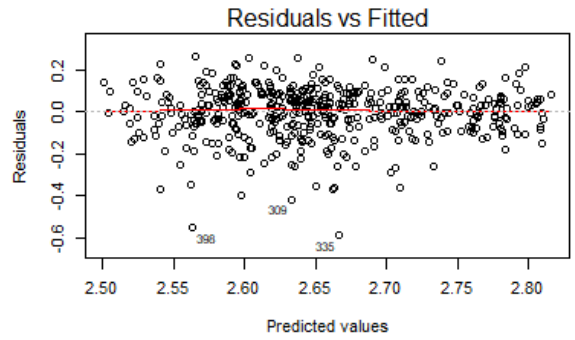


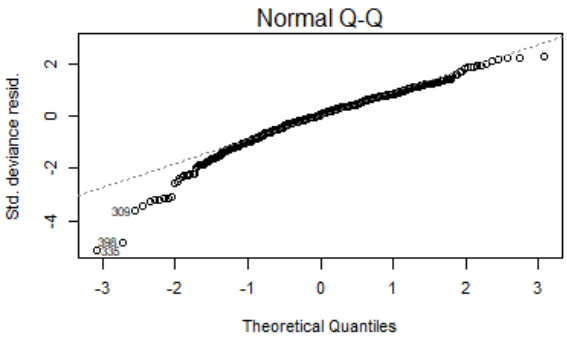


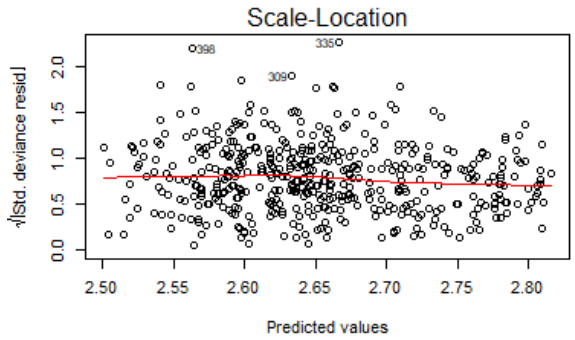


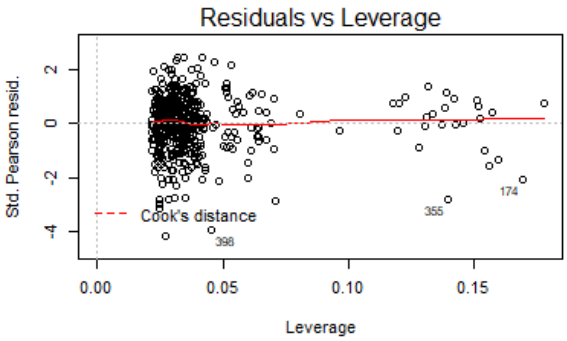


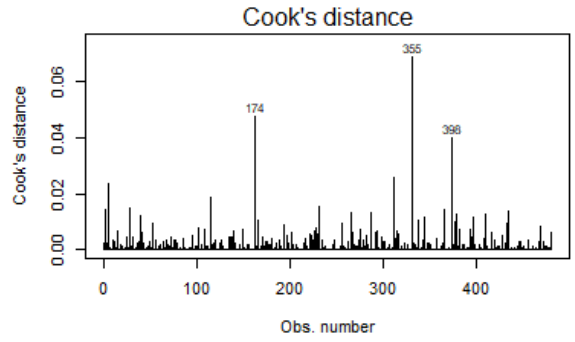
iii) Hb ~ M + Sex + Rep + Grid + Blood + Time + Sex*Rep + Sex*Grid, Gamma family (log link)



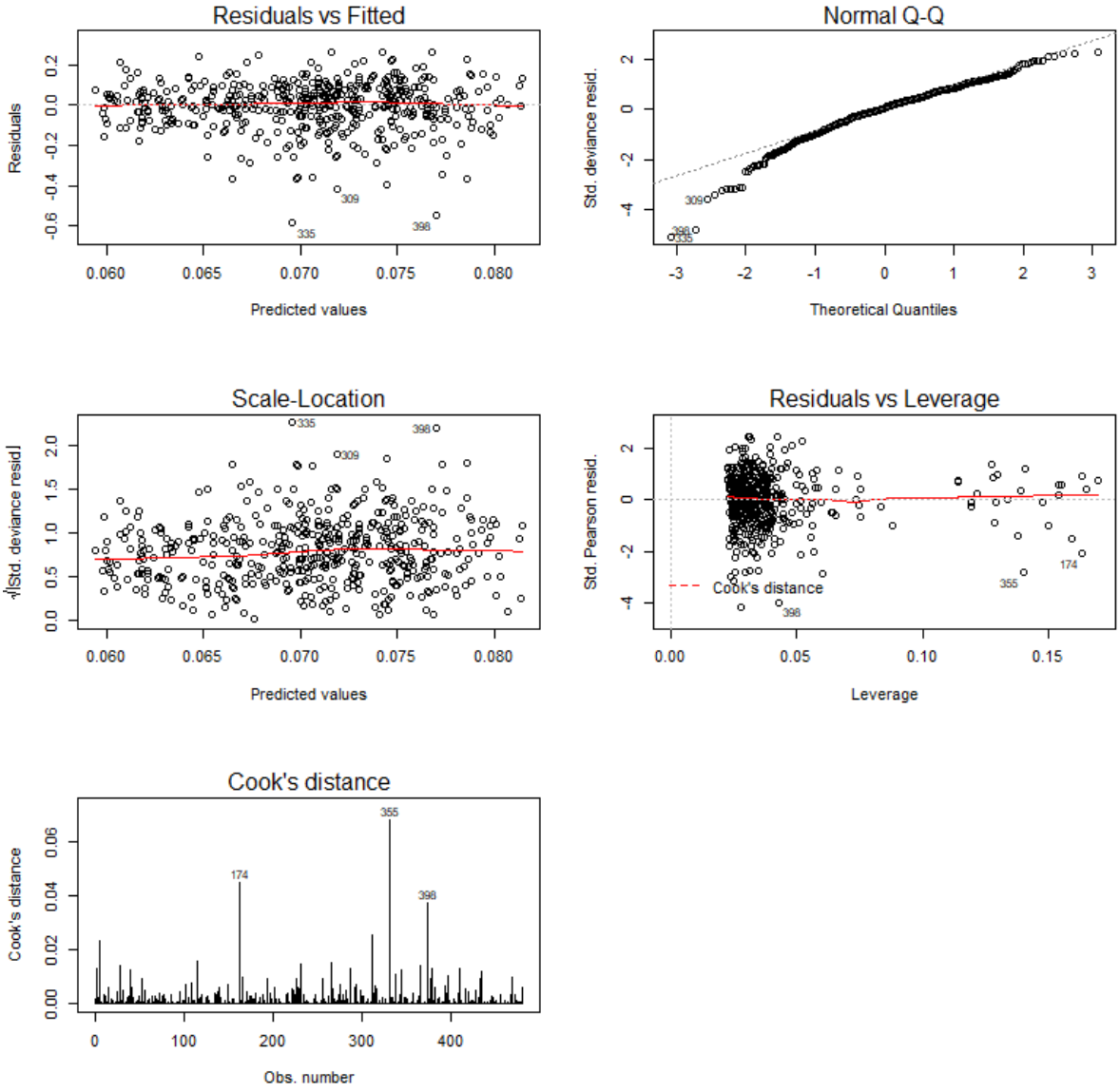






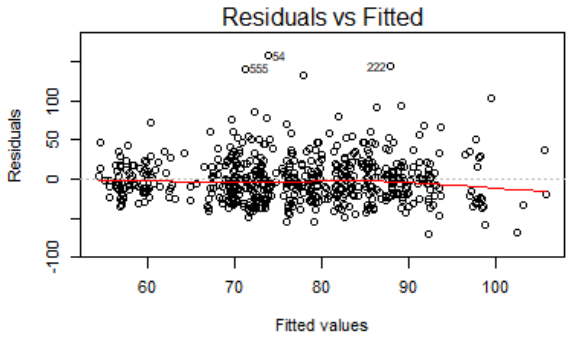


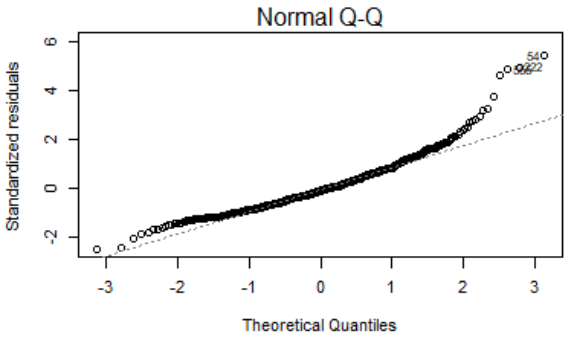
iv) Hb ~ M + Sex + Rep + Grid + Blood + Time + Sex*Rep + Sex*Grid, Gamma family (inverse link)

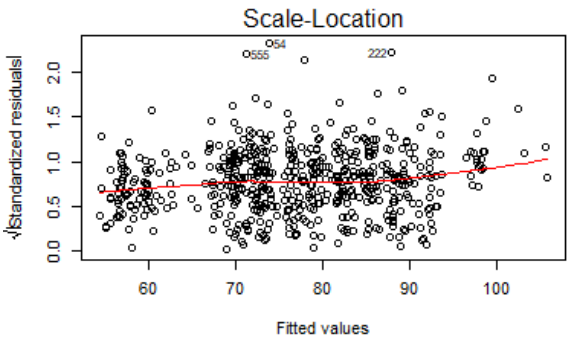


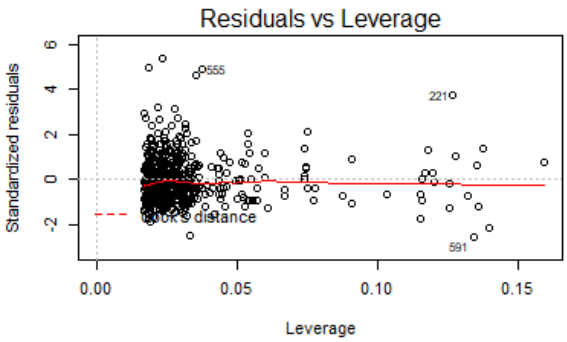
d) Glucose (Gl)

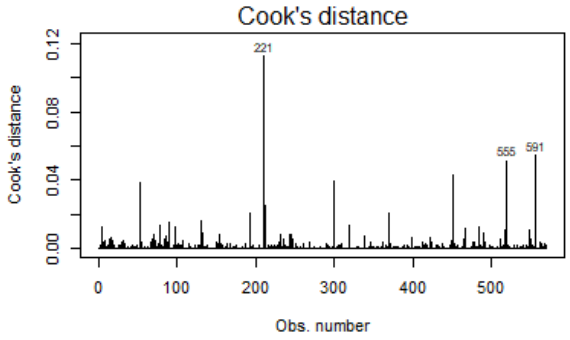
i) Gl ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



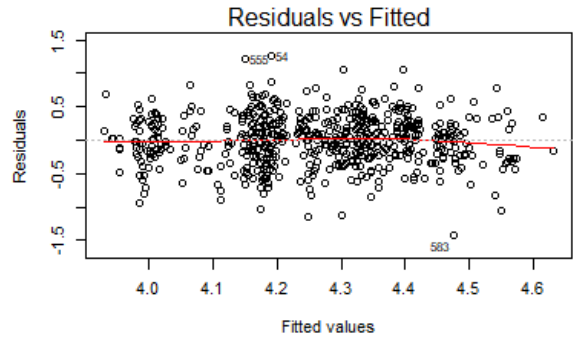


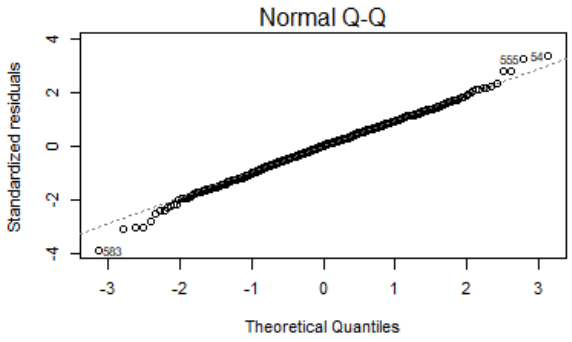


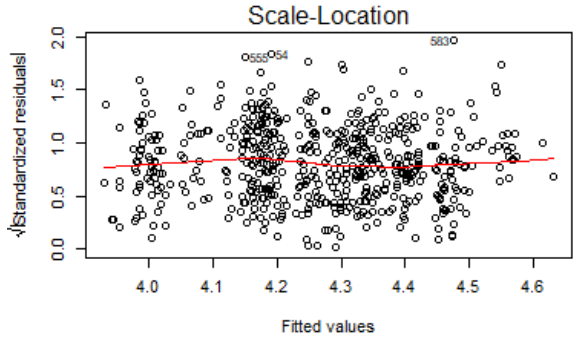


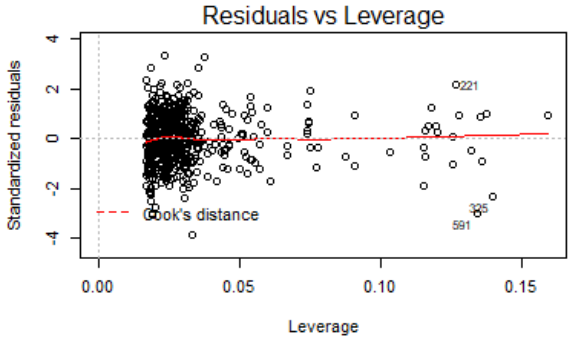


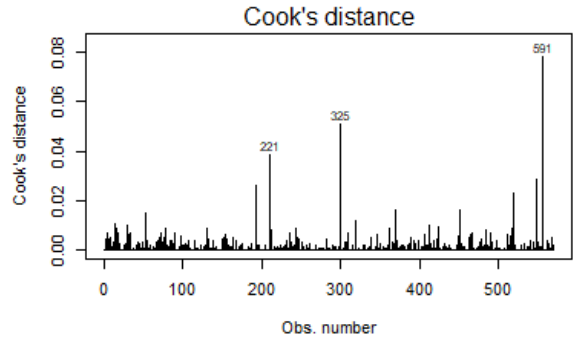
ii) ln (Gl) ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



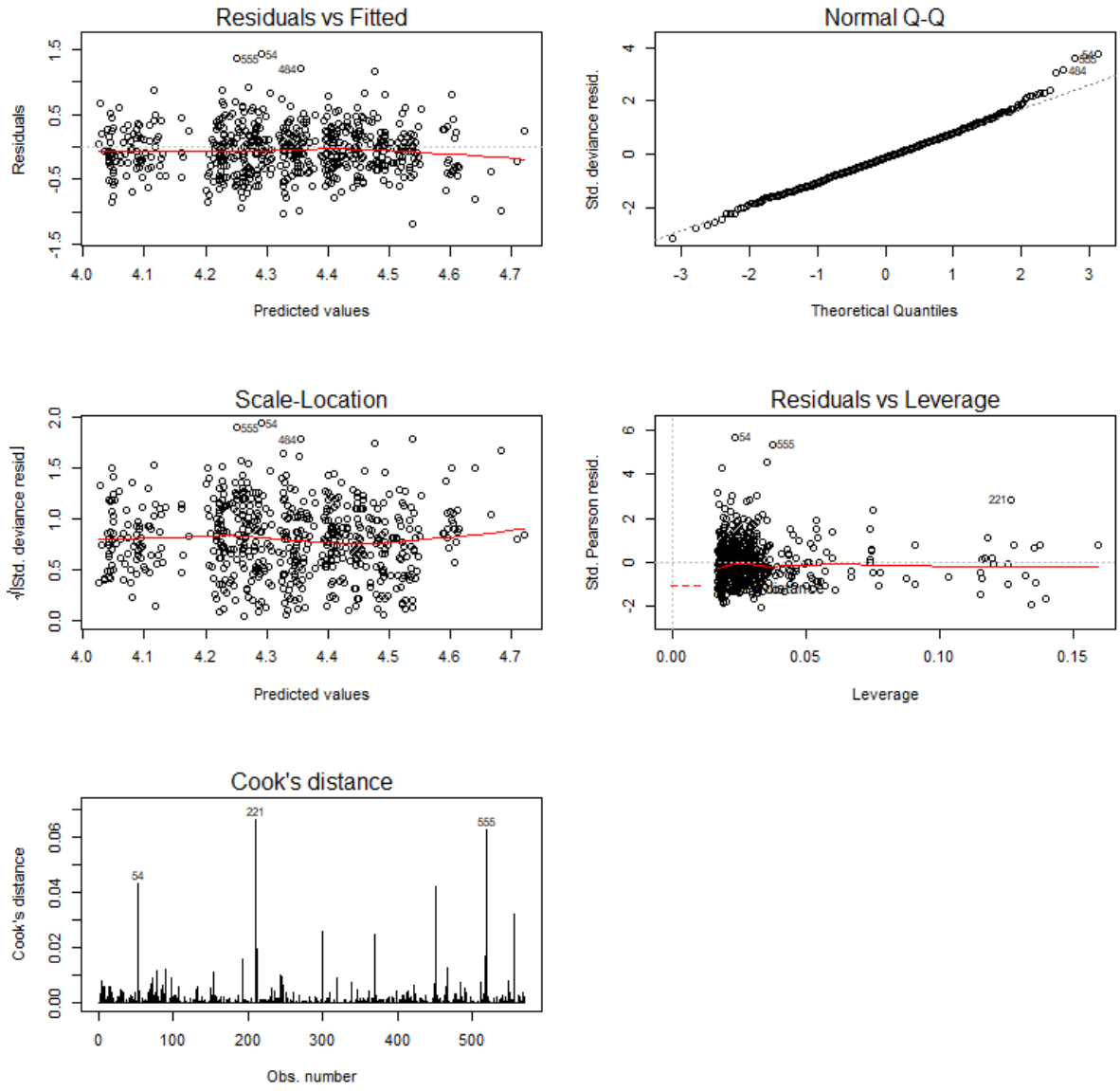




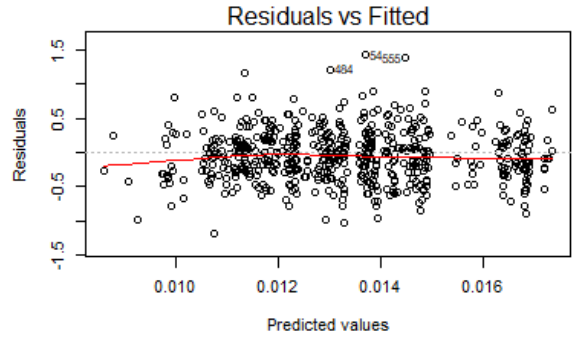


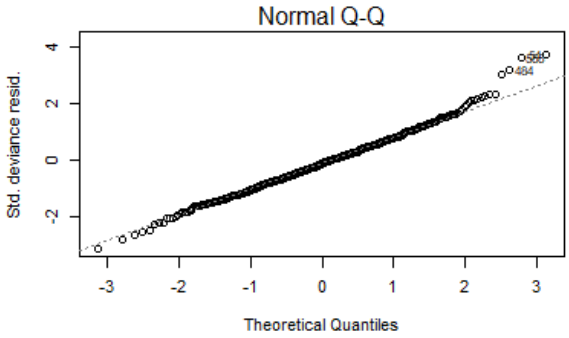


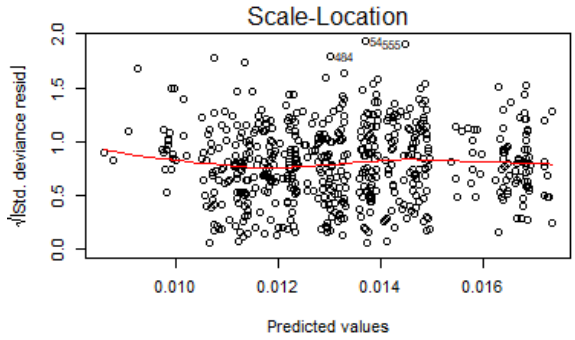
iii) Gl ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (log link)

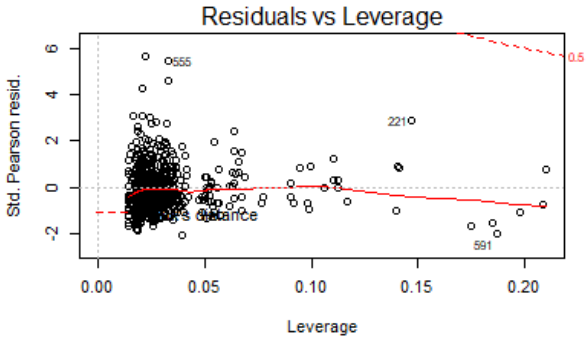


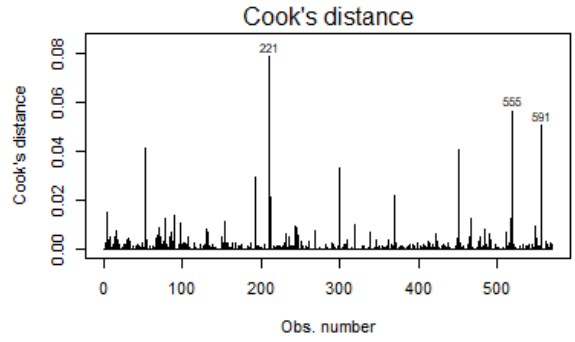
iv) Gl ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (inverse link)





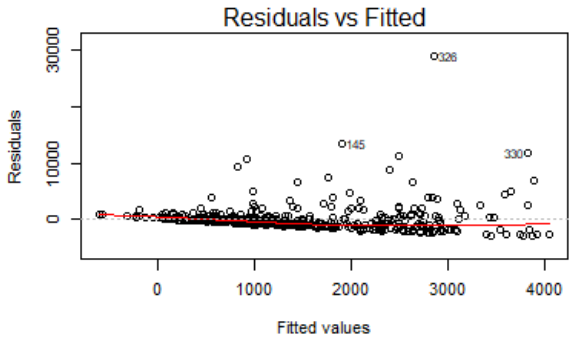


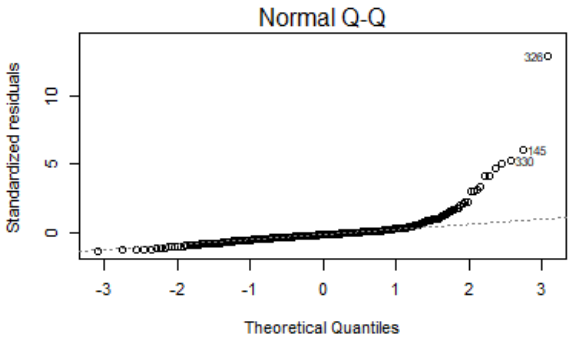


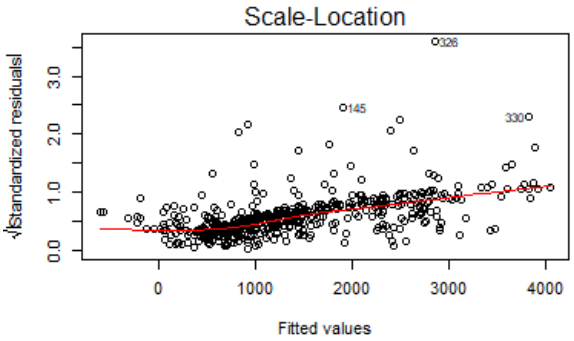


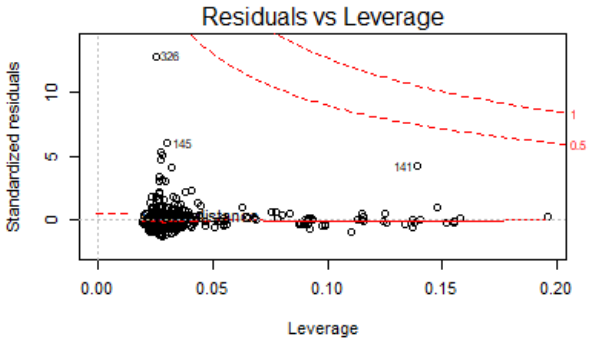
e) Faecal cortisol metabolites (FCM)

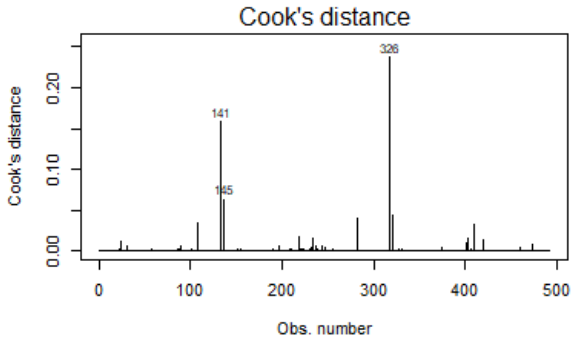
i) FCM ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



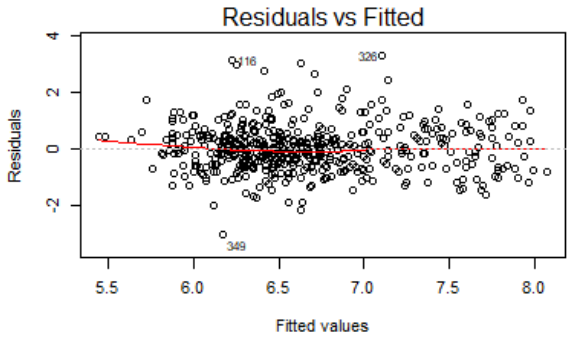


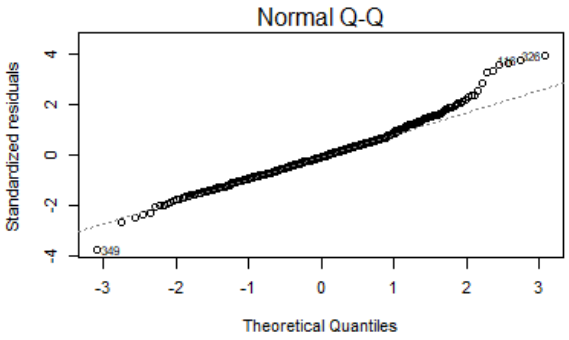


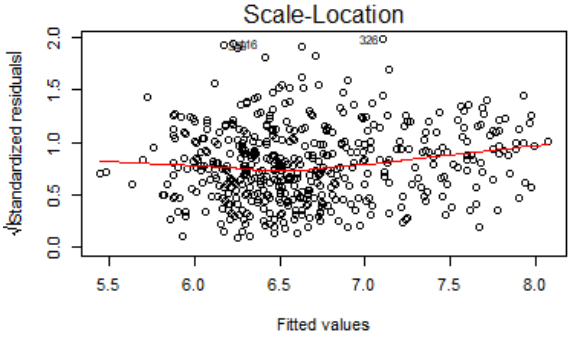


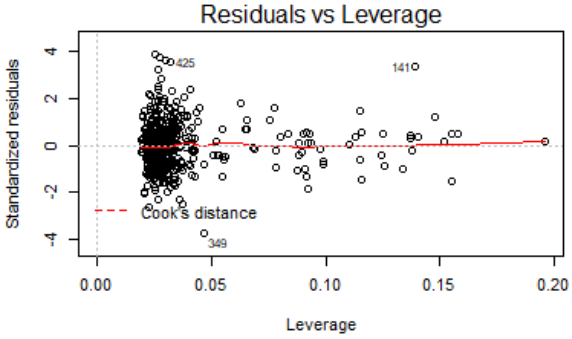


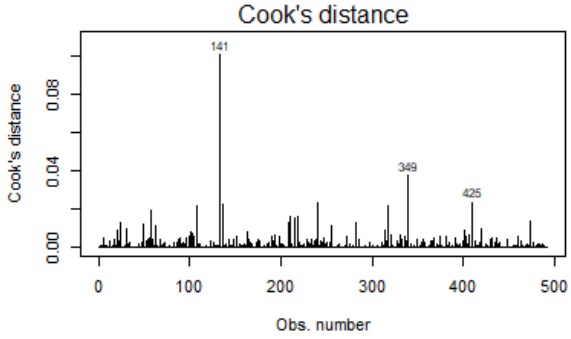
ii) ln (FCM) ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid



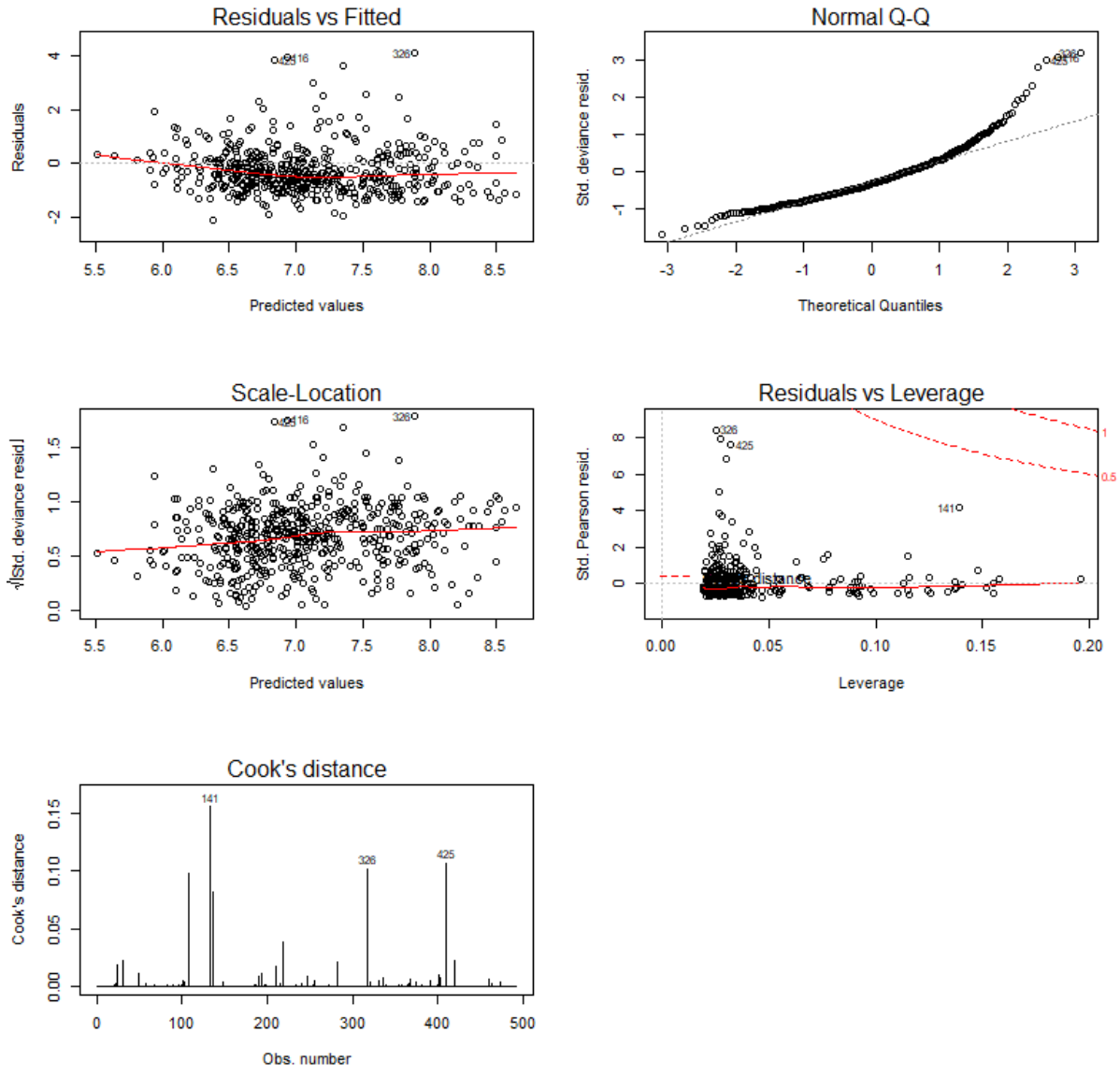








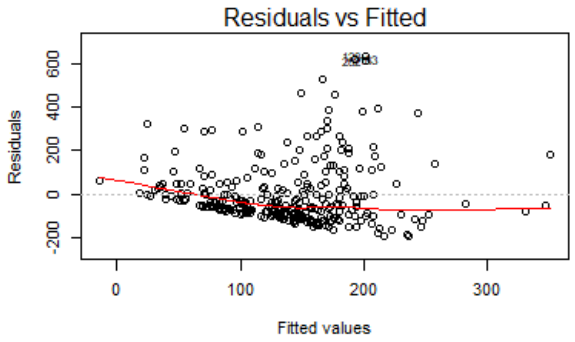
iii) FCM ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (log link)

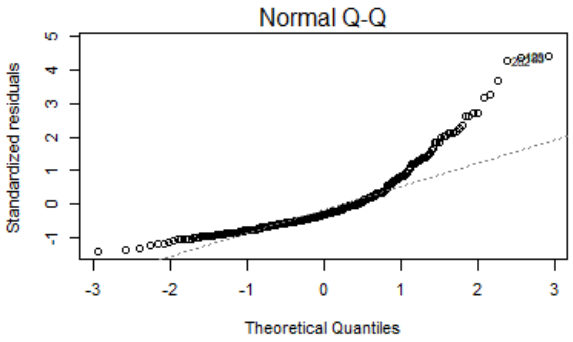


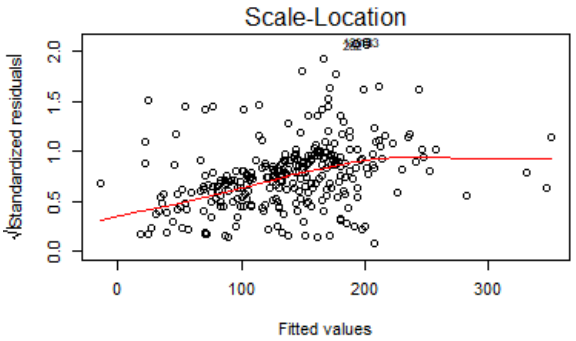
iv) FCM ~ M + Sex + Rep + Grid + Time + Sex*Rep + Sex*Grid, Gamma family (inverse link) – solution not available

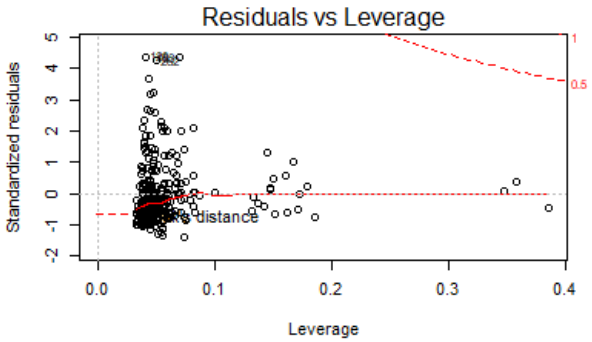
f) Total cortisol (CORT)

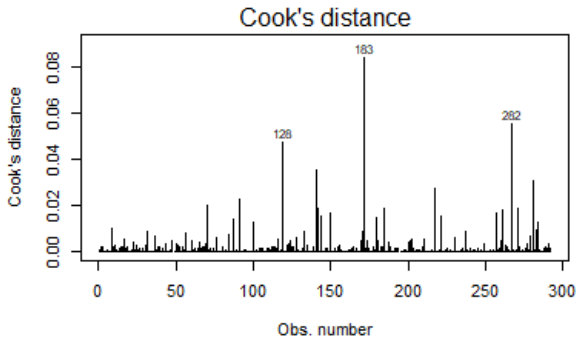
i) CORT ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid



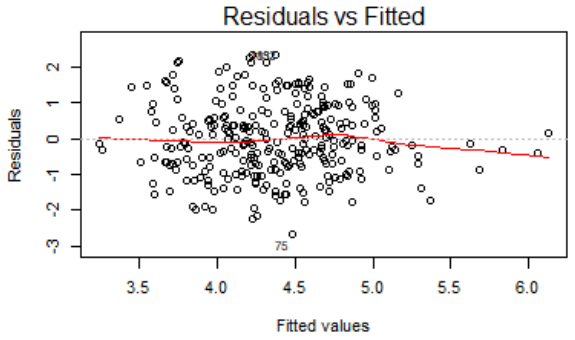


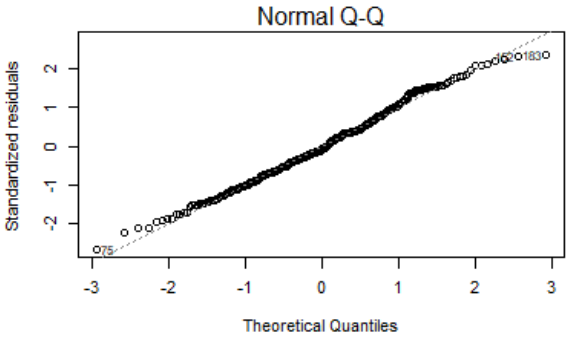


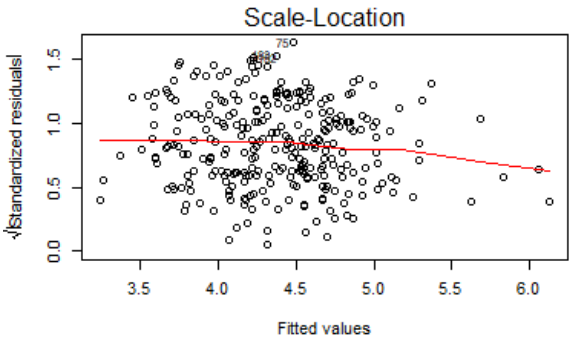


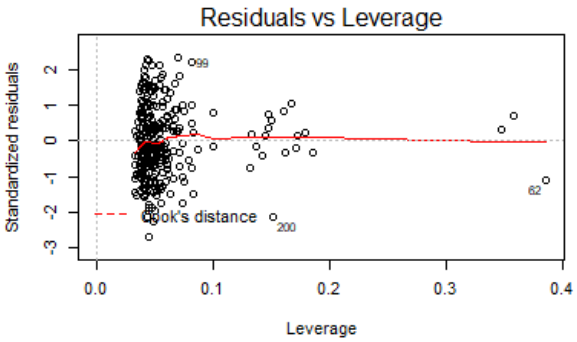


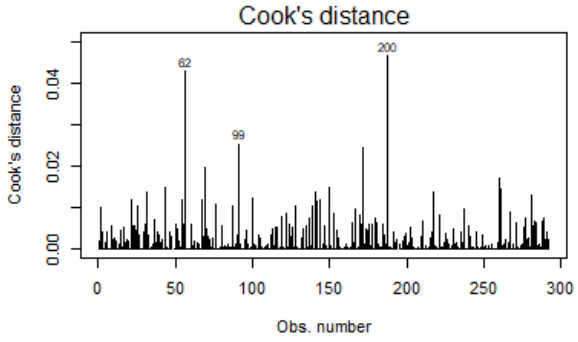
ii) ln (CORT) ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid



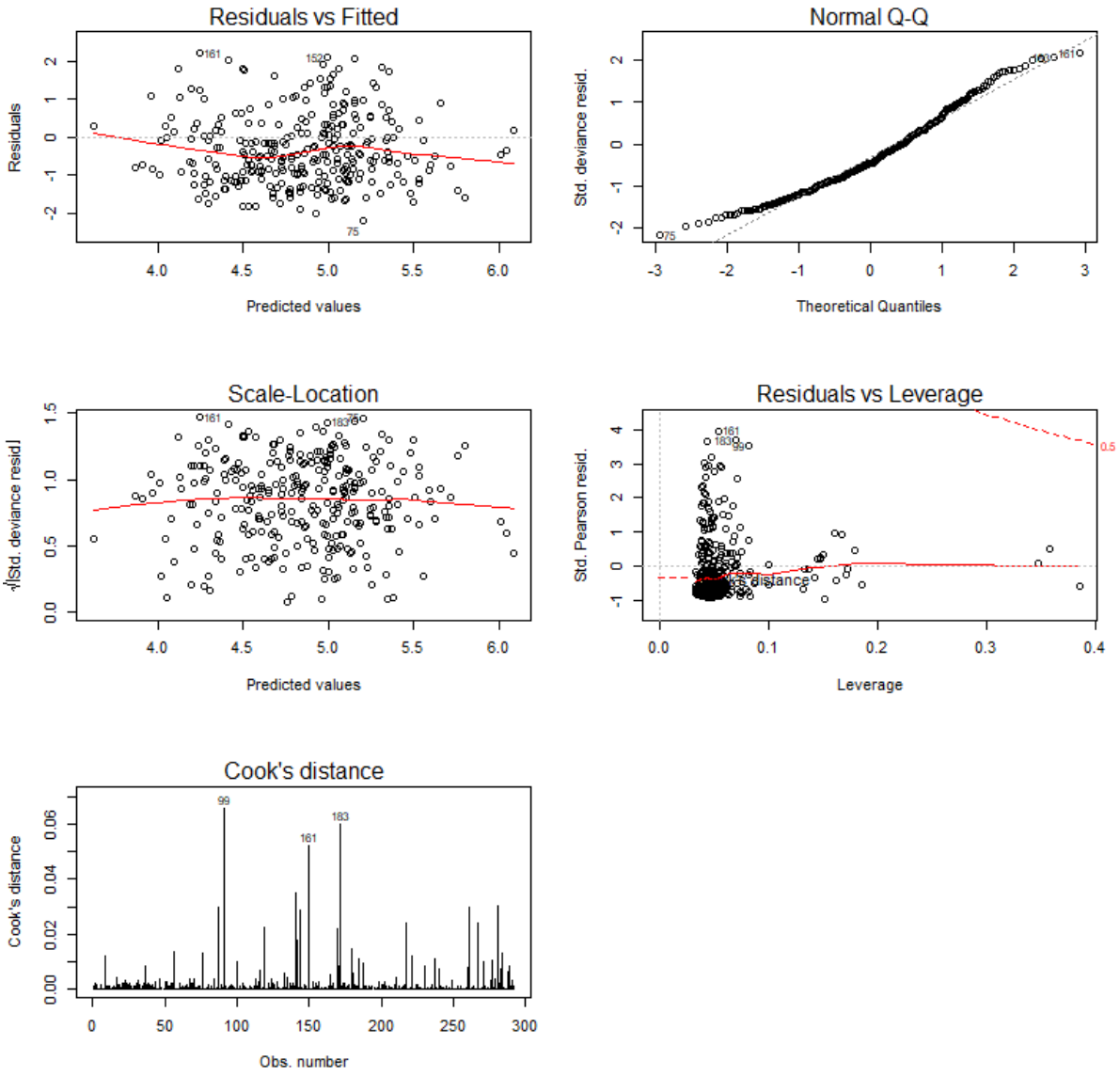




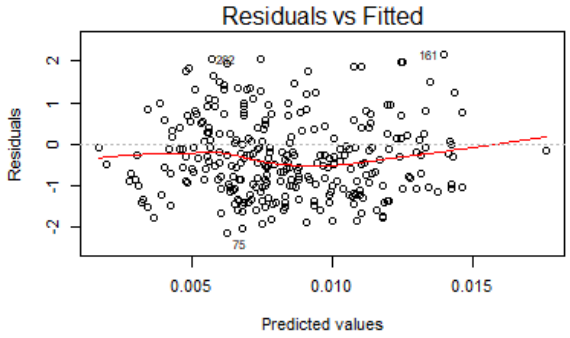


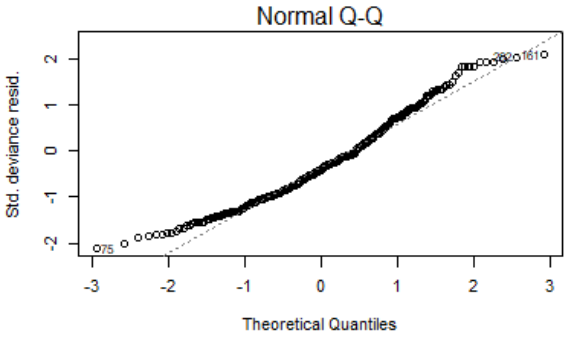


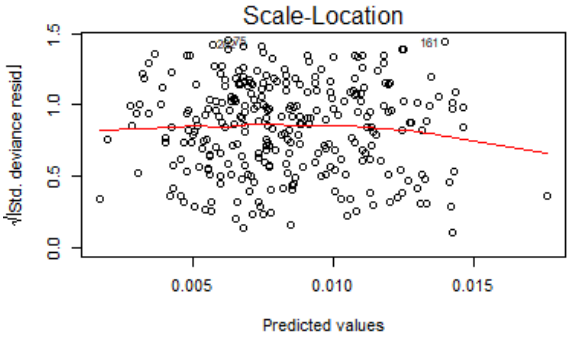
iii) CORT ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid, Gamma family (log link)

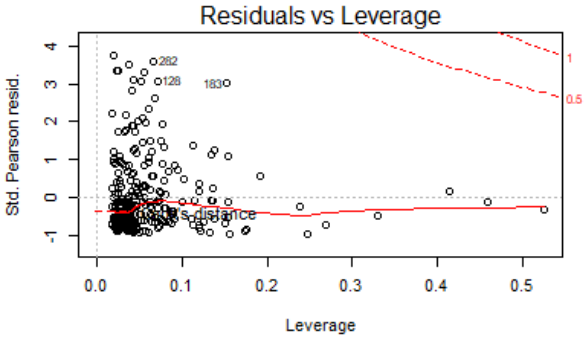


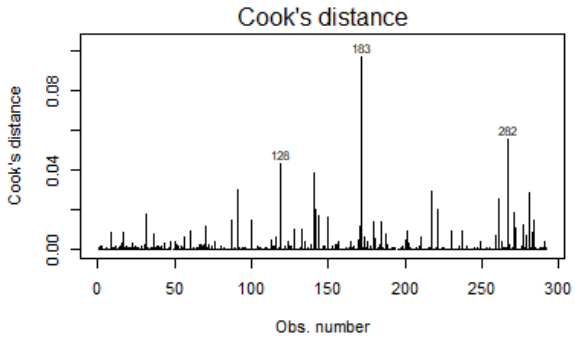
iv) CORT ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid, Gamma family (inverse link)





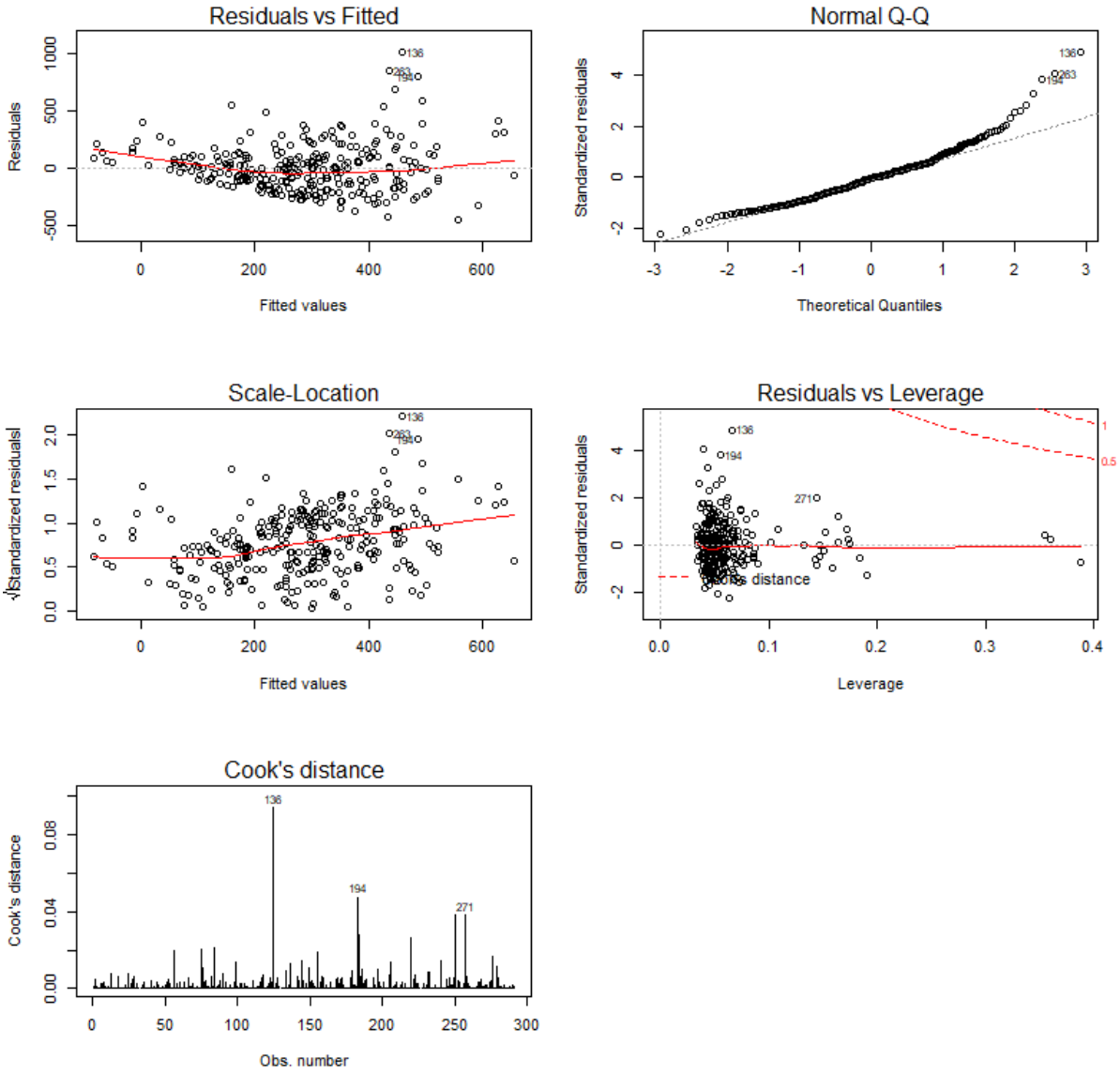




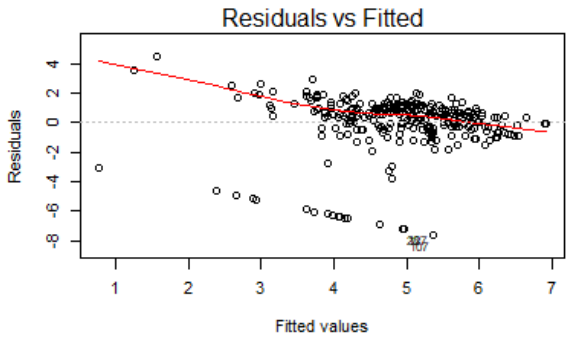


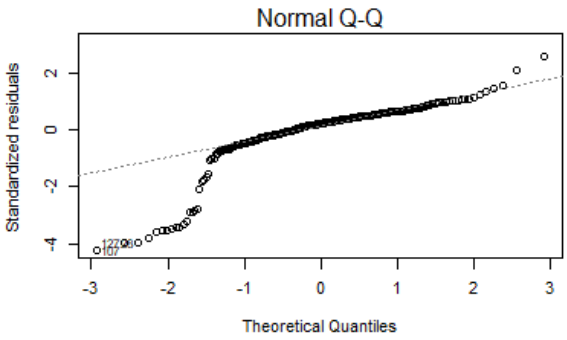
g) Maximum binding capacity (MCBC)

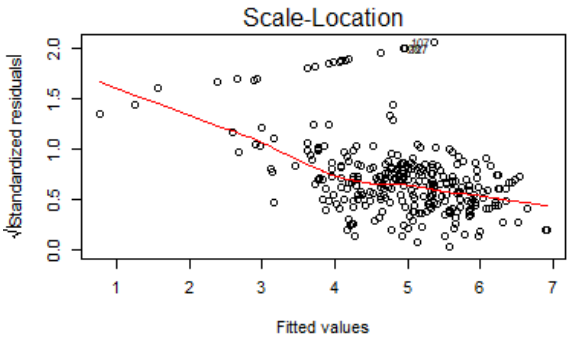
i) MCBC ~ M + Sex + Rep + Grid + Colour + Time + T.Blood + Sex*Rep + Sex*Grid

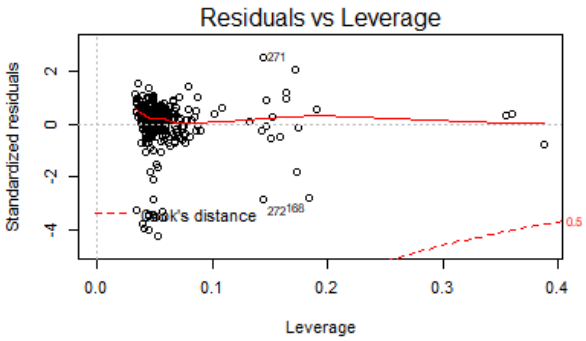


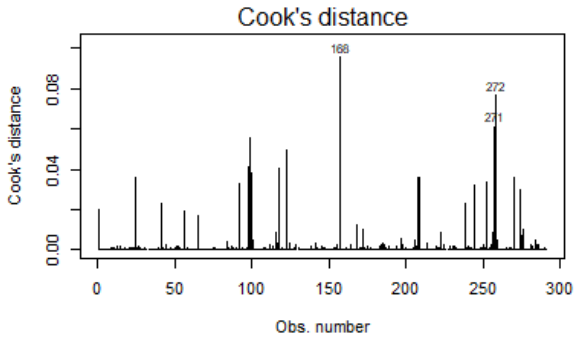
ii) ln (MCBC) ~ M + Sex + Rep + Grid + Colour + Time + T.Blood + Sex*Rep + Sex*Grid



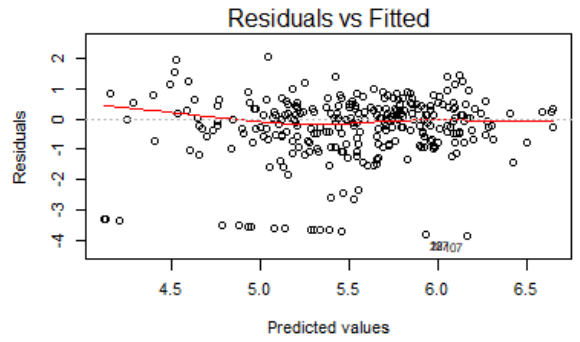


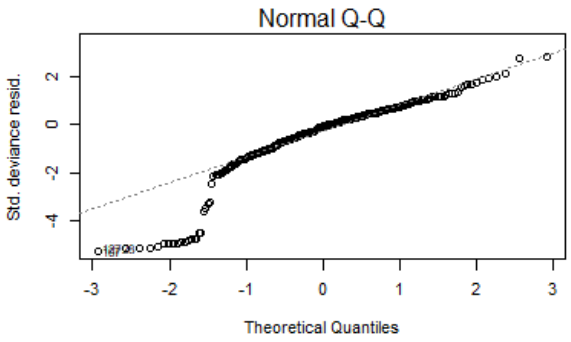


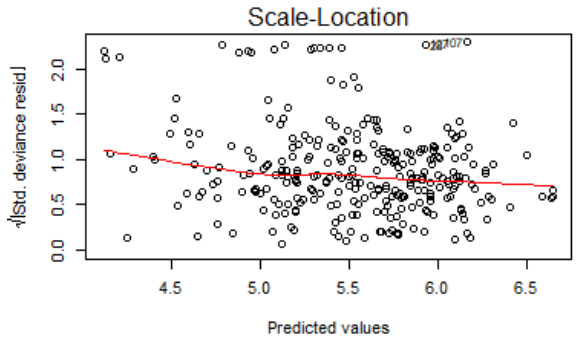


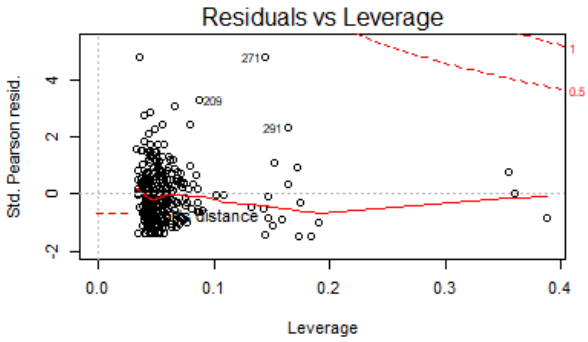


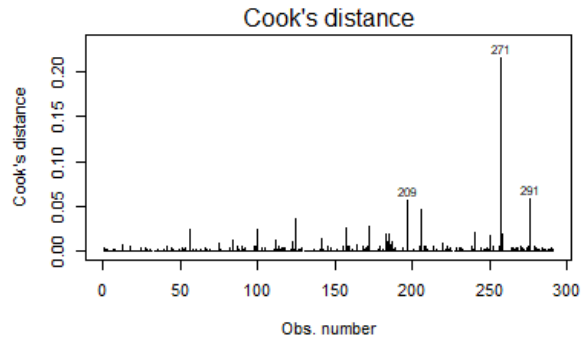
iii) MCBC ~ M + Sex + Rep + Grid + Colour + Time + T.Blood + Sex*Rep + Sex*Grid, Gamma family (log link)



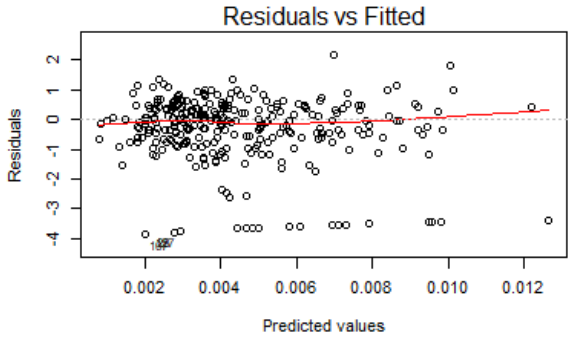


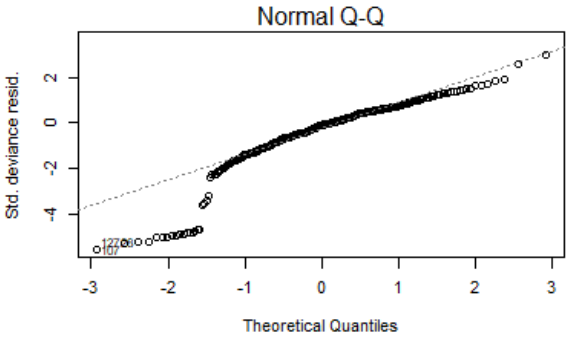


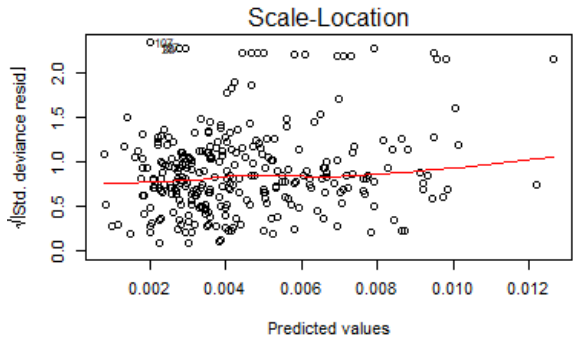


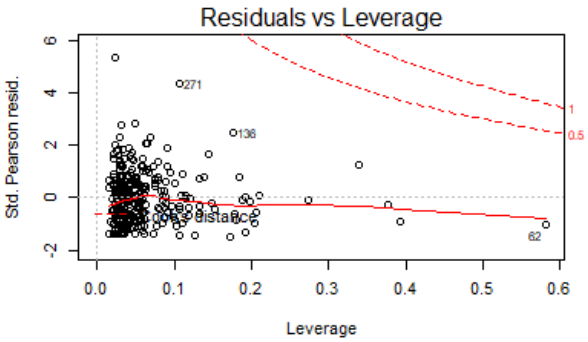


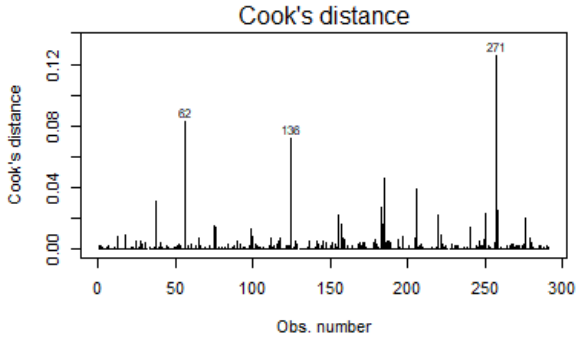
iv) MCBC ~ M + Sex + Rep + Grid + Colour + Time + T.Blood + Sex*Rep + Sex*Grid, Gamma family (inverse link)





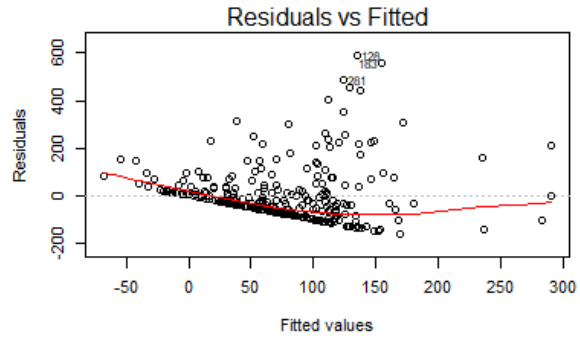


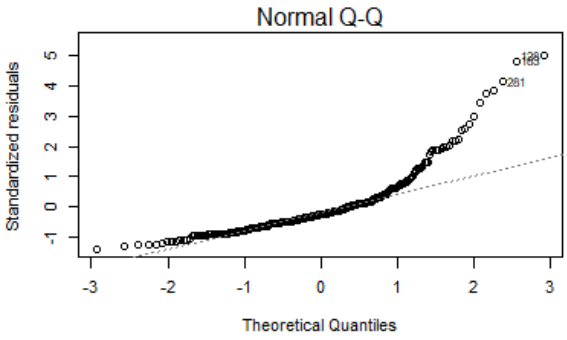


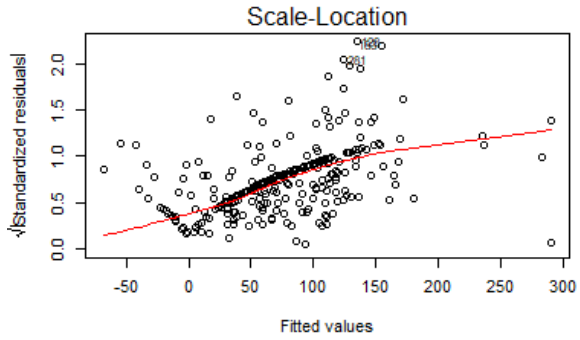


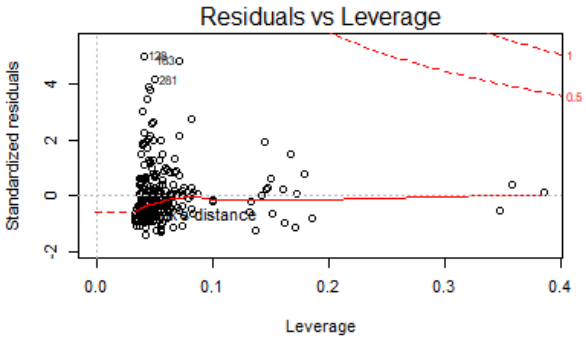
h) Free cortisol (FREE)

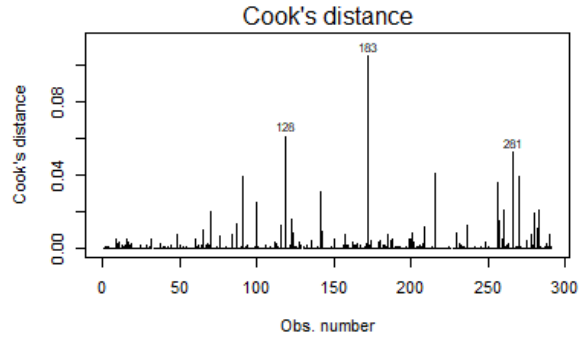
i) FREE ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid



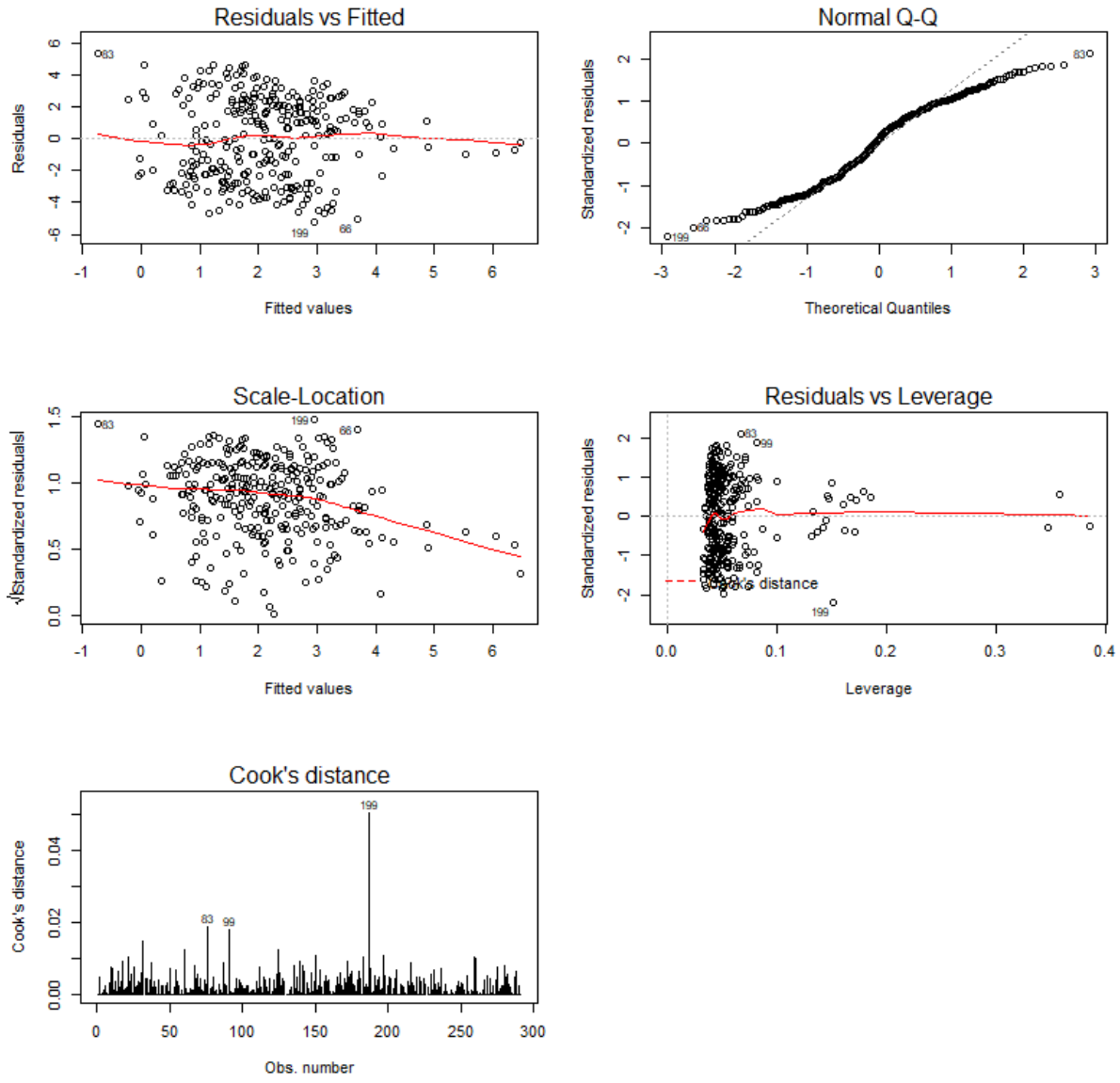






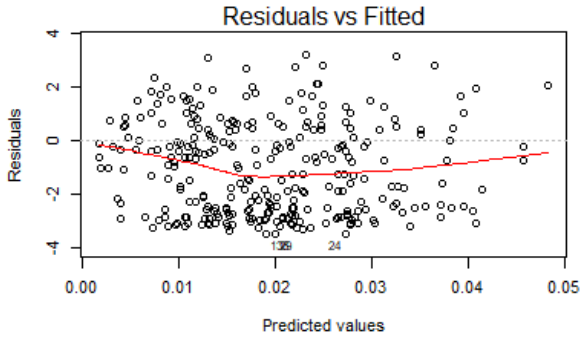


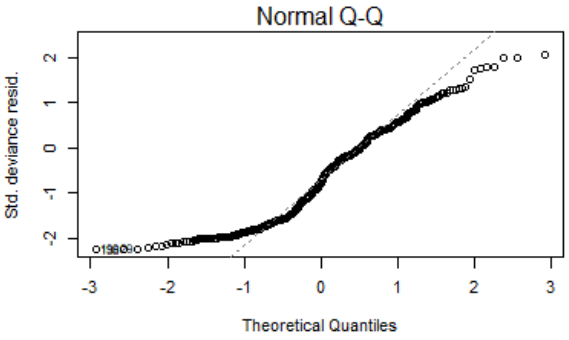
ii) ln (FREE) ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid

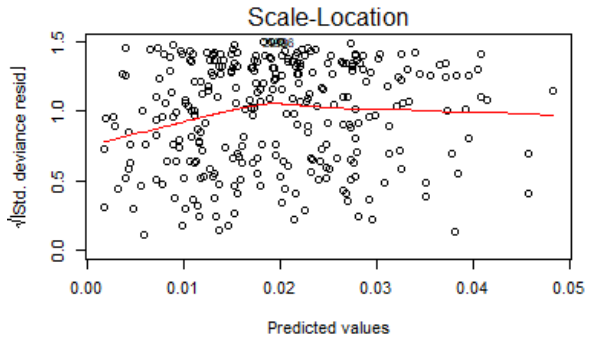


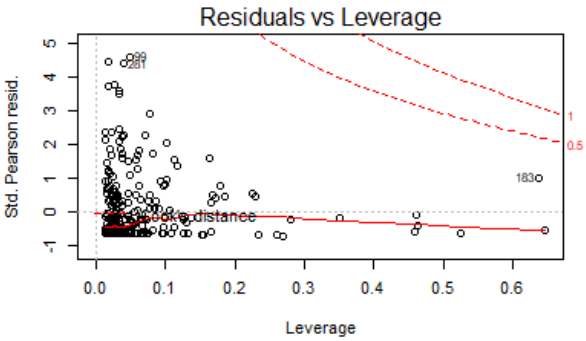
iii) FREE ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid, Gamma family (log link) – solution not available

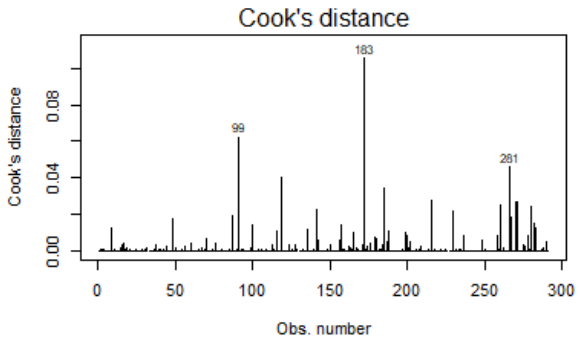
iv) FREE ~ M + Sex + Rep + Grid + Time + T.Blood + Sex*Rep + Sex*Grid, Gamma family (inverse link)











Appendix 5. The complete list of linear models for the log-transformed neutrophil/lymphocyte ratio of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, reproductive status (Rep), reproductive season (Seas), time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and reproductive season (Sex*Seas), and sex and experiment (Sex*Suppl). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	Seas + Time + Rep	6	951.69	0.00	0.17	-469.76
2	Seas + Time + Sex + Rep + Sex*Seas	9	951.86	0.17	0.16	-466.74
3	Seas + Time + Sex + Rep + Suppl + Sex*Seas	10	952.80	1.11	0.10	-466.16
4	Seas + Time + Rep + Suppl	7	952.87	1.18	0.10	-469.32
5	Seas + Time + Sex + Rep + Sex*Seas + Sex*Rep	10	952.95	1.26	0.09	-466.24
6	Seas + Time + Sex + Rep	7	953.74	2.05	0.06	-469.75
7	Seas + Time + Sex + Rep + Sex*Rep	8	953.80	2.11	0.06	-468.75
8	Seas + Time + Sex + Rep + Suppl + Sex*Seas + Sex*Rep	11	953.83	2.14	0.06	-465.63
9	Seas + Time + Sex + Rep + Suppl + Sex*Seas + Sex*Suppl	11	954.56	2.87	0.04	-465.99
10	Seas + Time + Sex + Rep + Suppl + Sex*Rep	9	954.94	3.24	0.03	-468.28
11	Seas + Time + Sex + Rep + Suppl	8	954.94	3.25	0.03	-469.31
12	Seas + Time + Sex + Rep + Suppl + Sex*Seas + Sex*Rep + Sex*Suppl	12	955.63	3.94	0.02	-465.48
13	M + Time + Rep	11	956.41	4.72	0.02	-466.92
14	Seas + Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	10	956.83	5.14	0.01	-468.18
15	Seas + Time + Sex + Rep + Suppl + Sex*Suppl	9	956.93	5.24	0.01	-469.27
16	M + Time + Rep + Suppl	12	957.62	5.92	0.01	-466.47
17	M + Time + Sex + Rep + Sex*Rep	13	957.82	6.12	0.01	-465.51
18	M + Time + Sex + Rep	12	958.52	6.83	0.01	-466.92
19	M + Time + Sex + Rep + Suppl + Sex*Rep	14	958.75	7.06	0.01	-464.92
20	M + Time + Sex + Rep + Suppl	13	959.71	8.02	0.00	-466.46
21	M + Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	15	960.62	8.93	0.00	-464.79
22	M + Time + Sex + Rep + Suppl + Sex*Suppl	14	961.68	9.98	0.00	-466.38
23	M + Time + Sex	11	962.88	11.19	0.00	-470.16

24	M + Time	10	963.78	12.09	0.00	-471.66
25	M + Time + Sex + Suppl	12	964.29	12.60	0.00	-469.81
26	Seas + Time + Sex	6	964.53	12.84	0.00	-476.18
27	M + Time + Suppl	11	964.66	12.97	0.00	-471.05
28	Seas + Time + Sex + Suppl	7	965.74	14.05	0.00	-475.75
29	M + Time + Sex + Suppl + Sex*Suppl	13	966.05	14.36	0.00	-469.63
30	Seas + Time	5	966.26	14.57	0.00	-478.07
31	Seas + Time + Sex + Sex*Seas	8	966.38	14.69	0.00	-475.03
32	Seas + Time + Suppl	6	966.79	15.10	0.00	-477.31
33	Seas + Time + Sex + Suppl + Sex*Seas	9	967.43	15.74	0.00	-474.52
34	Seas + Time + Sex + Suppl + Sex*Suppl	8	967.63	15.94	0.00	-475.66
35	Seas + Time + Sex + Suppl + Sex*Seas + Sex*Suppl	10	969.11	17.42	0.00	-474.32
36	Seas + Rep + Suppl	6	1043.10	91.41	0.00	-515.47
37	Seas + Rep	5	1044.60	92.91	0.00	-517.24
38	Seas + Sex + Rep + Suppl + Sex*Seas	9	1044.97	93.27	0.00	-513.30
39	Seas + Sex + Rep + Suppl	7	1045.13	93.44	0.00	-515.46
40	Seas + Sex + Rep + Suppl + Sex*Seas + Sex*Rep	10	1045.55	93.85	0.00	-512.55
41	Seas + Sex + Rep + Suppl + Sex*Rep	8	1046.18	94.49	0.00	-514.95
42	Seas + Sex + Rep	6	1046.49	94.80	0.00	-517.16
43	Seas + Sex + Rep + Sex*Seas	8	1046.77	95.07	0.00	-515.24
44	Seas + Sex + Rep + Suppl + Sex*Seas + Sex*Suppl	10	1046.94	95.24	0.00	-513.25
45	Seas + Sex + Rep + Suppl + Sex*Suppl	8	1047.17	95.48	0.00	-515.44
46	Seas + Sex + Rep + Sex*Seas + Sex*Rep	9	1047.50	95.81	0.00	-514.57
47	Seas + Sex + Rep + Suppl + Sex*Seas + Sex*Rep + Sex*Suppl	11	1047.53	95.84	0.00	-512.50
48	Seas + Sex + Rep + Sex*Rep	7	1047.63	95.94	0.00	-516.70
49	Seas + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	9	1048.20	96.51	0.00	-514.92
50	M + Rep + Suppl	11	1049.67	97.98	0.00	-513.57
51	M + Rep	10	1051.20	99.51	0.00	-515.38
52	M + Sex + Rep + Suppl	12	1051.66	99.97	0.00	-513.52
53	M + Sex + Rep + Suppl + Sex*Rep	13	1052.40	100.71	0.00	-512.83
54	M + Sex + Rep	11	1052.92	101.23	0.00	-515.20
55	M + Sex + Rep + Suppl + Sex*Suppl	13	1053.72	102.02	0.00	-513.49
56	M + Sex + Rep + Sex*Rep	12	1053.94	102.25	0.00	-514.66
57	M + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	14	1054.45	102.76	0.00	-512.80
58	M + Sex + Suppl	11	1057.08	105.39	0.00	-517.28
59	M + Sex	10	1058.24	106.55	0.00	-518.90
60	M + Suppl	10	1058.81	107.12	0.00	-519.19
61	Seas + Sex + Suppl	6	1058.88	107.19	0.00	-523.36

62	M + Sex + Suppl + Sex*Suppl	12	1058.96	107.27	0.00	-517.17
63	Seas + Sex	5	1060.71	109.02	0.00	-525.30
64	Seas + Sex + Suppl + Sex*Suppl	7	1060.80	109.11	0.00	-523.29
65	Seas + Suppl	5	1060.93	109.24	0.00	-525.41
66	M	9	1061.24	109.55	0.00	-521.44
67	Seas + Sex + Suppl + Sex*Seas	8	1061.48	109.79	0.00	-522.60
68	Seas + Sex + Suppl + Sex*Seas + Sex*Suppl	9	1063.31	111.61	0.00	-522.47
69	Seas + Sex + Sex*Seas	7	1063.59	111.89	0.00	-524.68
70	Seas	4	1064.22	112.53	0.00	-528.07
71	M + Sex + Rep + Sex*M	18	1068.37	102.36	0.00	-515.5
72	M + Sex + Rep + Sex*Rep	12	1068.78	102.77	0.00	-522.08
73	Seas + Sex + Suppl	6	1070.84	104.83	0.00	-529.34
74	M + Sex + Suppl	11	1070.84	104.83	0.00	-524.16
75	M + Sex + Suppl + Sex*M	18	1070.92	104.92	0.00	-516.78
76	M + Suppl	10	1072.29	106.28	0.00	-525.93
77	Seas + Suppl	5	1072.63	106.62	0.00	-531.26
78	M + Sex + Suppl + Sex*Suppl	12	1072.77	106.77	0.00	-524.08
79	Seas + Sex + Suppl + Sex*Suppl	7	1072.79	106.78	0.00	-529.29
80	M + Sex	10	1072.94	106.94	0.00	-526.25
81	M + Sex + Suppl + Sex*M + Sex*Suppl	19	1072.97	106.96	0.00	-516.72
82	M + Sex + Sex*M	17	1073.34	107.34	0.00	-519.06
83	Seas + Sex + Suppl + Sex*Seas	8	1073.4	107.39	0.00	-528.56
84	Seas + Sex	5	1073.51	107.50	0.00	-531.70
85	Seas + Sex + Suppl + Sex*Seas + Sex*Suppl	9	1075.27	109.26	0.00	-528.46
86	M	9	1075.77	109.77	0.00	-528.71
87	Seas + Sex + Sex*Seas	7	1076.38	110.37	0.00	-531.08
88	Seas	4	1076.85	110.84	0.00	-534.38

Appendix 6. Model-averaged beta coefficients for the log-transformed neutrophil/lymphocyte ratio of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	**Estimate**	**SE**	**2.5 %**	**97.5 %**
Intercept	-1.13	0.10	-1.32	-0.94
Reproductive season	0.53	0.20	0.15	0.91
Post-reproductive season	0.27	0.15	-0.02	0.55
Time	1.18×10^{-4}	1.20×10^{-4}	-1.18×10^{-4}	3.53×10^{-4}
Reproductive status	0.36	0.16	0.05	0.66
Male	-0.07	0.09	-0.25	0.12
Reproductive season*Male	0.20	0.25	-0.28	0.69
Post-reproductive season*Male	0.13	0.29	-0.43	0.69
Supplementation	-0.02	0.05	-0.12	0.08
Reproductive status*Male	-0.02	0.15	-0.31	0.28
Supplementation*Male	3.32×10^{-3}	0.03	-0.06	0.06

Appendix 7. The complete list of linear models for the log-transformed body condition of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, reproductive status (Rep), time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), and sex and experiment (Sex*Suppl). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	M + Sex + Rep + Suppl + Sex*Rep	15	-1133.60	0.00	0.63	582.02
2	M + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	16	-1131.59	2.01	0.23	582.05
3	M + Sex + Rep + Sex*Rep	14	-1130.69	2.91	0.15	579.54
4	M + Sex + Rep + Suppl	14	-1081.64	51.96	0.00	555.02
5	M + Sex + Rep + Suppl + Sex*Suppl	15	-1079.66	53.94	0.00	555.05
6	M + Sex + Rep	13	-1079.30	54.30	0.00	552.82
7	M + Sex + Suppl	13	-1055.98	77.62	0.00	541.16
8	M + Sex	12	-1054.47	79.13	0.00	539.38
9	M + Sex + Suppl + Sex*Suppl	14	-1053.94	79.66	0.00	541.16
10	M + Time + Sex + Rep + Sex*Rep	14	-1038.89	94.71	0.00	533.75
11	M + Time + Sex + Rep + Suppl + Sex*Rep	15	-1038.30	95.30	0.00	534.49
12	M + Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	16	-1037.62	95.98	0.00	535.20
13	M + Time + Sex + Rep	13	-982.95	150.65	0.00	504.73
14	M + Time + Sex + Rep + Suppl	14	-981.93	151.67	0.00	505.27
15	M + Time + Sex + Rep + Suppl + Sex*Suppl	15	-981.08	152.52	0.00	505.88
16	M + Time + Sex	12	-946.78	186.82	0.00	485.61
17	M + Time + Sex + Suppl	13	-945.19	188.41	0.00	485.85
18	M + Time + Sex + Suppl + Sex*Suppl	14	-944.27	189.33	0.00	486.43
19	M + Rep + Suppl	13	-909.10	224.50	0.00	467.72
20	M + Rep	12	-898.56	235.04	0.00	461.42
21	M + Time + Rep + Suppl	13	-796.78	336.82	0.00	411.65
22	M + Time + Rep	12	-791.23	342.37	0.00	407.84
23	M + Suppl	12	-719.50	414.10	0.00	371.89
24	M	11	-704.29	429.31	0.00	363.27
25	M + Sex + Rep + Suppl + Sex*Rep	15	-1133.60	0.00	0.63	582.02
26	M + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	16	-1131.59	2.01	0.23	582.05

Appendix 8. Model-averaged beta coefficients for the log-transformed body condition of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	2.63	0.02	2.60	2.66
Jan	0.14	0.02	0.10	0.17
Mar/Apr	0.16	0.01	0.13	0.19
Jun/Jul	0.15	0.02	0.12	0.19
Sept	0.45	0.02	0.41	0.50
2. Dec	0.58	0.03	0.53	0.64
2. Jan	0.52	0.04	0.44	0.60
2. Mar/Apr	0.47	0.03	0.40	0.54
2. Jun/Jul	0.41	0.04	0.33	0.50
2. Sept	0.60	0.05	0.50	0.69
Male	0.09	0.01	0.07	0.12
Reproductive status	0.02	0.02	-0.02	0.07
Supplementation	-0.02	0.01	-0.04	0.01
Reproductive status*Male	0.16	0.02	0.12	0.21
Supplementation*Male	9.94×10^{-4}	89.5×10^{-4}	-0.02	0.02

Appendix 9. The complete list of linear models for the haemoglobin concentration of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, reproductive status (Rep), grid, origin of the blood sample (Blood), time inside trap (Time), the interactions between sex and reproductive status (Sex*Rep), and sex and grid (Sex*Grid). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	Time + Blood + M + Sex + Rep + Grid	16	1852.73	0.00	0.34	-909.78
2	Time + Blood + M + Sex + Rep + Grid + Sex*Rep	17	1854.28	1.55	0.16	-909.48
3	Time + Blood + M + Rep + Grid	15	1854.44	1.71	0.14	-911.71
4	Time + M + Sex + Rep + Grid	15	1854.90	2.17	0.11	-911.93
5	Time + Blood + M + Sex + Grid	15	1855.77	3.04	0.07	-912.37
6	Time + M + Sex + Rep + Grid + Sex*Rep	16	1856.47	3.74	0.05	-911.65
7	Time + M + Rep + Grid	14	1856.61	3.88	0.05	-913.85
8	Time + Blood + M + Sex + Rep + Grid + Sex*Grid	19	1857.91	5.18	0.03	-909.13
9	Time + M + Sex + Grid	14	1857.96	5.23	0.03	-914.53
10	Time + Blood + M + Sex + Rep + Grid + Sex*Rep + Sex*Grid	20	1859.47	6.74	0.01	-908.82
11	Time + M + Sex + Rep + Grid + Sex*Grid	18	1860.05	7.32	0.01	-911.28
12	Time + M + Sex + Rep + Grid + Sex*Rep + Sex*Grid	19	1861.62	8.89	0.00	-910.98
13	Time + Blood + M + Sex + Grid + Sex*Grid	18	1861.68	8.95	0.00	-912.10
14	Time + M + Sex + Grid + Sex*Grid	17	1863.83	11.10	0.00	-914.25
15	Time + Blood + M + Grid	14	1867.37	14.64	0.00	-919.23
16	Time + M + Grid	13	1869.55	16.82	0.00	-921.38
17	Time + Blood + M + Sex + Rep	13	1879.77	27.04	0.00	-926.50
18	Time + Blood + M + Sex + Rep + Sex*Rep	14	1879.83	27.10	0.00	-925.46
19	Time + Blood + M + Rep	12	1880.31	27.58	0.00	-927.82
20	Time + Blood + M + Sex	12	1882.33	29.60	0.00	-928.83
21	Time + M + Sex + Rep	12	1883.45	30.72	0.00	-929.39
22	Time + M + Sex + Rep + Sex*Rep	13	1883.51	30.78	0.00	-928.36
23	Time + M + Rep	11	1884.22	31.49	0.00	-930.83
24	Time + M + Sex	11	1885.90	33.17	0.00	-931.67
25	Time + Blood + M	11	1890.78	38.05	0.00	-934.11
26	Time + M	10	1894.77	42.04	0.00	-937.15
27	Time + Blood + Sex + Rep + Grid	9	1907.40	54.67	0.00	-944.51

28	Time + Blood + Sex + Rep + Grid + Sex*Rep	10	1908.50	55.77	0.00	-944.02
29	Time + Blood + Rep + Grid	8	1909.96	57.23	0.00	-946.83
30	Time + Blood + Sex + Rep + Grid + Sex*Grid	12	1911.25	58.52	0.00	-943.29
31	Time + Blood + Sex + Rep + Grid + Sex*Rep + Sex*Grid	13	1912.43	59.70	0.00	-942.83
32	Time + Sex + Rep + Grid	8	1917.35	64.62	0.00	-950.52
33	Time + Sex + Rep + Grid + Sex*Rep	9	1919.11	66.38	0.00	-950.36
34	Time + Rep + Grid	7	1919.23	66.50	0.00	-952.49
35	Time + Sex + Rep + Grid + Sex*Grid	11	1921.15	68.42	0.00	-949.29
36	Time + Sex + Rep + Grid + Sex*Rep + Sex*Grid	12	1922.96	70.23	0.00	-949.15
37	Time + Blood + Sex + Rep	6	1925.63	72.90	0.00	-956.73
38	Time + Blood + Sex + Rep + Sex*Rep	7	1925.82	73.09	0.00	-955.79
39	Time + Blood + Rep	5	1926.10	73.37	0.00	-957.99
40	Time + Sex + Rep	5	1937.25	84.52	0.00	-963.56
41	Time + Rep	4	1937.39	84.66	0.00	-964.65
42	Time + Sex + Rep + Sex*Rep	6	1938.39	85.66	0.00	-963.10
43	Time + Blood + Sex + Grid	8	1945.21	92.48	0.00	-964.45
44	Time + Blood + Sex + Grid + Sex*Grid	11	1949.47	96.74	0.00	-963.46
45	Time + Blood + Grid	7	1957.89	105.16	0.00	-971.83
46	Time + Blood + Sex	5	1964.14	111.41	0.00	-977.01
47	Time + Sex + Grid	7	1964.78	112.05	0.00	-975.27
48	Time + Sex + Grid + Sex*Grid	10	1969.37	116.64	0.00	-974.45
49	Time + Blood	4	1973.00	120.27	0.00	-982.46
50	Time + Grid	6	1977.32	124.59	0.00	-982.57
51	Time + Sex	4	1985.97	133.24	0.00	-988.94
52	Time	3	1995.33	142.60	0.00	-994.64

Appendix 10. Model-averaged beta coefficients for the haemoglobin concentration of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	13.46	0.34	12.80	14.13
Time	8.26×10^{-4}	3.28×10^{-4}	1.84×10^{-4}	14.69×10^{-4}
Tail vein	-0.32	0.25	-0.80	0.17
Mar/Apr	-0.11	0.28	-0.66	0.45
Jun/Jul	0.04	0.35	-0.64	0.73
Sept	1.22	0.44	0.36	2.08
2. Dec	-1.41	0.54	-2.46	-0.36
2. Mar/Apr	-0.29	0.63	-1.53	0.95
2. Jun/Jul	-1.39	0.68	-2.72	-0.06
2. Sept	0.03	0.70	-1.36	1.41
Male	0.27	0.24	-0.20	0.75
Reproductive status	0.66	0.38	-0.09	1.41
JB1	-0.94	0.25	-1.44	-0.44
JB2	0.14	0.25	-0.35	0.62
JB4	-0.28	0.27	-0.81	0.26
Reproductive status*Male	0.06	0.21	-0.35	0.47

Appendix 11. The complete list of linear models for the log-transformed glucose concentration of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, reproductive status (Rep), grid, time inside trap (Time), the interactions between sex and reproductive status (Sex*Rep), and sex and grid (Sex*Grid). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	M + Time + Rep + Grid	14	518.86	0.00	0.58	-245.05
2	M + Time + Sex + Rep + Grid	15	520.96	2.11	0.20	-245.05
3	M + Time + Sex + Rep + Grid + Sex*Rep	16	521.38	2.53	0.16	-244.20
4	M + Time + Sex + Rep + Grid + Sex*Grid	18	524.91	6.06	0.03	-243.84
5	M + Time + Sex + Rep + Grid + Sex*Rep + Sex*Grid	19	525.29	6.43	0.02	-242.95
6	M + Time + Sex + Grid	14	529.28	10.43	0.00	-250.26
7	M + Time + Grid	13	531.46	12.60	0.00	-252.40
8	M + Time + Sex + Grid + Sex*Grid	17	533.67	14.82	0.00	-249.28
9	M + Time + Rep	11	534.23	15.37	0.00	-255.88
10	M + Time + Sex + Rep	12	536.25	17.40	0.00	-255.85
11	M + Time + Sex + Rep + Sex*Rep	13	537.79	18.94	0.00	-255.57
12	M + Time + Sex	11	544.80	25.94	0.00	-261.16
13	M + Rep + Grid	13	548.06	29.20	0.00	-260.72
14	M + Time	10	548.20	29.34	0.00	-263.90
15	M + Sex + Rep + Grid	14	550.15	31.29	0.00	-260.72
16	M + Sex + Rep + Grid + Sex*Rep	15	550.89	32.03	0.00	-260.04
17	M + Sex + Rep + Grid + Sex*Grid	17	553.76	34.90	0.00	-259.36
18	M + Sex + Rep + Grid + Sex*Rep + Sex*Grid	18	554.39	35.53	0.00	-258.61
19	M + Sex + Grid	13	559.02	40.17	0.00	-266.20
20	M + Grid	12	561.36	42.50	0.00	-268.42
21	M + Rep	10	562.88	44.02	0.00	-271.26
22	M + Sex + Grid + Sex*Grid	16	563.23	44.38	0.00	-265.16
23	M + Sex + Rep	11	564.87	46.02	0.00	-271.21
24	M + Sex + Rep + Sex*Rep	12	566.66	47.80	0.00	-271.07
25	M + Sex	10	574.10	55.24	0.00	-276.86
26	M	9	577.66	58.81	0.00	-279.68

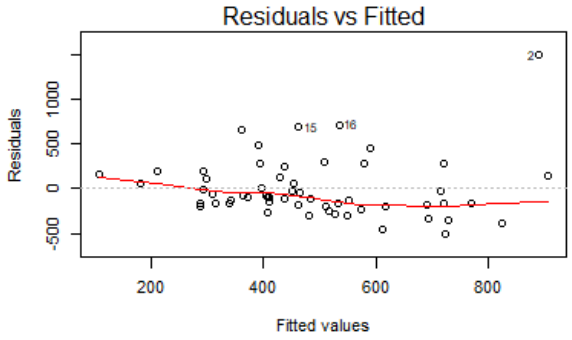
Appendix 12. Model-averaged beta coefficients for the log-transformed glucose concentration of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

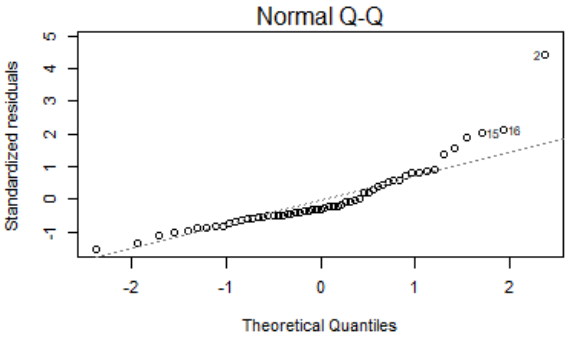
Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	4.02	0.07	3.89	4.16
Mar/Apr	0.19	0.05	0.09	0.30
Jun/Jul	0.03	0.06	-0.10	0.15
Sept	0.15	0.08	0.00	0.31
2. Dec	0.12	0.10	-0.07	0.31
2. Mar/Apr	0.18	0.11	-0.04	0.40
2. Jun/Jul	0.41	0.14	0.14	0.67
2. Sept	0.25	0.14	-0.03	0.53
Time	5.36×10^{-5}	6.58×10^{-5}	-0.18×10^{-5}	7.56×10^{-5}
Reproductive status	0.20	0.06	0.07	0.32
JB1	0.17	0.05	0.07	0.28
JB2	0.01	0.05	-0.09	0.11
JB4	0.12	0.06	0.01	0.23
Male	-0.01	0.03	-0.07	0.06
Reproductive status*Male	0.02	0.05	-0.08	0.12

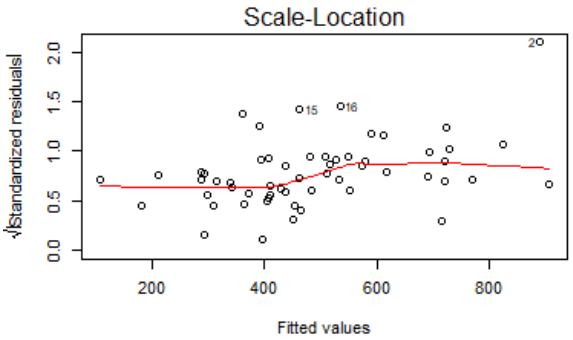
Appendix 13. Diagnostic plots of the global models for the faecal cortisol metabolites (FCM) of *Gracilinanus agilis* from the biological validation. Results were presented considering a) all samples (N = 58) and b) removing urine-contaminated and old individuals (N = 49). The investigated models were: i) linear; ii) linear with the response variable transformed to natural logarithm; iii) generalized linear using gamma family and log link function; iv) and generalized linear using gamma family and inverse link function. The effects in each model were: time inside trap divided in 7 groups from 00 h to 18 h at intervals of 3 hours (Group), sex, and time of capture standardized in minutes after sunset (Time.cap). Graphics for each model in clockwise direction: residuals vs fitted plot, normal QQ plot, residuals vs leverage plot, cook's distance plot and scale-location or spread-location plot. Labeled points represent possible outliers, high-leverage and/or influential points, and were investigated. Cook's distance is a measure of the influence of points based on the standardized residual and the leverage of the points.

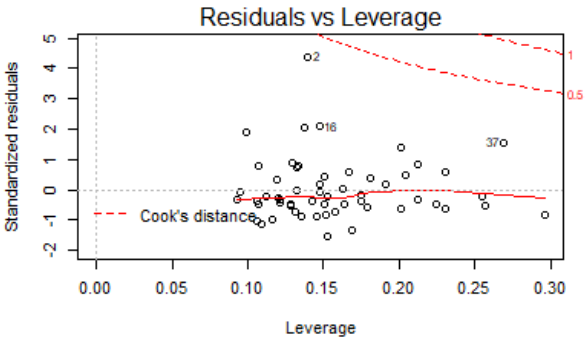
a)

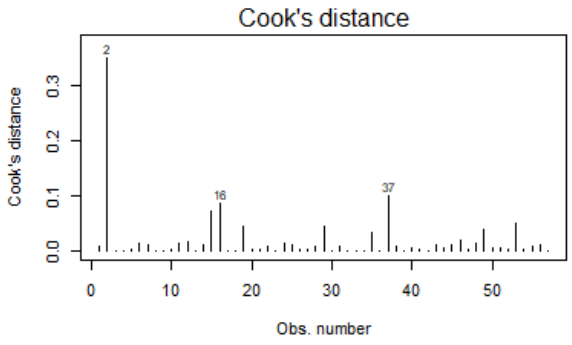
i) FCM ~ Group + Sex + Time



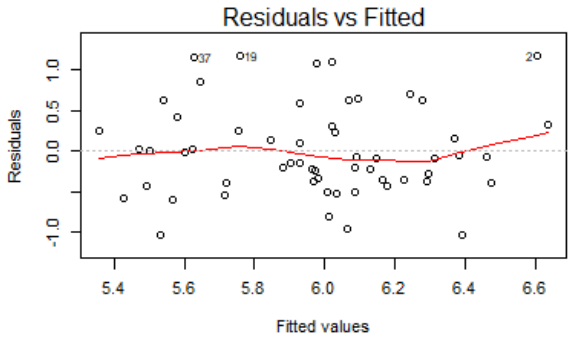


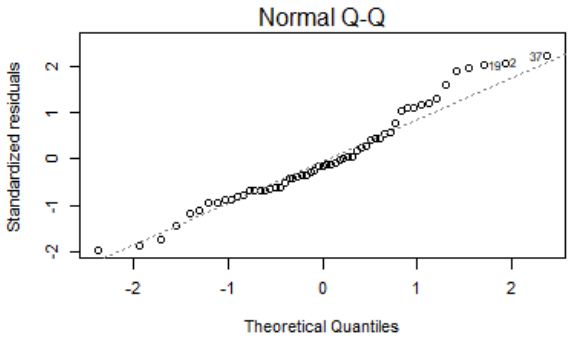


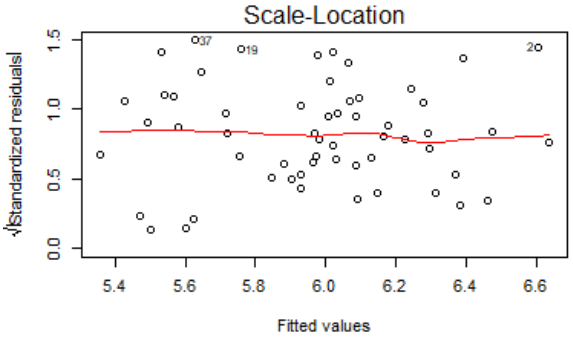


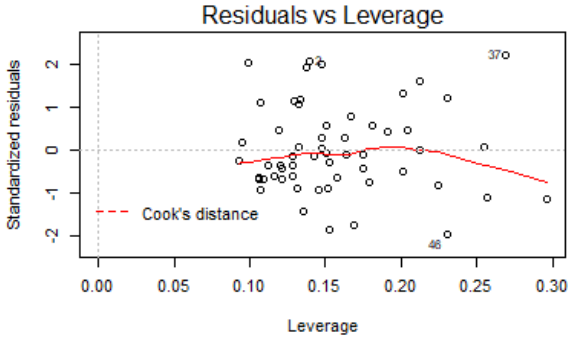


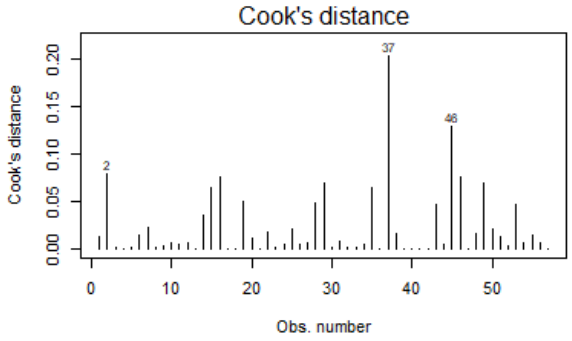
ii) ln (FCM) ~ Group + Sex + Time



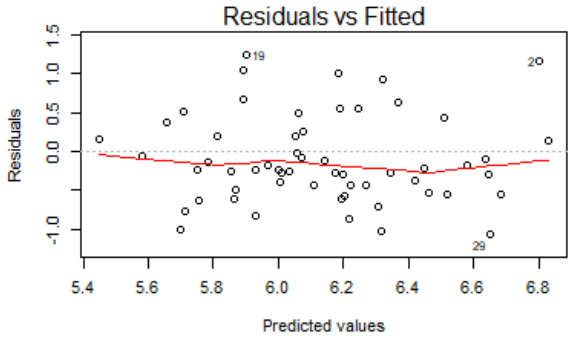


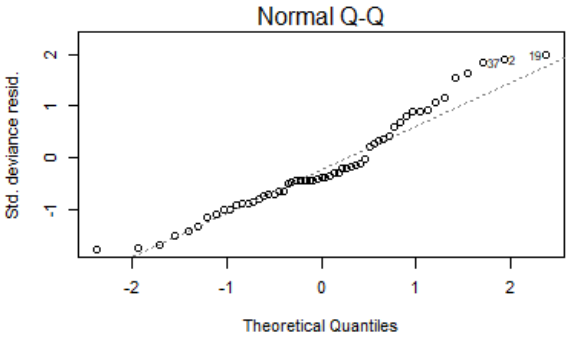


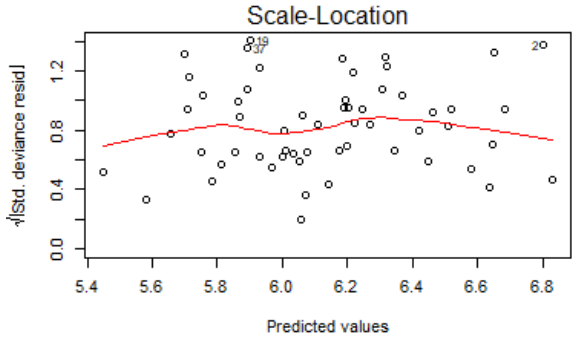


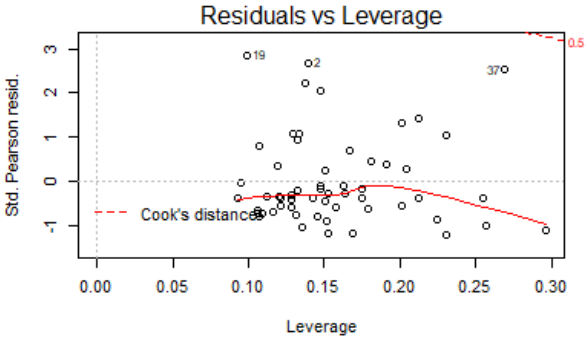


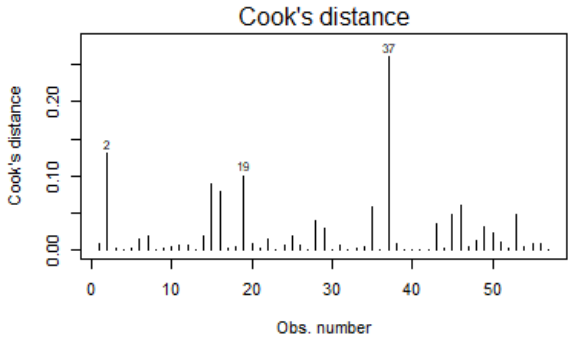
iii) FCM ~ Group + Sex + Time, Gamma family (log link)



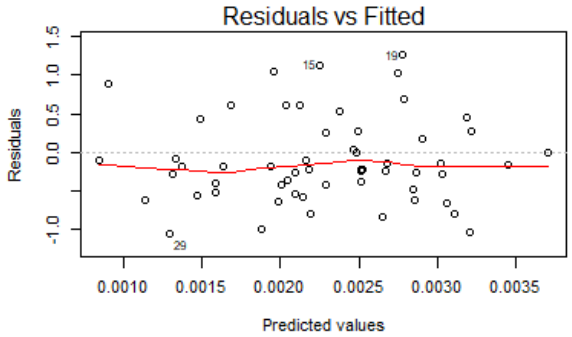


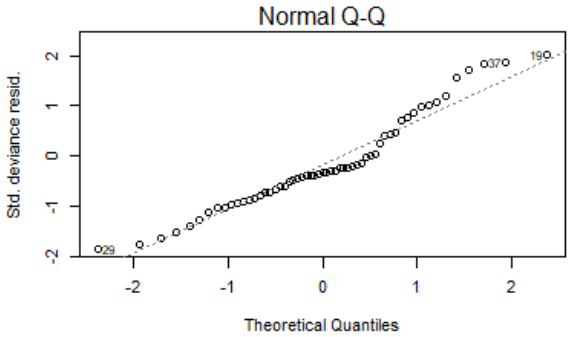


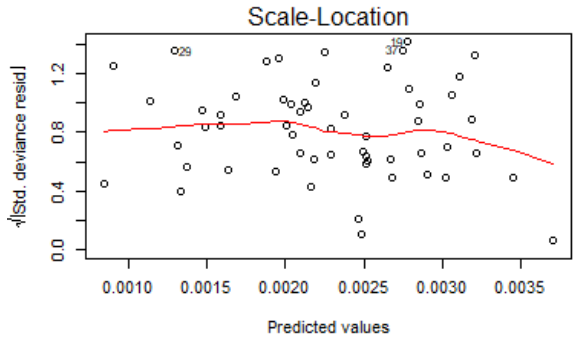


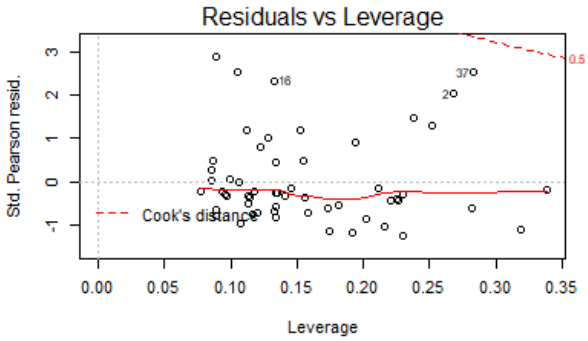


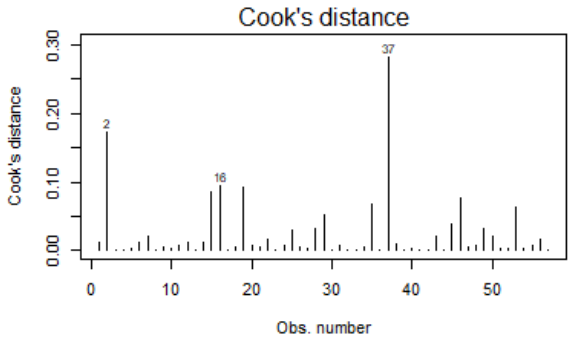
iv) FCM ~ Group + Sex + Time, Gamma family (inverse link)





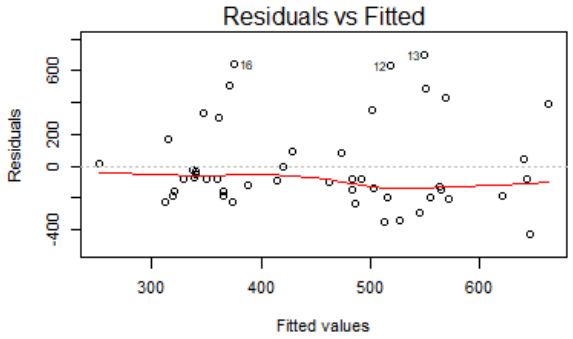


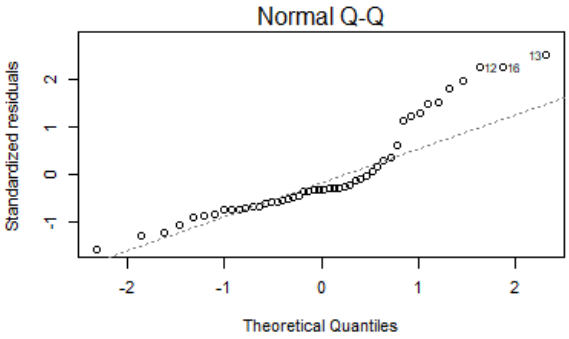


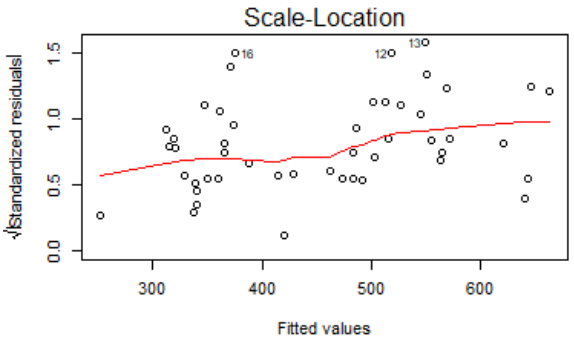


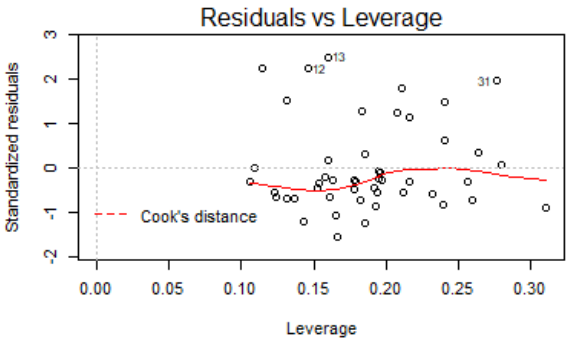
b)

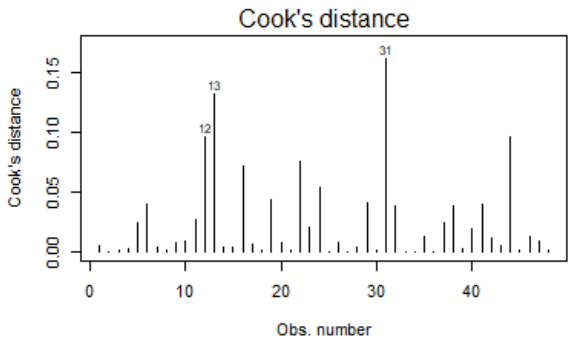
i) FCM ~ Group + Sex + Time



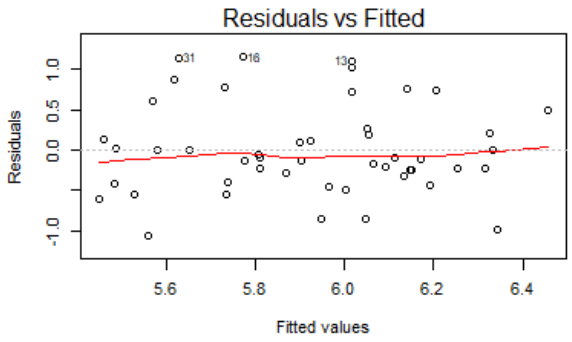


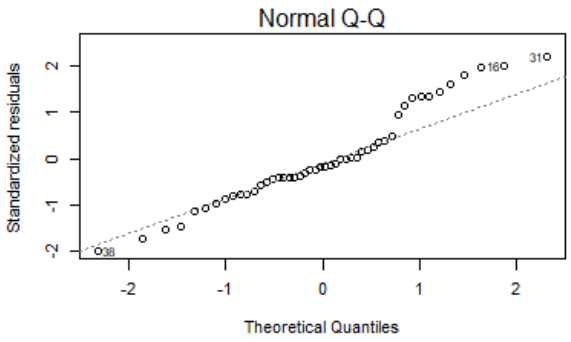


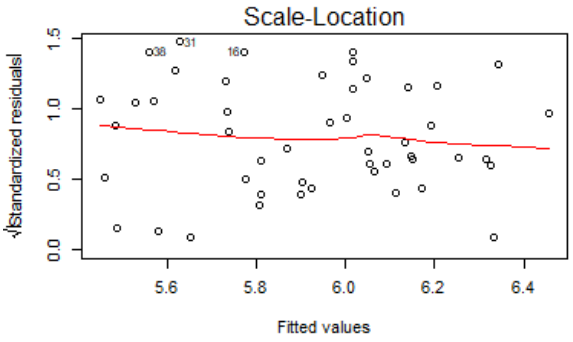


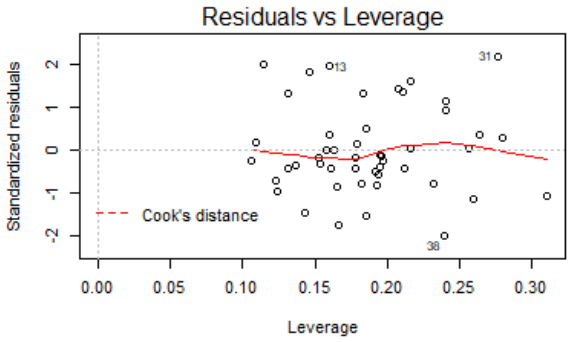


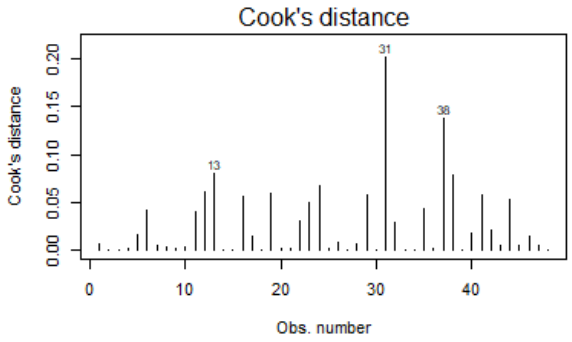
ii) ln (FCM) ~ Group + Sex + Time



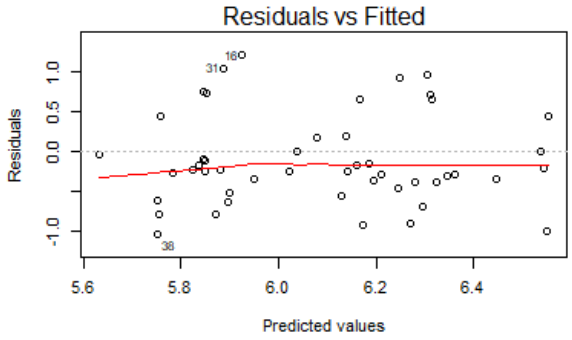


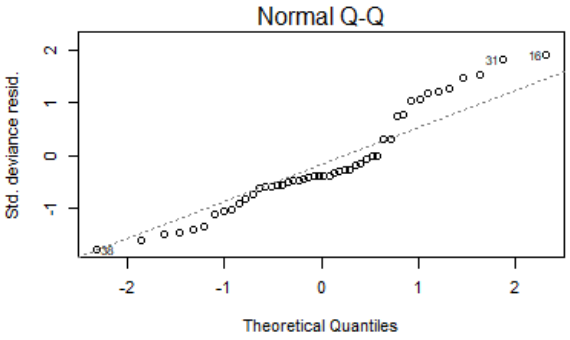


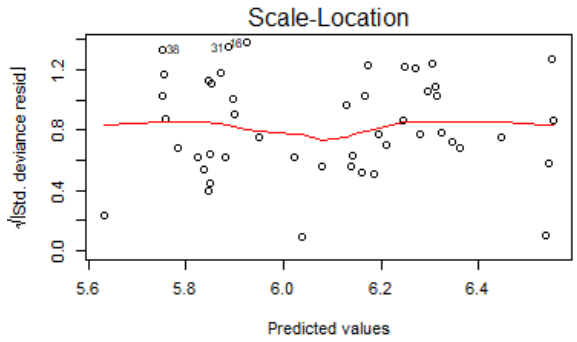


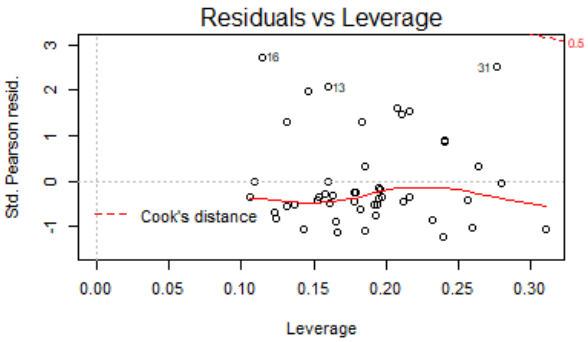


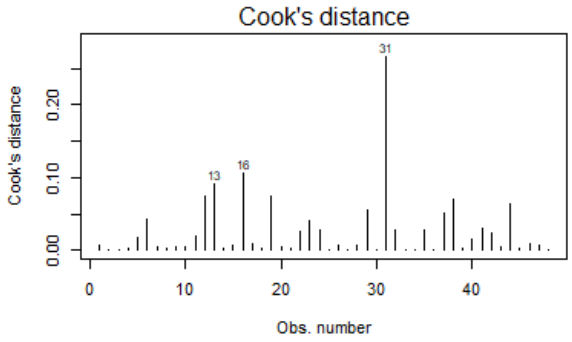
iii) FCM ~ Group + Sex + Time, Gamma family (log link)



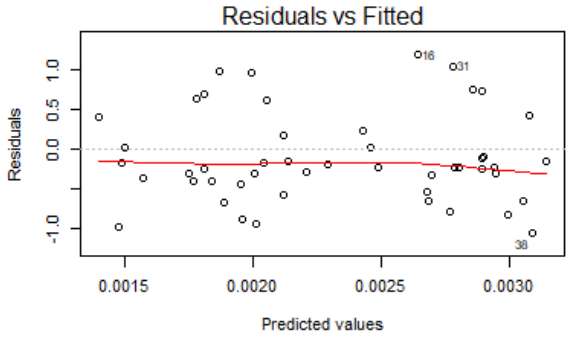


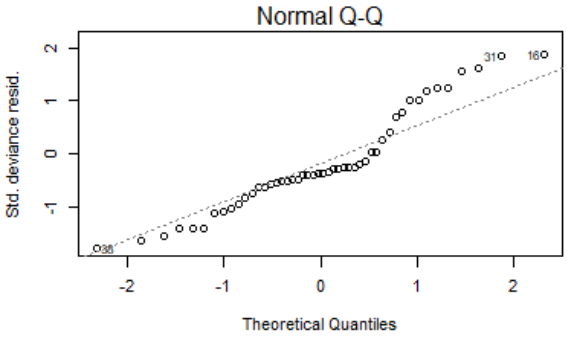


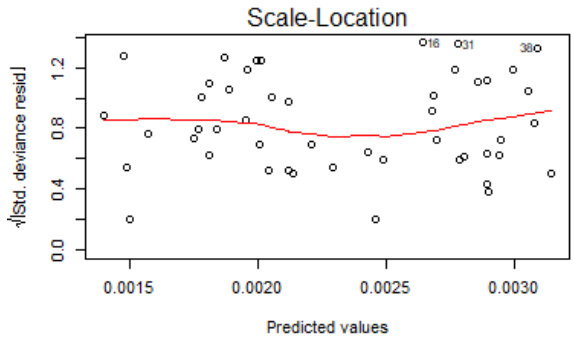


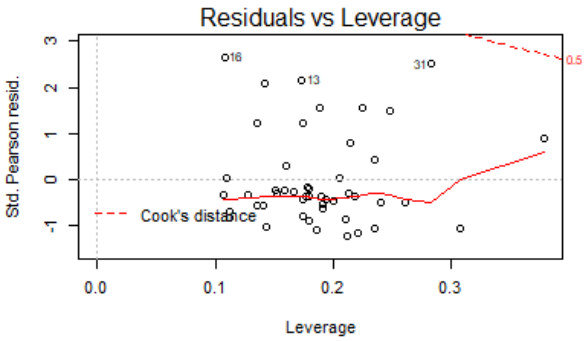


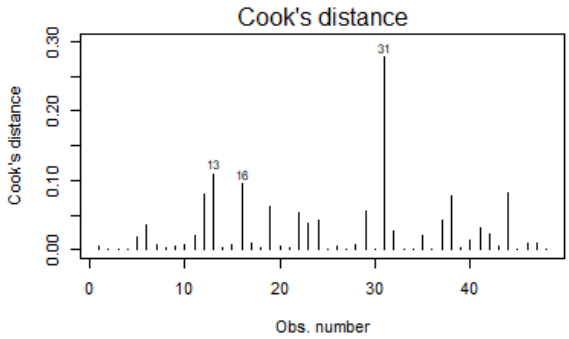
iv) FCM ~ Group + Sex + Time, Gamma family (inverse link)











Appendix 14. Model-averaged beta coefficients for the log-transformed faecal cortisol metabolites of *Gracilinanus agilis* from the biological validation, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
a) N = 57				
Intercept	5.76	0.44	4.85	6.63
Time.cap	-5.83×10^{-4}	5.34×10^{-4}	-16.24×10^{-4}	5.04×10^{-4}
00 h	0.38	0.51	-0.63	1.41
03 h	0.28	0.41	-0.53	1.10
06 h	0.47	0.61	-0.72	1.70
09 h	0.27	0.41	-0.53	1.10
12 h	0.13	0.31	-0.50	0.78
15 h	0.36	0.51	-0.64	1.41
Male	0.08	0.14	-0.21	0.37
b) N = 48				
Intercept	5.93	0.16	5.61	6.26
Time.cap	-2.30×10^{-4}	4.18×10^{-4}	-10.64×10^{-4}	6.04×10^{-4}
Male	0.06	0.13	-0.21	0.32

Appendix 15. The complete list of linear models for the log-transformed faecal cortisol metabolites of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: month adapted to the life cycle of the individuals (M), sex, reproductive status (Rep), time inside trap (Time), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), and sex and experiment (Sex*Suppl). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	M + Time + Sex + Suppl	12	1192.07	0.00	0.29	-583.71
2	M + Time + Sex + Rep + Suppl	13	1192.67	0.60	0.21	-582.95
3	M + Time + Sex + Rep + Suppl + Sex*Rep	14	1193.71	1.65	0.13	-582.41
4	M + Time + Sex + Suppl + Sex*Suppl	13	1194.05	1.98	0.11	-583.64
5	M + Time + Sex + Rep + Suppl + Sex*Suppl	14	1194.67	2.60	0.08	-582.89
6	M + Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	15	1195.71	3.64	0.05	-582.35
7	M + Time + Sex	11	1196.15	4.08	0.04	-586.80
8	M + Time + Rep + Suppl	12	1196.55	4.49	0.03	-585.95
9	M + Time + Sex + Rep	12	1196.59	4.53	0.03	-585.97
10	M + Time + Sex + Rep + Sex*Rep	13	1197.90	5.84	0.02	-585.57
11	M + Time + Rep	11	1198.64	6.58	0.01	-588.04
12	M + Time + Suppl	11	1198.87	6.81	0.01	-588.16
13	M + Time	10	1200.85	8.79	0.00	-590.20
14	M + Sex + Suppl	11	1273.77	81.71	0.00	-625.62
15	M + Sex + Rep + Suppl	12	1274.26	82.19	0.00	-624.81
16	M + Sex + Rep + Suppl + Sex*Rep	13	1274.39	82.33	0.00	-623.83
17	M + Sex + Suppl + Sex*Suppl	12	1275.65	83.59	0.00	-625.51
18	M + Sex + Rep + Suppl + Sex*Suppl	13	1276.15	84.09	0.00	-624.71
19	M + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	14	1276.29	84.22	0.00	-623.71
20	M + Rep + Suppl	11	1278.86	86.80	0.00	-628.16
21	M + Sex	10	1279.19	87.12	0.00	-629.37
22	M + Sex + Rep	11	1279.77	87.71	0.00	-628.62
23	M + Suppl	10	1279.99	87.93	0.00	-629.77
24	M + Sex + Rep + Sex*Rep	12	1280.29	88.22	0.00	-627.83
25	M + Rep	10	1282.16	90.10	0.00	-630.86
26	M	9	1283.14	91.08	0.00	-632.39

Appendix 16. Model-averaged beta coefficients for the log-transformed faecal cortisol metabolites of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	5.71	0.15	5.41	6.00
Mar/Apr	-0.12	0.12	-0.36	0.12
Jun/Jul	-0.15	0.13	-0.42	0.11
Sept	1.08	0.16	0.76	1.39
2. Dec	0.30	0.22	-0.12	0.73
2. Mar/Apr	-0.40	0.27	-0.92	0.12
2. Jun/Jul	-0.60	0.29	-1.18	-0.03
2. Sept	0.58	0.32	-0.04	1.20
Time	8.80×10^{-4}	1.44×10^{-4}	5.96×10^{-4}	11.63×10^{-4}
Male	0.23	0.11	0.01	0.45
Supplementation	0.18	0.10	-0.02	0.37
Reproductive status	0.02	0.12	-0.22	0.26
Reproductive status*Male	-0.04	0.11	-0.25	0.18
Supplementation*Male	0.01	0.08	-0.15	0.18

Appendix 17. The complete list of linear models for the log-transformed total cortisol of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: sex, age class (Age), reproductive status (Rep), time inside trap (Time), time of blood collection (T.Blood), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and age class (Sex*Age), and sex and experiment (Sex*Suppl). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	Time + Age + T.Blood + Sex + Rep + Sex*Rep	9	832.78	0.00	0.18	-407.07
2	Time + Age + T.Blood + Sex + Rep + Sex*Age	10	833.18	0.40	0.15	-406.19
3	Time + Age + T.Blood + Sex + Rep	8	833.56	0.78	0.12	-408.52
4	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Rep	10	834.27	1.49	0.09	-406.74
5	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age	11	834.68	1.90	0.07	-405.86
6	Time + Age + T.Blood + Sex + Rep + Sex*Age + Sex*Rep	11	834.78	1.99	0.07	-405.91
7	Time + Age + T.Blood + Sex + Rep + Suppl	9	835.05	2.26	0.06	-408.20
8	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	11	835.98	3.20	0.04	-406.51
9	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age + Sex*Rep	12	836.31	3.53	0.03	-405.59
10	Time + T.Blood + Sex + Rep + Sex*Rep	7	836.40	3.61	0.03	-411.00
11	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age + Sex*Suppl	12	836.48	3.69	0.03	-405.67
12	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Suppl	10	836.84	4.06	0.02	-408.02
13	Time + T.Blood + Sex + Rep + Suppl + Sex*Rep	8	837.57	4.78	0.02	-410.53
14	Time + Age + T.Blood + Sex	7	837.81	5.03	0.02	-411.70
15	Time + Age + T.Blood + Sex + Rep + Suppl + Sex*Age + Sex*Rep + Sex*Suppl	13	838.05	5.27	0.01	-405.36
16	Time + T.Blood + Sex + Rep	6	838.37	5.59	0.01	-413.04
17	Time + Age + T.Blood + Sex + Suppl	8	838.83	6.05	0.01	-411.16
18	Time + T.Blood + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	9	839.26	6.48	0.01	-410.31
19	Time + Age + T.Blood + Sex + Sex*Age	9	839.38	6.60	0.01	-410.37

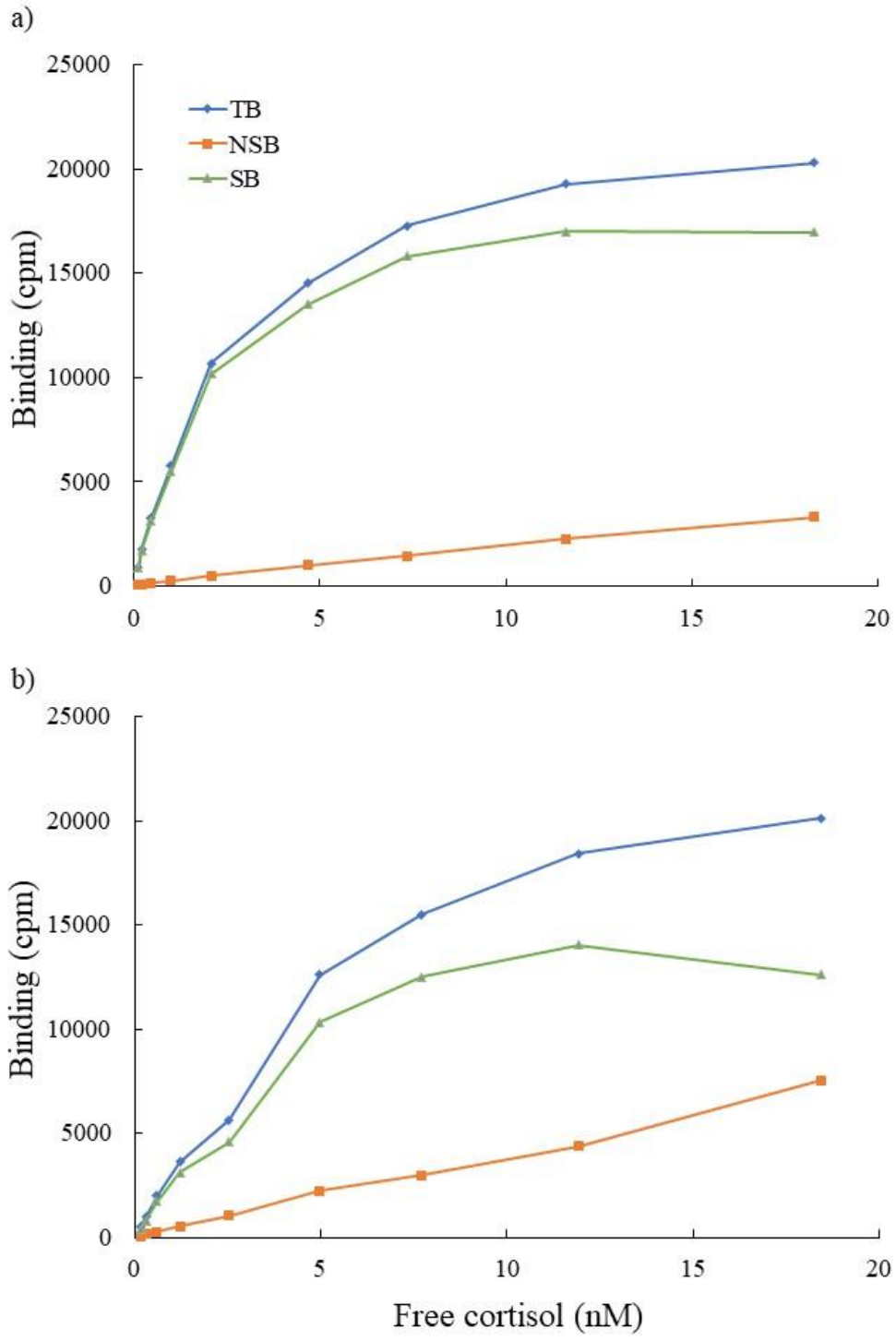
20	Time + T.Blood + Sex + Rep + Suppl	7	839.50	6.72	0.01	-412.55
21	Time + T.Blood + Sex	5	839.76	6.98	0.01	-414.77
22	Time + Age + T.Blood + Sex + Suppl + Sex*Age	10	840.35	7.57	0.00	-409.78
23	Time + Age + T.Blood + Sex + Suppl + Sex*Suppl	9	840.65	7.87	0.00	-411.00
24	Time + T.Blood + Sex + Suppl	6	840.70	7.92	0.00	-414.20
25	Time + T.Blood + Sex + Rep + Suppl + Sex*Suppl	8	841.28	8.50	0.00	-412.38
26	Time + Age + T.Blood + Sex + Suppl + Sex*Age + Sex*Suppl	11	842.18	9.40	0.00	-409.61
27	Time + T.Blood + Sex + Suppl + Sex*Suppl	7	842.46	9.68	0.00	-414.03
28	Time + Age + Sex + Rep + Sex*Age	9	844.69	11.91	0.00	-413.03
29	Time + Age + Sex + Rep + Sex*Rep	8	845.13	12.35	0.00	-414.31
30	Time + Age + Sex + Rep + Suppl + Sex*Age	10	845.96	13.18	0.00	-412.59
31	Time + Age + Sex + Rep	7	846.07	13.29	0.00	-415.84
32	Time + Age + Sex + Rep + Sex*Age + Sex*Rep	10	846.39	13.61	0.00	-412.80
33	Time + Age + Sex + Rep + Suppl + Sex*Rep	9	846.39	13.61	0.00	-413.88
34	Time + Age + T.Blood	6	846.80	14.02	0.00	-417.25
35	Time + Age + T.Blood + Suppl	7	846.87	14.08	0.00	-416.23
36	Time + Age + T.Blood + Rep	7	847.26	14.48	0.00	-416.43
37	Time + Age + Sex + Rep + Suppl	8	847.36	14.57	0.00	-415.42
38	Time + Age + T.Blood + Rep + Suppl	8	847.52	14.74	0.00	-415.50
39	Time + Age + Sex + Rep + Suppl + Sex*Age + Sex*Suppl	11	847.61	14.83	0.00	-412.33
40	Time + Age + Sex + Rep + Suppl + Sex*Age + Sex*Rep	11	847.69	14.91	0.00	-412.37
41	Time + Sex + Rep + Sex*Rep	6	847.72	14.93	0.00	-417.71
42	Time + Age + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	10	847.93	15.15	0.00	-413.57
43	Time + T.Blood + Suppl	5	848.43	15.65	0.00	-419.11
44	Time + T.Blood	4	848.52	15.74	0.00	-420.19
45	Time + Sex + Rep + Suppl + Sex*Rep	7	848.70	15.92	0.00	-417.15
46	Time + Age + Sex + Rep + Suppl + Sex*Suppl	9	849.00	16.21	0.00	-415.18
47	Time + Age + Sex + Rep + Suppl + Sex*Age + Sex*Rep + Sex*Suppl	12	849.29	16.51	0.00	-412.08
48	Time + Age + Sex	6	849.48	16.69	0.00	-418.59
49	Time + Sex + Rep	5	849.66	16.88	0.00	-419.73
50	Time + T.Blood + Rep + Suppl	6	849.71	16.93	0.00	-418.71
51	Time + T.Blood + Rep	5	849.76	16.98	0.00	-419.77
52	Time + Age + Sex + Sex*Age	8	850.19	17.41	0.00	-416.84
53	Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	8	850.24	17.46	0.00	-416.87

54	Time + Age + Sex + Suppl	7	850.30	17.52	0.00	-417.95
55	Time + Sex + Rep + Suppl	6	850.63	17.85	0.00	-419.17
56	Time + Age + Sex + Suppl + Sex*Age	9	850.92	18.14	0.00	-416.14
57	Time + Sex	4	851.14	18.36	0.00	-421.50
58	Time + Sex + Suppl	5	851.92	19.14	0.00	-420.85
59	Time + Age + Sex + Suppl + Sex*Suppl	8	851.97	19.19	0.00	-417.73
60	Time + Sex + Rep + Suppl + Sex*Suppl	7	852.27	19.48	0.00	-418.94
61	Time + Age + Sex + Suppl + Sex*Age + Sex*Suppl	10	852.62	19.83	0.00	-415.92
62	Time + Sex + Suppl + Sex*Suppl	6	853.52	20.74	0.00	-420.61
63	Time + Age + Suppl	6	858.31	25.53	0.00	-423.01
64	Time + Age	5	858.54	25.76	0.00	-424.16
65	Time + Age + Rep + Suppl	7	859.36	26.58	0.00	-422.48
66	Time + Age + Rep	6	859.43	26.65	0.00	-423.57
67	Time + Suppl	4	859.71	26.92	0.00	-425.78
68	Time	3	860.06	27.28	0.00	-426.99
69	Time + Rep + Suppl	5	861.01	28.23	0.00	-425.40
70	Time + Rep	4	861.34	28.55	0.00	-426.60

Appendix 18. Model-averaged beta coefficients for the log-transformed total cortisol of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	**Estimate**	**SE**	**2.5 %**	**97.5 %**
Intercept	3.44	0.31	2.83	4.05
Time	13.25×10^{-4}	2.49×10^{-4}	8.36×10^{-4}	18.15×10^{-4}
Age 5	-0.21	0.24	-0.68	0.27
Age 6-7	-0.04	0.35	-0.73	0.65
T.Blood	15.97×10^{-4}	11.61×10^{-4}	-6.88×10^{-4}	38.82×10^{-4}
Male	-0.24	0.28	-0.80	0.32
Reproductive status	0.47	0.19	0.10	0.85
Reproductive status*Male	-0.19	0.28	-0.74	0.35
Age 5*Male	-0.20	0.33	-0.84	0.44
Age 6-7*Male	-0.37	0.58	-1.50	0.77
Supplementation	0.03	0.10	-0.16	0.22
Supplementation*Male	0.02	0.09	-0.16	0.19

Appendix 19. Saturation binding curves for *Gracilinanus agilis* at a) 4 °C using 1/39 dilution and b) 37 °C using 1/18 dilution of pooled plasma. TB is the total binding curve, NSB is the non-specific binding curve and SB is the specific binding curve, which is calculated by subtracting the NSB from the TB. We did not obtain an adequate curve at 37 °C.



Appendix 20. The complete list of linear models for the maximum binding capacity of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: sex, age class (Age), reproductive status (Rep), time inside trap (Time), time of blood collection (T.Blood), grid, colour of the plasma sample (Colour), the interactions between sex and reproductive status (Sex*Rep), sex and age class (Sex*Age), and sex and grid (Sex*Grid). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Grid	15	3942.88	0.00	0.39	-1955.56
2	Time + Colour + Age + T.Blood + Sex + Rep + Grid	12	3944.68	1.79	0.16	-1959.77
3	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Rep + Sex*Grid	16	3945.01	2.12	0.14	-1955.50
4	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Grid	17	3945.80	2.92	0.09	-1954.77
5	Time + Colour + Age + T.Blood + Sex + Grid + Sex*Grid	14	3946.65	3.76	0.06	-1958.56
6	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Rep	13	3946.85	3.97	0.05	-1959.77
7	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Age	14	3947.37	4.48	0.04	-1958.92
8	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Rep + Sex*Grid	18	3947.68	4.79	0.04	-1954.57
9	Time + Colour + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Rep	15	3949.50	6.62	0.01	-1958.87
10	Time + Colour + Age + T.Blood + Sex + Grid + Sex*Age + Sex*Grid	16	3950.14	7.25	0.01	-1958.07
11	Time + Colour + Age + T.Blood + Sex + Grid	11	3950.18	7.30	0.01	-1963.62
12	Time + Colour + Age + T.Blood + Sex + Grid + Sex*Age	13	3953.43	10.55	0.00	-1963.06
13	Time + Colour + Age + T.Blood + Rep + Grid	11	3958.56	15.68	0.00	-1967.80
14	Time + Colour + Age + T.Blood + Sex + Rep	9	3958.89	16.00	0.00	-1970.12
15	Time + Colour + Age + T.Blood + Sex + Rep + Sex*Age	11	3960.36	17.47	0.00	-1968.70
16	Time + Colour + Age + T.Blood + Sex + Rep + Sex*Rep	10	3960.94	18.06	0.00	-1970.07
17	Time + Colour + Age + T.Blood + Sex + Rep + Sex*Age + Sex*Rep	12	3962.52	19.64	0.00	-1968.70

18	Time + Colour + Age + T.Blood + Rep	8	3965.69	22.81	0.00	-1974.59
19	Time + Colour + Age + T.Blood + Sex	8	3967.03	24.15	0.00	-1975.26
20	Time + Colour + Age + T.Blood + Sex + Sex*Age	10	3969.36	26.48	0.00	-1974.29
21	Time + Age + T.Blood + Sex + Rep + Grid	11	3972.76	29.87	0.00	-1974.90
22	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Grid	14	3972.99	30.11	0.00	-1971.73
23	Time + Colour + Age + T.Blood + Grid	10	3973.91	31.03	0.00	-1976.56
24	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Rep	12	3974.91	32.03	0.00	-1974.89
25	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Rep + Sex*Grid	15	3975.08	32.20	0.00	-1971.66
26	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Age	13	3975.28	32.40	0.00	-1973.98
27	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Grid	16	3975.66	32.77	0.00	-1970.83
28	Time + Age + T.Blood + Sex + Grid + Sex*Grid	13	3975.98	33.09	0.00	-1974.33
29	Time + Age + T.Blood + Sex + Grid	10	3977.15	34.26	0.00	-1978.18
30	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Rep	14	3977.19	34.31	0.00	-1973.83
31	Time + Age + T.Blood + Sex + Rep + Grid + Sex*Age + Sex*Rep + Sex*Grid	17	3977.20	34.32	0.00	-1970.47
32	Time + Age + T.Blood + Sex + Grid + Sex*Age + Sex*Grid	15	3979.41	36.52	0.00	-1973.82
33	Time + Colour + T.Blood + Sex + Rep + Grid + Sex*Grid	13	3980.16	37.27	0.00	-1976.42
34	Time + Age + T.Blood + Sex + Grid + Sex*Age	12	3980.47	37.58	0.00	-1977.67
35	Time + Age + T.Blood + Rep + Grid	10	3980.50	37.61	0.00	-1979.85
36	Time + Colour + T.Blood + Sex + Rep + Grid + Sex*Rep + Sex*Grid	14	3981.60	38.71	0.00	-1976.04
37	Time + Colour + Age + T.Blood	7	3981.71	38.83	0.00	-1983.66
38	Time + Age + T.Blood + Sex + Rep	8	3982.03	39.14	0.00	-1982.76
39	Time + Colour + T.Blood + Sex + Rep + Grid	10	3982.56	39.67	0.00	-1980.89
40	Time + Age + T.Blood + Sex + Rep + Sex*Age	10	3983.41	40.53	0.00	-1981.31
41	Time + Age + T.Blood + Sex + Rep + Sex*Rep	9	3984.11	41.22	0.00	-1982.73
42	Time + Colour + T.Blood + Sex + Rep + Grid + Sex*Rep	11	3984.31	41.43	0.00	-1980.68
43	Time + Age + T.Blood + Rep	7	3985.21	42.33	0.00	-1985.41
44	Time + Age + T.Blood + Sex + Rep + Sex*Age + Sex*Rep	11	3985.55	42.67	0.00	-1981.30

45	Time + Age + T.Blood + Sex	7	3988.67	45.79	0.00	-1987.14
46	Time + Colour + T.Blood + Rep + Grid	9	3990.63	47.75	0.00	-1986.00
47	Time + Age + T.Blood + Sex + Sex*Age	9	3991.13	48.25	0.00	-1986.24
48	Time + Age + T.Blood + Grid	9	3992.35	49.46	0.00	-1986.85
49	Time + Colour + T.Blood + Sex + Rep	7	3994.05	51.16	0.00	-1989.83
50	Time + Colour + T.Blood + Sex + Rep + Sex*Rep	8	3996.14	53.26	0.00	-1989.82
51	Time + Colour + T.Blood + Rep	6	3997.52	54.64	0.00	-1992.61
52	Time + Colour + T.Blood + Sex + Grid + Sex*Grid	12	3997.70	54.81	0.00	-1986.29
53	Time + Age + T.Blood	6	3997.81	54.92	0.00	-1992.75
54	Time + Colour + Age + Sex + Rep + Grid + Sex*Grid	14	4001.17	58.29	0.00	-1985.83
55	Time + Colour + T.Blood + Sex + Grid	9	4002.13	59.24	0.00	-1991.74
56	Time + Colour + Age + Sex + Rep + Grid + Sex*Rep + Sex*Grid	15	4003.25	60.36	0.00	-1985.76
57	Time + Colour + Age + Sex + Rep + Grid	11	4003.79	60.90	0.00	-1990.42
58	Time + Colour + Age + Sex + Rep + Grid + Sex*Age + Sex*Grid	16	4004.56	61.68	0.00	-1985.30
59	Time + Colour + Age + Sex + Grid + Sex*Grid	13	4005.12	62.24	0.00	-1988.91
60	Time + Colour + Age + Sex + Rep + Grid + Sex*Rep	12	4005.93	63.05	0.00	-1990.41
61	Time + Colour + Age + Sex + Rep + Grid + Sex*Age + Sex*Rep + Sex*Grid	17	4006.32	63.43	0.00	-1985.05
62	Time + Colour + Age + Sex + Rep + Grid + Sex*Age	13	4006.97	64.09	0.00	-1989.83
63	Time + Colour + Age + Sex + Grid + Sex*Age + Sex*Grid	15	4009.00	66.12	0.00	-1988.63
64	Time + Colour + Age + Sex + Rep + Grid + Sex*Age + Sex*Rep	14	4009.04	66.16	0.00	-1989.77
65	Time + Colour + Age + Sex + Grid	10	4009.42	66.54	0.00	-1994.32
66	Time + T.Blood + Sex + Rep + Grid + Sex*Grid	12	4011.78	68.89	0.00	-1993.33
67	Time + T.Blood + Sex + Rep + Grid	9	4012.60	69.71	0.00	-1996.98
68	Time + Colour + Age + Sex + Grid + Sex*Age	12	4013.07	70.18	0.00	-1993.98
69	Time + T.Blood + Sex + Rep + Grid + Sex*Rep + Sex*Grid	13	4013.20	70.32	0.00	-1992.94
70	Time + Colour + T.Blood + Sex	6	4013.42	70.54	0.00	-2000.56
71	Time + T.Blood + Sex + Rep + Grid + Sex*Rep	10	4014.31	71.42	0.00	-1996.76
72	Time + Colour + Age + Sex + Rep	8	4015.65	72.77	0.00	-1999.57
73	Time + T.Blood + Rep + Grid	8	4015.74	72.86	0.00	-1999.62
74	Time + Colour + Age + Rep + Grid	10	4016.60	73.71	0.00	-1997.91

75	Time + Colour + Age + Sex + Rep + Sex*Rep	9	4017.73	74.84	0.00	-1999.55
76	Time + Colour + Age + Sex + Rep + Sex*Age	10	4017.73	74.85	0.00	-1998.47
77	Time + Colour + T.Blood + Grid	8	4018.71	75.82	0.00	-2001.10
78	Time + T.Blood + Sex + Rep	6	4019.62	76.73	0.00	-2003.66
79	Time + Colour + Age + Sex + Rep + Sex*Age + Sex*Rep	11	4019.89	77.00	0.00	-1998.47
80	Time + T.Blood + Rep	5	4020.11	77.23	0.00	-2004.95
81	Time + T.Blood + Sex + Rep + Sex*Rep	7	4021.66	78.78	0.00	-2003.63
82	Time + Colour + Age + Rep	7	4022.01	79.13	0.00	-2003.81
83	Time + Colour + T.Blood	5	4023.55	80.67	0.00	-2006.67
84	Time + Colour + Age + Sex	7	4023.79	80.91	0.00	-2004.70
85	Time + T.Blood + Sex + Grid + Sex*Grid	11	4025.08	82.20	0.00	-2001.07
86	Time + Colour + Age + Sex + Sex*Age	9	4026.62	83.73	0.00	-2003.99
87	Time + T.Blood + Sex + Grid	8	4027.58	84.69	0.00	-2005.53
88	Time + Age + Sex + Rep + Grid + Sex*Grid	13	4029.18	86.30	0.00	-2000.94
89	Time + Age + Sex + Rep + Grid	10	4029.84	86.95	0.00	-2004.53
90	Time + Age + Sex + Rep + Grid + Sex*Rep + Sex*Grid	14	4031.23	88.35	0.00	-2000.86
91	Time + Age + Sex + Rep + Grid + Sex*Rep	11	4031.96	89.08	0.00	-2004.51
92	Time + Colour + Age + Grid	9	4032.11	89.22	0.00	-2006.73
93	Time + Age + Sex + Rep + Grid + Sex*Age + Sex*Grid	15	4032.14	89.26	0.00	-2000.21
94	Time + Age + Sex + Grid + Sex*Grid	12	4032.42	89.54	0.00	-2003.65
95	Time + Age + Sex + Rep + Grid + Sex*Age	12	4032.69	89.80	0.00	-2003.79
96	Time + Age + Sex + Rep + Grid + Sex*Age + Sex*Rep + Sex*Grid	16	4033.55	90.66	0.00	-1999.79
97	Time + Age + Sex + Grid	9	4034.48	91.59	0.00	-2007.92
98	Time + Age + Sex + Rep + Grid + Sex*Age + Sex*Rep	13	4034.51	91.63	0.00	-2003.60
99	Time + T.Blood + Sex	5	4034.85	91.97	0.00	-2012.32
100	Time + Age + Sex + Grid + Sex*Age + Sex*Grid	14	4036.11	93.23	0.00	-2003.30
101	Time + Colour + Sex + Rep + Grid + Sex*Grid	12	4036.62	93.74	0.00	-2005.76
102	Time + T.Blood + Grid	7	4036.96	94.08	0.00	-2011.28
103	Time + Age + Sex + Rep	7	4037.20	94.32	0.00	-2011.40
104	Time + Age + Rep + Grid	9	4037.22	94.34	0.00	-2009.29
105	Time + Colour + Sex + Rep + Grid + Sex*Rep + Sex*Grid	13	4038.06	95.18	0.00	-2005.38
106	Time + Age + Sex + Grid + Sex*Age	11	4038.07	95.19	0.00	-2007.57
107	Time + Colour + Age	6	4038.10	95.22	0.00	-2012.90
108	Time + Age + Sex + Rep + Sex*Age	9	4039.01	96.13	0.00	-2010.19
109	Time + Age + Sex + Rep + Sex*Rep	8	4039.28	96.40	0.00	-2011.39
110	Time + Colour + Sex + Rep + Grid	9	4039.87	96.99	0.00	-2010.62

111	Time + T.Blood	4	4040.08	97.20	0.00	-2015.97
112	Time + Age + Rep	6	4040.38	97.49	0.00	-2014.04
113	Time + Age + Sex + Rep + Sex*Age + Sex*Rep	10	4041.10	98.21	0.00	-2010.16
114	Time + Colour + Sex + Rep + Grid + Sex*Rep	10	4041.63	98.74	0.00	-2010.43
115	Time + Age + Sex	6	4043.96	101.08	0.00	-2015.83
116	Time + Age + Sex + Sex*Age	8	4046.79	103.91	0.00	-2015.14
117	Time + Colour + Rep + Grid	8	4047.59	104.70	0.00	-2015.54
118	Time + Age + Grid	8	4049.50	106.62	0.00	-2016.50
119	Time + Colour + Sex + Rep	6	4049.53	106.65	0.00	-2018.62
120	Time + Colour + Sex + Rep + Sex*Rep	7	4051.60	108.72	0.00	-2018.61
121	Time + Colour + Rep	5	4052.90	110.01	0.00	-2021.35
122	Time + Age	5	4053.29	110.40	0.00	-2021.54
123	Time + Colour + Sex + Grid + Sex*Grid	11	4053.51	110.63	0.00	-2015.29
124	Time + Colour + Sex + Grid	8	4058.51	115.63	0.00	-2021.01
125	Time + Sex + Rep + Grid + Sex*Grid	11	4066.63	123.75	0.00	-2021.85
126	Time + Sex + Rep + Grid + Sex*Rep + Sex*Grid	12	4068.06	125.17	0.00	-2021.47
127	Time + Colour + Sex	5	4068.19	125.30	0.00	-2028.99
128	Time + Sex + Rep + Grid	8	4068.32	125.44	0.00	-2025.91
129	Time + Sex + Rep + Grid + Sex*Rep	9	4070.03	127.15	0.00	-2025.70
130	Time + Rep + Grid	7	4071.48	128.59	0.00	-2028.54
131	Time + Sex + Rep	5	4073.74	130.85	0.00	-2031.77
132	Time + Rep	4	4074.36	131.48	0.00	-2033.11
133	Time + Colour + Grid	7	4075.01	132.13	0.00	-2030.31
134	Time + Sex + Rep + Sex*Rep	6	4075.76	132.87	0.00	-2031.73
135	Time + Colour	4	4078.49	135.60	0.00	-2035.17
136	Time + Sex + Grid + Sex*Grid	10	4079.88	136.99	0.00	-2029.55
137	Time + Sex + Grid	7	4083.07	140.18	0.00	-2034.34
138	Time + Sex	4	4088.83	145.94	0.00	-2040.35
139	Time + Grid	6	4092.75	149.87	0.00	-2040.23
140	Time	3	4094.50	151.62	0.00	-2044.21

Appendix 21. Model-averaged beta coefficients for the maximum binding capacity of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	579.27	95.36	391.83	766.70
Time	0.06	0.05	-0.04	0.17
Dark plasma	-154.91	27.47	-208.98	-100.84
Age 5	-89.44	44.58	-177.16	-1.72
Age 6-7	-239.05	63.71	-364.42	-113.67
T.Blood	0.62	0.25	0.14	1.11
Male	-237.27	100.93	-435.44	-39.10
Reproductive status	-78.37	34.70	-149.38	2.65
JB1	-232.25	80.41	-390.25	-74.26
JB2	-280.20	88.49	-453.97	-106.42
JB4	-228.92	87.91	-401.62	-56.22
JB1*Male	164.03	83.34	-81.09	319.38
JB2*Male	224.64	80.88	-75.45	401.80
JB4*Male	201.64	88.10	-83.52	376.45
Reproductive status*Male	-14.96	54.56	-52.83	46.76
Age 5*Male	2.23	67.03	-49.46	50.09
Age 6-7*Male	126.18	113.81	-102.87	138.74

Appendix 22. The complete list of linear models for the log-transformed free cortisol of *Gracilinanus agilis* in four patches of "cerradão", two with food supplementation experiment and two controls. The effects were: sex, reproductive status (Rep), reproductive season (Seas), time inside trap (Time), time of blood collection (T.Blood), food supplementation experiment (Suppl), the interactions between sex and reproductive status (Sex*Rep), sex and reproductive season (Sex*Seas), and sex and experiment (Sex*Suppl). The symbol # is the rank of the model, K is the number of parameters, AICc is the Akaike's information criteria corrected for small samples, ΔAICc is the difference between the values of AICc of each model and the first model, w is the Akaike weight, and LL is the log-likelihood of the models. Selected models have their rank numbers in bold.

#	Models	K	AICc	ΔAICc	w	LL
1	Time + Seas + T.Blood + Suppl	7	1357.08	0.00	0.23	-671.34
2	Time + Seas + T.Blood + Rep + Suppl	8	1357.83	0.76	0.16	-670.66
3	Time + Seas + T.Blood + Sex + Rep + Suppl	9	1358.66	1.59	0.10	-670.01
4	Time + Seas + T.Blood + Sex + Suppl	8	1358.89	1.81	0.09	-671.18
5	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Rep	10	1359.79	2.71	0.06	-669.49
6	Time + Seas + T.Blood	6	1360.40	3.32	0.04	-674.05
7	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Suppl	10	1360.66	3.59	0.04	-669.93
8	Time + Seas + T.Blood + Sex + Suppl + Sex*Seas	10	1360.66	3.59	0.04	-669.93
9	Time + Seas + T.Blood + Sex + Suppl + Sex*Suppl	9	1360.88	3.80	0.03	-671.11
10	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Seas	11	1361.38	4.30	0.03	-669.21
11	Time + Seas + T.Blood + Rep	7	1361.42	4.35	0.03	-673.51
12	Time + Seas + T.Blood + Sex + Rep	8	1361.70	4.62	0.02	-672.59
13	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	11	1361.83	4.76	0.02	-669.44
14	Time + Seas + T.Blood + Sex	7	1361.86	4.78	0.02	-673.73
15	Time + Seas + T.Blood + Sex + Suppl + Sex*Seas + Sex*Suppl	11	1362.75	5.68	0.01	-669.90
16	Time + Seas + T.Blood + Sex + Rep + Sex*Rep	9	1362.79	5.72	0.01	-672.07
17	Time + T.Blood + Sex + Rep + Suppl	7	1363.36	6.28	0.01	-674.48
18	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Seas + Sex*Suppl	12	1363.48	6.40	0.01	-669.17
19	Time + Seas + T.Blood + Sex + Sex*Seas	9	1363.53	6.45	0.01	-672.44
20	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Seas + Sex*Rep	12	1363.56	6.48	0.01	-669.21

21	Time + T.Blood + Sex + Rep + Suppl + Sex*Rep	8	1364.12	7.04	0.01	-673.80
22	Time + Seas + T.Blood + Sex + Rep + Sex*Seas	10	1364.30	7.22	0.01	-671.75
23	Time + T.Blood + Sex + Rep + Suppl + Sex*Suppl	8	1365.03	7.96	0.00	-674.26
24	Time + T.Blood + Rep + Suppl	6	1365.58	8.50	0.00	-676.64
25	Time + Seas + T.Blood + Sex + Rep + Suppl + Sex*Seas + Sex*Rep + Sex*Suppl	13	1365.67	8.59	0.00	-669.17
26	Time + T.Blood + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	9	1365.87	8.79	0.00	-673.61
27	Time + Seas + T.Blood + Sex + Rep + Sex*Seas + Sex*Rep	11	1366.46	9.38	0.00	-671.75
28	Time + T.Blood + Sex + Rep	6	1368.06	10.99	0.00	-677.88
29	Time + T.Blood + Sex + Rep + Sex*Rep	7	1368.74	11.66	0.00	-677.17
30	Time + T.Blood + Suppl	5	1371.80	14.72	0.00	-680.79
31	Time + T.Blood + Rep	5	1372.00	14.92	0.00	-680.89
32	Time + T.Blood + Sex + Suppl	6	1372.43	15.35	0.00	-680.06
33	Time + T.Blood + Sex + Suppl + Sex*Suppl	7	1374.10	17.02	0.00	-679.85
34	Time + Seas + Suppl	6	1374.37	17.30	0.00	-681.04
35	Time + Seas + Rep + Suppl	7	1374.96	17.88	0.00	-680.28
36	Time + Seas + Sex + Rep + Suppl	8	1375.86	18.78	0.00	-679.67
37	Time + Seas + Sex + Suppl	7	1376.23	19.16	0.00	-680.92
38	Time + Seas + Sex + Rep + Suppl + Sex*Rep	9	1376.98	19.90	0.00	-679.17
39	Time + Seas	5	1377.54	20.46	0.00	-683.66
40	Time + Seas + Sex + Rep + Suppl + Sex*Suppl	9	1377.84	20.77	0.00	-679.60
41	Time + T.Blood + Sex	5	1377.85	20.78	0.00	-683.82
42	Time + Seas + Sex + Suppl + Sex*Seas	9	1377.95	20.87	0.00	-679.65
43	Time + Seas + Sex + Suppl + Sex*Suppl	8	1378.22	21.14	0.00	-680.85
44	Time + T.Blood	4	1378.27	21.20	0.00	-685.07
45	Time + Seas + Rep	6	1378.43	21.35	0.00	-683.07
46	Time + Seas + Sex + Rep + Suppl + Sex*Seas	10	1378.55	21.47	0.00	-678.88
47	Time + Seas + Sex + Rep	7	1378.76	21.68	0.00	-682.18
48	Time + Seas + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	10	1379.01	21.94	0.00	-679.11
49	Time + Seas + Sex	6	1379.07	21.99	0.00	-683.38
50	Time + Seas + Sex + Rep + Sex*Rep	8	1379.89	22.81	0.00	-681.69
51	Time + Seas + Sex + Suppl + Sex*Seas + Sex*Suppl	10	1380.03	22.95	0.00	-679.62
52	Time + Seas + Sex + Rep + Suppl + Sex*Seas + Sex*Suppl	11	1380.63	23.55	0.00	-678.84
53	Time + Sex + Rep + Suppl	6	1380.66	23.58	0.00	-684.18
54	Time + Seas + Sex + Rep + Suppl + Sex*Seas + Sex*Rep	11	1380.71	23.63	0.00	-678.88

55	Time + Seas + Sex + Sex*Seas	8	1380.75	23.67	0.00	-682.12
56	Time + Sex + Rep + Suppl + Sex*Rep	7	1381.37	24.29	0.00	-683.49
57	Time + Seas + Sex + Rep + Sex*Seas	9	1381.39	24.32	0.00	-681.38
58	Time + Sex + Rep + Suppl + Sex*Suppl	7	1382.35	25.27	0.00	-683.98
59	Time + Rep + Suppl	5	1382.73	25.65	0.00	-686.26
60	Time + Seas + Sex + Rep + Suppl + Sex*Seas + Sex*Rep + Sex*Suppl	12	1382.81	25.73	0.00	-678.84
61	Time + Sex + Rep + Suppl + Sex*Rep + Sex*Suppl	8	1383.13	26.05	0.00	-683.31
62	Time + Seas + Sex + Rep + Sex*Seas + Sex*Rep	10	1383.54	26.46	0.00	-681.37
63	Time + Sex + Rep	5	1385.19	28.12	0.00	-687.49
64	Time + Sex + Rep + Sex*Rep	6	1385.86	28.78	0.00	-686.78
65	Time + Rep	4	1389.00	31.93	0.00	-690.43
66	Time + Suppl	4	1389.45	32.37	0.00	-690.66
67	Time + Sex + Suppl	5	1390.28	33.20	0.00	-690.03
68	Time + Sex + Suppl + Sex*Suppl	6	1391.99	34.91	0.00	-689.85
69	Time + Sex	4	1395.50	38.43	0.00	-693.68
70	Time	3	1395.69	38.61	0.00	-694.80

Appendix 23. Model-averaged beta coefficients for the log-transformed free cortisol of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	-0.38	0.72	-1.79	1.04
Time	2.57×10^{-3}	0.62×10^{-3}	1.35×10^{-3}	3.79×10^{-3}
Reproductive season	0.87	0.51	-0.12	1.87
Post-reproductive season	2.23	0.69	0.87	3.59
T.Blood	0.25×10^{-3}	2.95×10^{-3}	-5.55×10^{-3}	6.05×10^{-3}
Supplementation	0.64	0.39	-0.14	1.41
Reproductive status	0.33	0.49	-0.64	1.29
Male	-0.09	0.32	-0.72	0.54
Reproductive status*Male	-0.06	0.27	-0.58	0.47
Supplementation*Male	-0.02	0.21	-0.44	0.39
Reproductive season*Male	-0.07	0.30	-0.65	0.52
Post-reproductive season*Male	-0.05	0.49	-1.01	0.91

Appendix 1. Mean ± standard deviation of haemoglobin concentration (Hg), hematocrit (Hct) and body condition (SMI) of each group of *Gracilinanus agilis* during the study from April 2015 to December 2016. Number of records in parentheses.

	Control areas						Manipulated areas						Total		
	Wet season			Dry season			Wet season			Dry season					
	Hg (g/dL)	Hct (%)	SMI (g)	Hg (g/dL)	Hct (%)	SMI (g)	Hg (g/dL)	Hct (%)	SMI (g)	Hg (g/dL)	Hct (%)	SMI (g)	Hg (g/dL)	Hct (%)	SMI (g)
Non-parasitized															
F	13.0 ± 1.4 (23)	38.2 ± 4.0 (23)	18.1 ± 2.8 (20)	14.2 ± 1.7 (26)	41.5 ± 5.4 (26)	16.8 ± 2.1 (29)	14.4 ± 1.5 (46)	42.3 ± 4.5 (46)	17.3 ± 2.4 (45)	14.9 ± 1.6 (38)	43.4 ± 4.3 (37)	16.8 ± 2.2 (39)	14.3 ± 1.7 (133)	41.8 ± 4.9 (132)	17.2 ± 2.4 (133)
M	13.7 ± 1.4 (45)	40.3 ± 4.1 (45)	21.1 ± 3.4 (45)	15.1 ± 1.8 (40)	44.1 ± 5.0 (39)	21.0 ± 2.8 (40)	14.5 ± 1.3 (41)	42.6 ± 3.9 (41)	21.3 ± 4.6 (39)	15.5 ± 1.8 (47)	45.0 ± 4.9 (45)	19.5 ± 2.3 (47)	14.7 ± 1.7 (173)	43.0 ± 4.8 (170)	20.7 ± 3.4 (171)
Parasitized															
F	12.0 ± 1.7 (12)	35.3 ± 5.1 (12)	18.2 ± 2.4 (11)	9.4 ± 0.8 (2)	27.5 ± 2.1 (2)	20.0 ± 6.5 (3)	12.7 ± 2.2 (31)	37.5 ± 6.6 (31)	18.4 ± 3.3 (29)	11.6 ± 1.8 (8)	33.9 ± 5.2 (8)	17.1 ± 2.7 (8)	12.3 ± 2.1 (53)	36.0 ± 6.3 (53)	18.2 ± 3.2 (51)
M	12.3 ± 1.9 (24)	36.3 ± 5.7 (24)	21.9 ± 5.4 (23)	12.4 ± 1.8 (6)	36.5 ± 5.2 (6)	20.9 ± 3.0 (7)	12.8 ± 2.5 (14)	37.6 ± 7.3 (14)	22.0 ± 3.9 (13)	9.1 ± 0.8 (2)	26.5 ± 2.1 (2)	17.2 ± 3.3 (2)	12.3 ± 2.1 (46)	36.3 ± 6.3 (46)	21.6 ± 4.6 (45)
Total															
	13.0 ± 1.7 (104)	38.3 ± 5.0 (104)	20.4 ± 4.0 (99)	14.4 ± 2.1 (74)	42.1 ± 6.0 (73)	19.4 ± 3.4 (79)	13.9 ± 1.9 (132)	40.8 ± 5.7 (132)	19.3 ± 4.0 (126)	14.8 ± 2.2 (95)	43.0 ± 6.0 (92)	18.2 ± 2.6 (96)	14.0 ± 2.1 (405)	40.9 ± 5.9 (401)	19.3 ± 3.7 (400)

Appendix 2. Model-averaged beta coefficients for the haemoglobin concentration of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	13.00	1.49	10.07	15.93
Botfly	-7.76	2.45	-12.57	-2.95
Max.Temp	0.13	0.04	0.05	0.20
Humid	-0.03	0.01	-0.05	-0.02
Botfly*Humid	0.07	0.02	0.03	0.11
Botfly*Max.Temp	0.02	0.06	-0.09	0.13

Appendix 3. Model-averaged beta coefficients for body condition of *Gracilinanus agilis*, their respective unconditional standard errors (SE) and their lower and upper 95 % confidence limits.

Coefficient	Estimate	SE	2.5 %	97.5 %
Intercept	16.34	6.68	3.23	29.45
Male	3.42	0.32	2.79	4.05
Max.Temp	-0.05	0.25	-0.53	0.43
Min.Temp	0.41	0.47	-0.52	1.34
Min.Temp*Max.Temp	-0.01	0.02	-0.04	0.03