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Can we improve maternal care in sows? Maternal behavioural traits important for piglet survival in loose-housed sow herds

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ABSTRACT

The primary objective of this survey was to investigate the relationship between qualitative maternal behavioural scores (nest building activities, sow communication and sow carefulness), piglet mortality and the number of weaned piglets on commercial farms with loose-housed lactating (Norsvin Landrace × Yorkshire) sows. Secondly, the impact of these scores on productivity compared to the physical condition of sows (movement disorders, body condition, and shoulder lesions) was assessed. Data on maternal care behaviours and physical condition were collected on 895 sows from 45 commercial farms. Farmers scored sows on their physical condition (movement disorder: MD, body condition: BCS, shoulder lesions: SL) and qualitative maternal care behaviours (nest building activities prior to farrowing: NBA; and sow communication: SC, and carefulness: SCR after farrowing, while sows were standing, moving and just before lying down). There was a low positive correlation between NBA and SC ($r = 0.102$; $P = 0.026$) and between NBA and SCR ($r = 0.149$; $P = 0.010$), but a high positive between SC and SCR ($r = 0.565$; $P < 0.001$). Higher SC and SCR were associated with lower piglet mortality ($P < 0.001$, $P = 0.013$, respectively), and a greater number of weaned piglets were associated with higher scores for NBA ($P = 0.009$), SC ($P < 0.001$) and SCR ($P = 0.009$). Maternal care behaviour had a greater impact on piglet mortality and the number of weaned piglets than sow physical condition (MD, BCS, SL). We tested 7 different models (combinations of behavioural scores) and compared their relative predictive accuracies using Akaike information criteria (AIC). The model including SC and SCR had the best predictive accuracy for piglet mortality/weaned piglets. There was between-sow variation in maternal care behaviours (SC and SCR) and both were unaffected by litter size. Since these behaviours were also easy to score for the farmers, combining SC and SCR have the

greatest potential to be tested in nucleus herds for calculation of genetic variation and heritability, and should be taken into account into future breeding programmes for sows.

Keywords: nest building, piglet mortality, sow carefulness, sow communication, sow physical condition

INTRODUCTION

Although modern maternal sow breeding programmes have resulted in more piglets weaned (Ocepek et al., 2017), piglet mortality is still a major welfare and economic issue as approximately 20% of born piglets are dead or eventually died before weaning (Ocepek et al., 2016a). Piglet survival until weaning depends on interacting factors such as the physical environment (Andersen et al., 2007), management routines (Andersen et al., 2007, Rosvold et al., 2016), piglet viability (Pedersen et al., 2011), and maternal behaviour (Andersen et al. 2005; Ocepek and Andersen, 2017). Promoting maternal care behaviours in sows kept loose during farrowing and lactation, can result in fewer piglet deaths, improve the welfare of pigs and, thus, contribute to more sustainable breeding.

Despite attempts to promote maternal care traits (Grandinson et al., 2003; Lovendahl et al., 2005; Vangen et al., 2005), there are methodological challenges with measuring traits accurately. Recently, Ocepek and Andersen (2017) defined simple qualitative scorings of maternal care behaviours important for piglet survival (sow nest building, sow communication and carefulness).

To be useful under commercial conditions, these scores need to be simple and practical for farmers to be able to assess those traits on the farm.

The primary objective of this survey was to investigate the relationship between qualitative maternal behavioural scores (nest building activities, sow communication and sow carefulness), piglet mortality and the number of weaned piglets on commercial farms with loose-housed lactating (Norsvin Landrace × Yorkshire) sows. Secondly, the impact of these scores on productivity compared to the physical condition of sows (movement disorders, body condition, and shoulder lesions) was assessed.

MATERIAL AND METHODS

The present experiment was conducted in accordance with the laws and regulations controlling experiments and procedures on live animals in Norway and was approved by the Norwegian Animal Research Authority, following the Norwegian Regulation on Animal Experimentation Act of 1996.

Farm selection and study design

Forty-five commercial pig farms were visited, meeting the following criteria: 1) had loose-housed lactating Norsvin Landrace × Swedish Yorkshire sows; 2) were located within the three major pig production regions in Norway (East, n = 16; West, n = 12; and Middle, n = 17); 3) differed in size (the numbers of litters born per year in each herd (Small = 30 – 110 litter per year (n = 14); Medium = 110 – 200 (n = 18); Large = 200 - … (n = 13); and 4) kept farm production records in Ingris (The National Efficiency Control Database, administrated by Animalia (Norwegian Meat and Poultry Research Centre) and Norsvin (Norwegian Pig Breeding Association)). To investigate the importance of sow behavioural and physical characteristics, an on-farm registration form was designed. The registration form, together with instructions (see below – 'On farm registration'), were sent to the farmers approximately one month before the onset of the study, which was followed up by a phone call and farm visitation by one of the trained researchers (MO or EMR). During the visit, additional information regarding environment and management routines on the farm was collected. The completed registration forms with behavioural and physical scores for each sow from one batch on the farm was sent to us, whereas the following production records for the same sows were collected from the Ingris database: parity number; number of live-born piglets; number of piglets that died after farrowing but before weaning; and number of weaned piglets (defined as number of the sow's own live-born piglets plus the number of piglets fostered on minus the number of piglets fostered off and minus the number of piglets that died after farrowing but before weaning).

On farm registration

The on farm registration form included qualitative behavioural scores developed by Ocepek and Andersen (2017), and physical scores as tested in Ocepek et al. (2016a).

Sow - physical scores. Sow physical condition scores (movement disorder (**MD**), body condition (**BCS**), shoulder lesions (**SL**)) were assessed while moving the sows from the gestation unit to the farrowing unit. MD were scored using a scale from 1 to 3 (1: normal, without visible movement problems; 2: marked movement disorders, walks slowly or limps in a stiff way; 3: severe movement problems, can hardly get up from a lying position or walk; Ocepek et al., 2016a). BCS was assessed using a grading scale from 1 to 5 and half points were used (Fig. 1). Presence of SL was assessed using a five-category scale. Score 0 was used when the shoulder region was intact, with healthy skin and without reddening or swelling. If SL were determined, scores from 1 to 4 were used (Fig. 2).

Sow - behavioural scores. Nest building score (**NBA**) was assessed after sows began to display preparation signs of farrowing (restless behaviour, nesting behaviour, and/or teats ejecting milk at hand milking) during morning or afternoon feeding within the last 24 hours before expected parturition. The NBA score included rooting (nosing in the nest building material on the floor), pawing (leg in the nest building material on the floor), carrying nest building material, and chewing nest building material while the sow was active (standing or moving around) using a scale from 1 to 3 as presented in table 1. Sow communication (**SC**, sniffing, grunting, and nudging) and sow carefulness (**CSR**) was assessed immediately after morning or afternoon feeding on day one or two postpartum while sows changed position, moved around and at the moment the

sow was about to lie down. Both scores, SC and SCR, were assessed with a scale from 1 to 4 as presented in table 1.

Housing and management routines

Housing. According to the Norwegian animal welfare regulations, gestation stalls and farrowing crates are banned (www.lovdata.no). During pregnancy, all sows must be kept in group-housing systems from four weeks after service. From day three before expected parturition, sows shall have access to nest building material. During farrowing and lactation, sows must be kept loose in a farrowing pen larger than 6.0 m^2 with a width of more than 1.8 m, allowing the sow to turn around. Plenty of the litter should be on the pen floor. Furthermore, the farrowing pen must be designed in a way that provides sufficient space for the sows during farrowing (and for farrowing assistant if needed) and a separate microclimate for the piglets that is inaccessible to the sow. Exceptions regarding confinement can be made for restless or aggressive sows but only for one week (from parturition until seventh day afterwards) in crates longer than 2.0 m with a width of 0.7 to 0.8 m, depending on the sow's size.

The mean size of the farrowing pens in the 45 farms was 7.5 ± 0.1 m^2 (range 6.0 - 10.5 m^2), with a mean width of 2.3 ± 0.0 (range 1.9 - 3.4) and none of the sows were crated at any time. Each sow was on average provisioned with 2.2 ± 0.32 kg (range 0.1 - 10 kg) of nest building material.

Management routines. The farms can be divided into four management groups (farms without routines, farms conducting more than two contacts per day with the sows (defined as touching, talking to and/or being present near the sow in the farrowing pen), farms performing three management routines at farrowing (defined as farmer presence at 80 – 100 % of farrowing's, drying and massaging newborn piglets, and practicing split suckling) and farms conducting both, contact with the sows and all management routines (Rosvold et al., 2016). All groups were included in the present study. Out of 45 farms, 10 farms did not perform any of the four management routines, 11 farms had contact with sows more than 2 times per day, 11 farms performed the three mentioned routines at farrowing, and 13 farms combined contact and the routines.

Collected data

The data contained information on 895 sows out of which 20 sows without BCS, 17 without MD, 18 without SL, 15 without NBA, 3 without SC.

To facilitate subsequent calculations, BCS scores were transformed into values from 1 to 3; thin (1.0-2.5), normal (3.0-3.5), fat (4.0-5.0). Around 13% percent of the sows were thin, 63 % of the sows were categorised as normal and 24 % of the sows were classified as fat. Approximatively, 93% of the sows had no signs of movement disorders, 6% were slower (limping, score 2), and less than 1% had severe movement problems (score 3). Furthermore, around 93% of the sows had healthy skin without SL, more than 6% were classified with initial shoulder injuries and less than 1% with moderate skin lesions (score 2) as well as serious shoulder lesions (score 3). As there

were very few higher scores for MD and SL, both traits were categorized into two classes (sows without MD and/or SL = class 1; sow with MD and/or SL = class 2).

Statistical analysis

Descriptive statistics were presented as arithmetic mean and SE. Statistical analyses were performed using SAS 9.4 statistical software program (SAS Institute. Inc., Cary, NC).

The effects of physical condition (MD, BCS, SL) as fixed effects (class variables) on behavioural scores (NBA, SC, SCR) were analysed using the GLIMMIX procedure (Multinomial distribution). Parity and litter size were included as continuous variables. Farm was specified as a random effect.

Polychoric correlation coefficients were used when testing the relationships between sow behavioural scores (NBA, SC, SCR).

The effect of behavioural (NBA, SC, SCR) and physical (MD, BCS, SL) scores as fixed class variables on piglet mortality and the number of weaned piglets were analysed using a mixed model (Proc Mixed). Farm (class variable) and parity and litter size (continuous variables) were included in the model. Sow nested within the farm was specified as a random effect.

To find the best combination of behavioural scores (7 combinations of defined scores), the model with the best relative predictive accuracy for piglet mortality/weaned piglets was determined using

213 the Akaike information criterion (AIC). The AIC values were transformed to Akaike weights to
214 provide the relative probability of each model having the best predictive accuracy.

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216

217 # RESULTS

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220 ## *Descriptive data*

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223 The mean number of sows per farm in a farrowing batch was 20.0 ± 0.9 (range 10 - 31), and sow
224 parity ranged from 1 to 9, with 33.9 % of the sows in first, 23.3 % in second, 18.7 % in third, 12.5
225 % in fourth, 7.1 % in fifth, 2.3 in sixth, 1.6 % in seventh, 0.3 % in eight, and 0.3 % in ninth parity.
226 The mean number of piglets at birth was 14.1 ± 0.1 (range 3 - 23) and at weaning 11.6 ± 0.1 (Fig.
227 3a), whereas the overall mean postnatal mortality was 16.3 ± 0.5% (Fig 3b).

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230 ## *Sow behaviour*

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233 ***Nest building behaviour score (NBA).*** During the last 24 hours before parturition, 22.8 % of the
234 sows showed no nest building activities (score 1), whereas 28.0 % of the sows spent the majority
235 of their time on NBA (score 3; Fig. 4a). There was no significant effect of parity, nor litter size on
236 NBA (Table 2). Sows with MD had a lower NBA than sows without (Table 2; Fig. 5a). Sows with
237 normal BCS had higher NBA compared to thin or fat sows (Table 2; Fig. 6). NBA was unaffected
238 by SL (Table 2).

239

240

241 ***Sow communication score (SC).*** While 34.9 % of the sows communicated every time they
242 changed position or moved around (score 4), 17.0 % of the sows communicated less than 50% of
243 the time they changed position or moved around (score 2; Fig. 4b). There was a negative
244 relationship between parity and SC (Table 2; Fig. 7a). SC was not significantly affected by litter
245 size (Table 2). Sows with MD had lower SC than sows without (Table 2; Fig. 5b). SC was not
246 significant effect by BCS nor SL (Table 2).

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248

249 ***Sow carefulness score (SCR).*** More than half of the sows (50.1 %) were classified as attentive,
250 careful and protective in more than 50% of the events when they changed position or moved
251 around (score 3), while 30.3 % of the sows were categorized as attentive, careful and protective
252 every time they changed position or moved around (score 4; Fig. 4c). There was a negative
253 relationship between parity and SCR (Table 2; Fig. 7b). SCR was not significantly affected by
254 litter size (Table 2). Sows with MD had lower SCR than sows without (Table 2; Fig. 5c). SCR was
255 not significantly affected by BCS nor SL (Table 2).

256

Interrelationship between behavioural scores. There was a low positive correlation between NBA and SC ($r = 0.102$; $P = 0.026$) and SCR ($r = 0.149$; $P = 0.010$) and a high positive correlation between SC and SCR ($r = 0.565$; $P < 0.001$).

Production parameters

Postnatal mortality. There was no significant effect of NBA on postnatal mortality (Table 3). Sows with higher SC had lower postnatal mortality (Table 3; Fig. 8a). The higher the SCR, the lower the postnatal mortality (Table 3; Fig. 8b). There was no significant effect of parity on postnatal mortality (Table 3). Mortality significantly increases in larger litters (Table 3; Fig. 9). Postnatal mortality was not significantly affected by sow physical condition (MD, BCS, and SL, Table 3). There was significant difference in postnatal mortality between farms (Table 3).

Number of weaned piglets. A high degree of NBA (Table 3; Fig. 10a), SC (Table 3; Fig. 10b) and SCR (Table 3; Fig. 10c) was associated with more piglets weaned. There was no significant effect of parity on number of weaned piglets (Table 3). More piglets were weaned in larger litters (Table 3; Fig. 11). Number of weaned piglets was not significantly affected by MD, BCS, and SL (Table 3). There was a significant difference between farms in number of weaned piglets (Table 3).

Predictive accuracy of behavioural scores for production parameters. Out of the 7 models (all combinations of defined scores), we found that model 6 including SC and SCR had the best predictive accuracy (lowest AIC values and highest AIC weights) for piglet mortality/weaned piglets (Table 4).

DISCUSSION

In accordance with recent experimental study that documented a clear relationship between maternal behavioural scores and piglets survival (Ocepek and Andersen, 2017), we succeed in finding similar results on 45 commercial farms with 895 LY sows. While an increased nest building activity (NBA) resulted in an increased number of weaned piglets, sow communication (SC) and carefulness (SCR) had the strongest effects on both mortality and the number of weaned piglets in loose-housed sows. In fact, the maternal behavioural scores had a stronger impact on piglet survival per se than physical traits such as movement disorders (MD), body condition score (BCS) and lesion score (SL). However, these physical traits along with parity, influenced the behavioural scores, indicating that the physical condition of the sow will affect maternal skills.

Our results showed that farmers understood the qualitative scoring system just by verbal advice (without on-site pre-training) and that the behavioural scores were important predictors for piglet survival. Using model selection, our results showed that a combination of SC and SCR had the

303 best predictive accuracy for determining levels of piglet mortality/weaned piglets. Thus, these
304 maternal care behaviours (SC and SCR) could be implemented in the breeding goal as a novel
305 approach to improve piglet survival and thus ensure future sustainable pig breeding.
306
307 Sows that communicated to large extent with their piglets and were careful with their own
308 movements when piglets were in close proximity (i.e. high scores for SC and SCR), had
309 substantially lower postnatal mortality and weaned more piglets. In Ocepek and Andersen (2017),
310 sows with higher SC and SCR were capable of weaning more piglets mainly due to fewer deaths
311 from maternal crushing. Additionally, higher SC was associated with a lower proportion of starved
312 piglets. Starvation and crushing constitutes more than 60% of all piglet deaths in loose-hosed sows
313 (Andersen et al., 2006; Vasdal et al., 2011; Ocepek et al., 2016b). Our study suggests that there
314 could be a great potential in selecting for maternal care directly. Sows with SC score 4 (highest) as
315 opposed to 1 (lowest) had almost 37% lower mortality and 15% more piglets weaned, while the
316 respective values for SCR were 15% and 8%. The trend of improving survival continued between
317 scores 4 and 2: sows with SC scores 4 compared to 2 had 35% lower mortality and 8% more
318 weaned piglets, whereas the respective values for SCR were 41% and 12%.
319
320 Another important finding was that SC and SCR scores were highly correlated, replicating results
321 in Ocepek and Andersen (2017). It appears that SC and SCR both represent good measures or
322 indicators of maternal care behaviour during the first few days after parturition when piglet losses
323 are most likely to occur. As sows establish contact with their piglets, through olfactory (sniffing),
324 auditory (grunting) and tactile (nudging) communicative cues, they can locate the piglets' position.
325 From an evolutionary point of view, this mechanism aids sows to keep the piglets in close
326 proximity, protecting them from danger. Awareness of the piglets' presence helps the sow to

become careful, attentive and protective around the piglets (without trampling on them or lie on them). Thus, stimulating sow motivation to care for her young is crucial for ensuring the future welfare and sustainability of pig production. This can be brought about through selecting for these particular maternal traits and by stimulating the sow to become more attentive through environmental factors (i.e. nest building material, good handling to prevent fear etc.). The simple scoring, the large individual variation and stability of the traits irrespective of litter size and breed (e.g. three different breeds show similar results: Ocepek and Andersen, 2017) make them particularly suited for selection.

Maternal care scores (SC and SCR) also decreased with parity. Thus, sows in earlier reproductive life appear to show better maternal care behaviour. This is not surprising, because breeding goals have emphasised greater maternal investment earlier in life (Canario et al., 2009; Ocepek et al., 2016a). A high maternal investment early in life has a substantial future cost in that it reduces the residual reproductive value of the sow, compromising longevity. We would like to pinpoint the importance of selection during the sows' reproductive live, rather than focus on the first two litters.

Furthermore, sows at farrowing might respond to suboptimal physical conditions of the sow by reducing maternal care. Here, we showed that if sows had problems with moving, they had lower scores for maternal care (i.e. SC and SCR) than sows without movement problems. It is, therefore, crucial to have healthy sows while promoting maternal care behaviours.

Even though sows have the internal motivation to prepare a proper nest for newborn piglets, this is mediated by their physical condition. We found that MD and BCS, two physical conditions, influenced NBA. Sows with movement disorders or sows that are classified as thin or fat invest

less time in NBA. Suboptimal MD or BCS causes difficulties for sows to lie down and stand up, as well as to move around (Bonde et al., 2004). This result highlights the necessity of making sure that the sow is healthy and in good physical condition before farrowing to ensure so that maternal behaviour can proceed as optimal as possible.

Piglet survival was partly affected by NBA. Higher NBA was associated with more piglets weaned, although this higher NBA was not clearly related to lower mortality. In Ocepek and Andersen (2017), sows that engaged in more NBA also weaned more piglets as fewer piglets died from maternal crushing. However, in their study, sows had ad libitum access to nest building material prior to parturition, while in our study access varied from 0.1 to 10.0kg. The performance of NBA is related to environmental factors (i.e. provision of nest building material). If amount of relevant external stimuli is insufficient or the timing before farrowing is wrong nest building activity may fail to make the sow relaxed and become attentive towards her young (e.g. Wischner et al., 2009). Although, there was between-sow variation in NBA scores and NBA was positively correlated with the other two behavioural scores as well as unaffected by parity and litter size, NBA had a minor effects on piglet survival under commercial conditions. On farms we cannot be sure that sufficient amount of nest building material is provided at the right time.

Finally, we identified impact of maternal care behaviours on productivity compared to physical conditions of the sows. Our results showed that maternal care behaviours are more direct predictors of piglet survival than the physical condition of the sow. However, suboptimal physical conditions at farrowing can reduce maternal care, indicating that physical condition is likely related to productivity through its effect of the expression of maternal care. Thus, improving sows

physical condition at farrowing promotes maternal care behaviours important for determining piglet survival.

CONCLUSSION

This study investigated the relationships between qualitative scores of maternal care behaviours (NBA, SC, SCR), sow physical condition variables (MD, BCS, SL) and piglet survival under commercial conditions. We found that farmers were able to implement the qualitative scoring system, and that maternal care behaviours were more predictive of piglet survival (low piglet morality and more weaned piglets) than physical condition of the sow. In particular, our results showed that a combination of SC and SCR had the best predictive accuracy for piglet mortality/weaned piglets. The large individual variation in SC and SCR, the fact that they were not affected by litter size, and easy to record for the farmer, indicates that they are suitable behavioural parameters for testing in nucleus herds to be implemented in the future breeding programme.

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448 Table 1. Scale definition of qualitative behavioural scores (reproduced by Ocepek and Andersen, 2017)

449

Behavioral scores	Definition of scale values
NBA[1]	1 - No nest building events observed
	2 - Less than 50 % of the active time spent nest building
	3 - More than 50 % of the active time spent nest building
SC[2]	1 - No events with communication, when the sow change position or move around
	2 - The sow communicates less than 50% of the event when she changes position or move around
	3 - The sow communicates more than 50% of the event when she changes position or move around
	4 - The sow communicates every event she changes position or move around
SCR[3]	1 - No events when sow is observed showing attentive, careful and protective behaviours
	2 - The sow is attentive, careful and protective less than 50% of the events when she changes position or move around
	3 - The sow is attentive, careful and protective more than 50% of the events when she changes position or move around
	4 - The sow is attentive, careful and protective every time she changes position or move around

450 [1]NBA = Nest building activities score
451 [2]SC = Sow communication score
452 [3]SCR = Sow carefulness score

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455 Table 2. Influence of fixed effects on qualitative behavioural scores
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Sow behavioural score	Parity		Litter size		MD[1]		BCS[2]		SL[3]	
	$F_{1, 805}$	P	$F_{1, 805}$	P	$F_{1, 805}$	P	$F_{2, 805}$	P	$F_{1, 805}$	P
NBA[4]	0.2	ns	0.0	ns	6.3	0.012	3.8	0.022	0.2	ns
SC[5]	14.3	<0.001	0.6	ns	3.7	0.050	1.5	ns	2.0	ns
SCR[6]	15.7	<0.001	1.5	ns	7.7	0.006	0.0	ns	0.3	ns

457 [1]MD = Movement disorder score
458 [2]BCS = Body condition score
459 [3]SL = Shoulder lesions score
460 [4]NBA = Nest building activities score
461 [5]SC = Sow communication score
462 [6]SCR = Sow carefulness score
463

464 Table 3. Influence of fixed effects on piglet mortality and survival trait

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Fixed effects	Mortality, %		Weaned piglets, n	
	$F_{(\ )}$	P	$F_{(\ )}$	P
NBA[1]	2.8 $_{(1, 799)}$	ns	6.8 $_{(1, 799)}$	0.009
SC[2]	13.7 $_{(1, 799)}$	<0.001	14.0 $_{(1, 799)}$	<0.001
SCR[3]	6.2 $_{(1, 799)}$	0.013	6.8 $_{(1, 799)}$	0.009
Parity	3.1 $_{(1, 799)}$	ns	3.3 $_{(1, 799)}$	ns
Litter size	695.1 $_{(1, 799)}$	<0.001	42.1 $_{(1, 799)}$	<0.001
MD[4]	0.1 $_{(1, 799)}$	ns	0.1 $_{(1, 799)}$	ns
BCS[5]	2.5 $_{(2, 799)}$	ns	0.7 $_{(2, 799)}$	ns
SL[6]	0.5 $_{(1, 799)}$	ns	0.5 $_{(1, 799)}$	ns
Farm	2.9 $_{(43, 799)}$	<0.001	2.7 $_{(43, 799)}$	<0.001

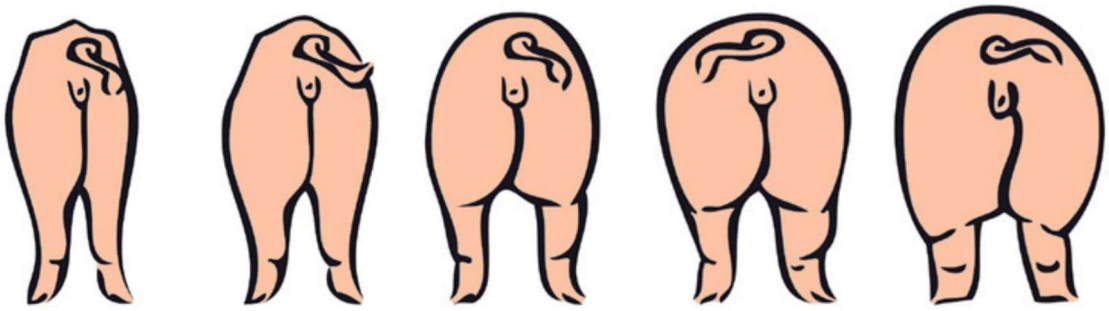
466 [1]NBA = Nest building activities score
467 [2]SC = Sow communication score
468 [3]SCR = Sow carefulness score
469 [4]MD = Movement disorder score
470 [5]BCS = Body condition score
471 [6]SL = Shoulder lesions score
472

473 Table 4. Predictive accuracy differences between different combination of behavioural scores for
474 piglet mortality and survival traits

475

Model	Postnatal mortality, %	AIC[1]	AIC weights[2] (%)
1	NBA[3]	3787.3	0.0
2	SC[4]	3735.5	0.0
3	SCR[5]	3738.5	0.0
4	NBA & SC	3735.9	0.0
5	NBA & SCR	3738.2	0.0
6	SC & SCR	3714.5	58.7
7	NBA, SC & SCR	3715.2	41.3
Model	Weaned piglets, n	AIC[1]	AIC weights[2] (%)
1	NBA	3896.4	0.3
2	SC	3889.0	10.8
3	SCR	3887.8	19.8
4	NBA & SC	3890.2	6.0
5	NBA & SCR	3889.0	10.9
6	SC & SCR	3886.7	34.3
7	NBA, SC & SCR	3888.0	17.9

476 [1]AIC = Akaike information criterion (smaller value, better predictive accuracy)
477 [2]AIC weights = Akaike weights (higher percentage, higher predictive accuracy)
478 [3]NBA = Nest building activities score
479 [4]SC = Sow communication score
480 [5]SCR = Sow carefulness score
481



Score	1	1.5	2	2.5	3	3.5	4.0	4.5	5.0
Definition	Very thin, with hips and backbone very prominent without fat covering hips and backbone		Thin, hip bones and backbone are easily felt without any pressure on the palms		Normal-good, it takes firm palm pressure to feel the hip bones and backbone		Fat; impossible to feel the bones at all, even when pressed with palm		Very fat, so fat that it is impossible to feel the hip bones and backbone even by pushing down with a single finger

482

483 Fig. 1: Body condition scores (Animalia, 2014)

Score 1	
Initial stage, mild lesions of the skin, including reddening or swelling or minor non-bleeding patches/wounds (diameter < 2cm)	
Score 2	
Moderate skin lesions, the wound includes the entire skin thickness and causes bleeding; crusts are common (diameter 2-3 cm), and the amount of granulation tissue is very moderate	
Score 3	
Serious lesions, these lesions include subcutaneous tissue, but not bone; swelling around the wound and production of granulation tissue are common (diameter 3-5 cm)	
Score 4	
Very serious lesions, serious injury involving the scapula bone. The tissue around the lesion is thickened and often adherent to the underlying bone, granulation tissue is common. The wound has commonly a diameter of 5 cm or more	

Fig. 2: Shoulder lesion scores (Animalia, 2014)

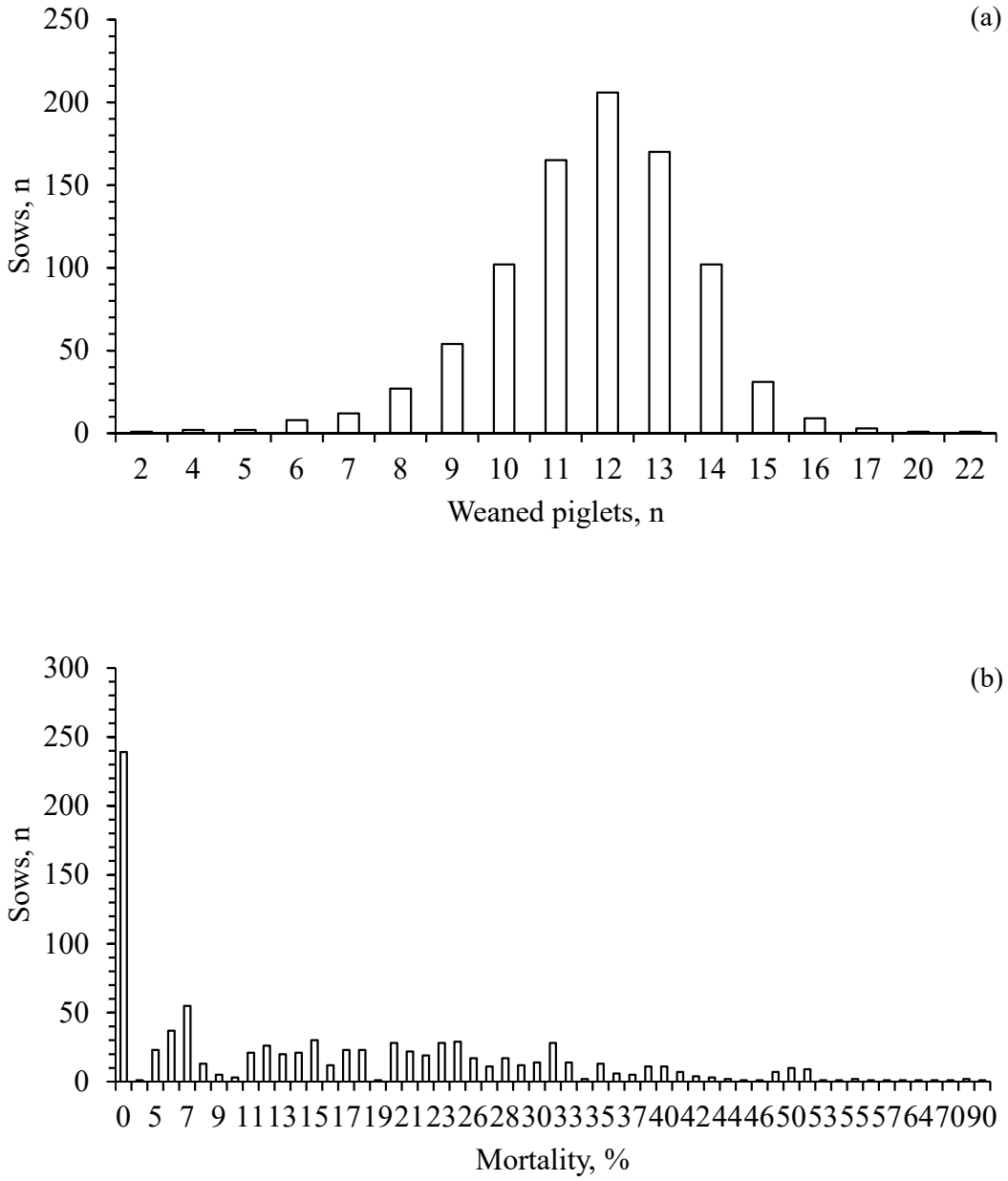
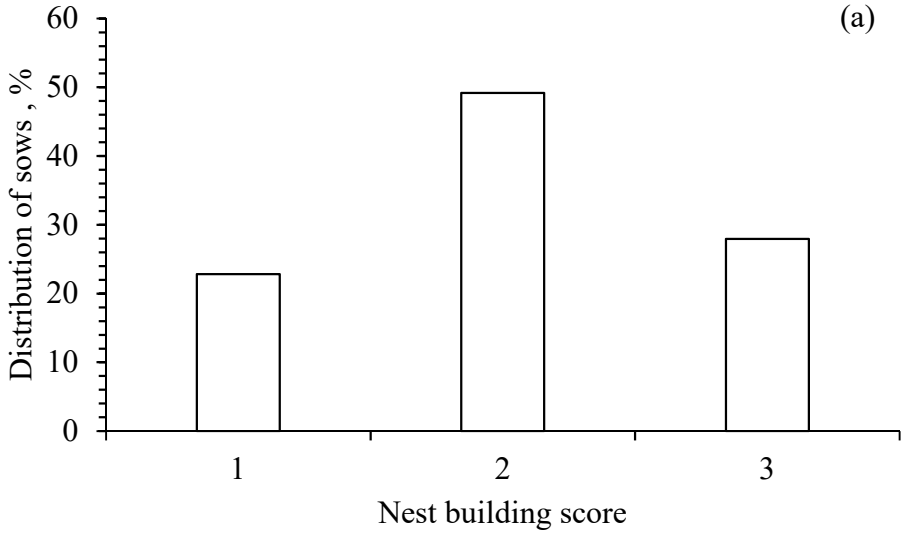
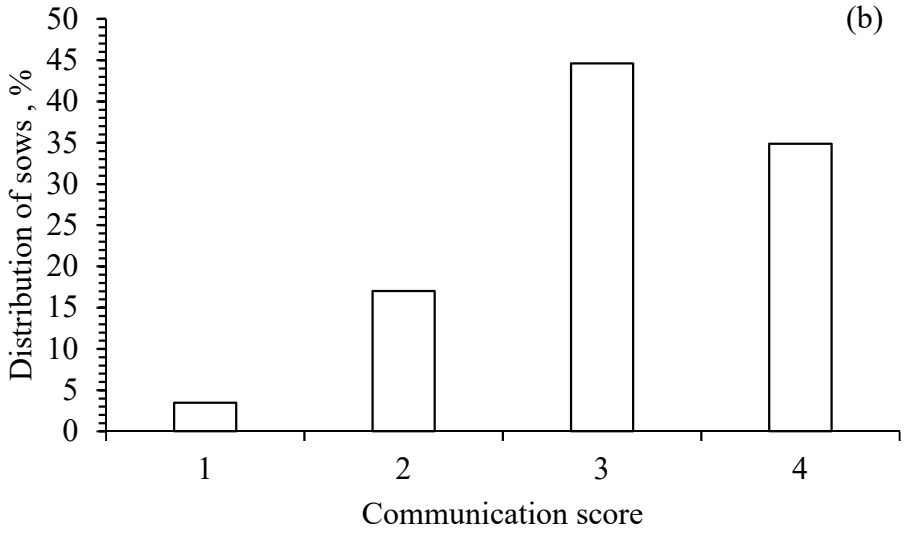
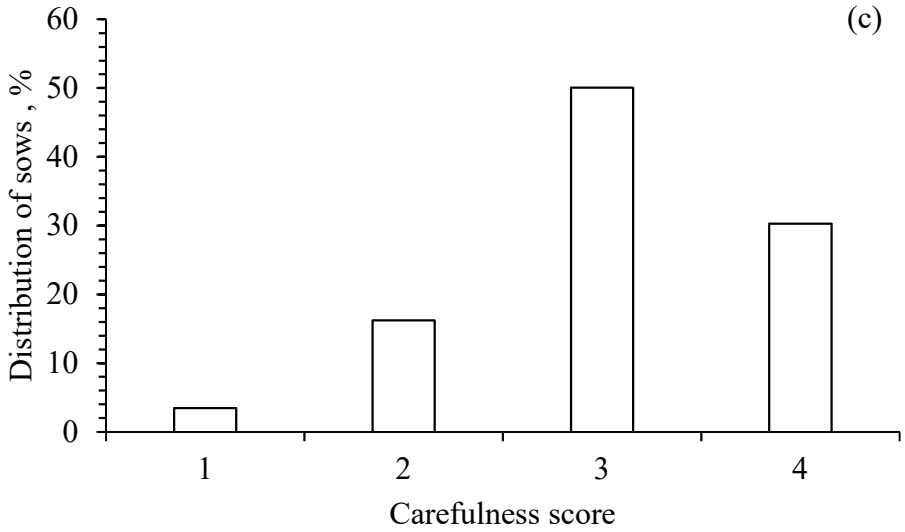


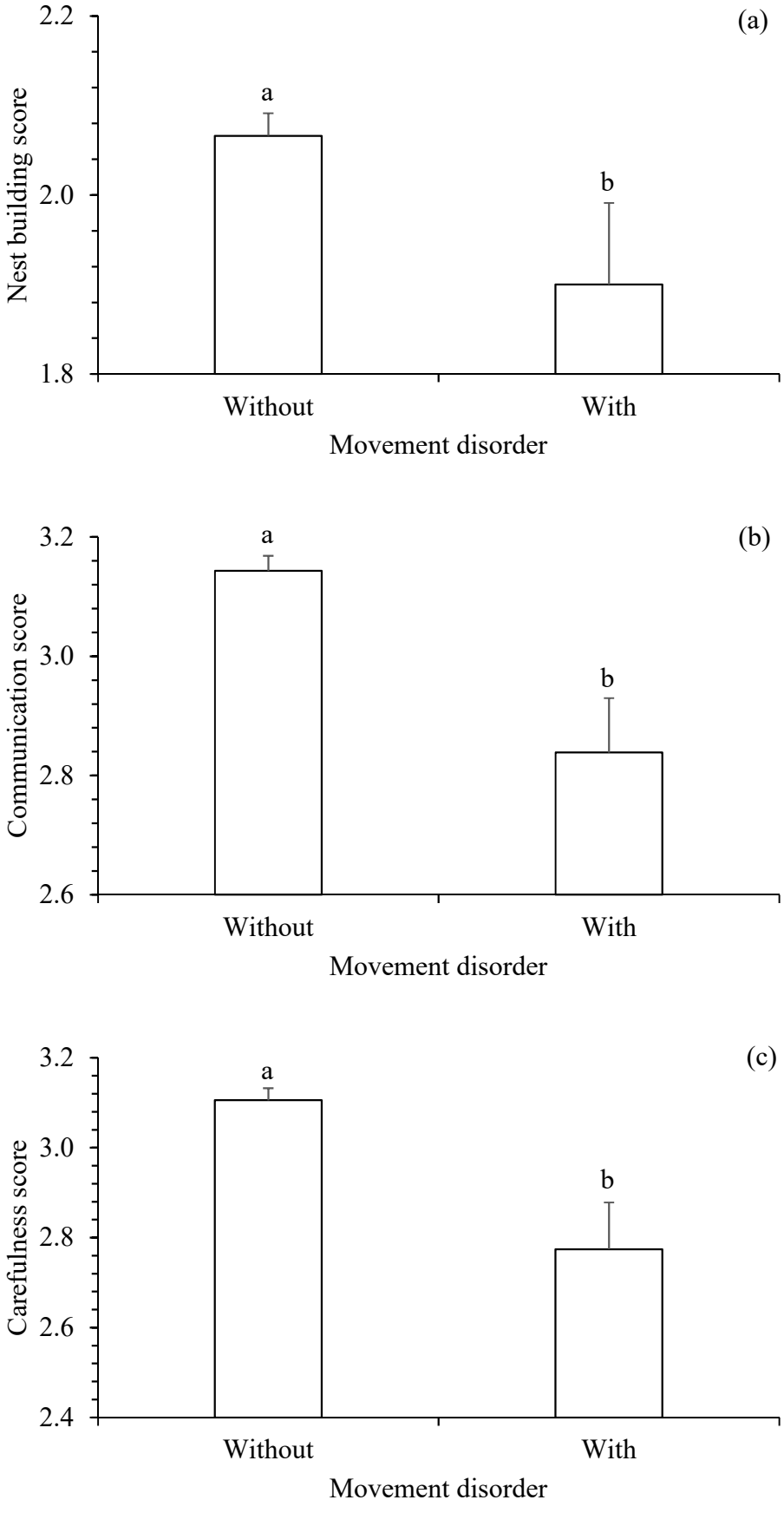
Fig. 3: Distributions of sows in relation to; (a) number of weaned piglets; (b) piglet mortality



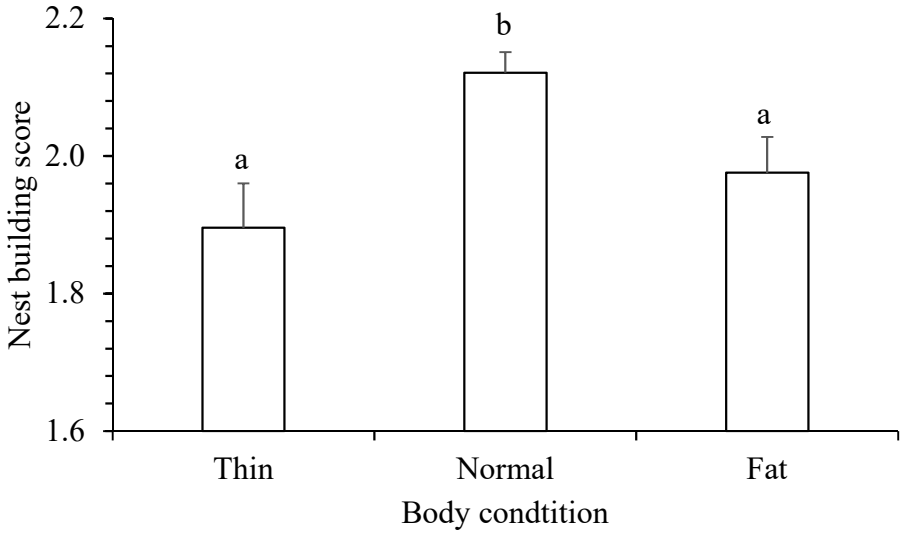




488 Fig. 4: Distributions of sows in relation to behavioural scores: (a) nest building; (b) sow
489 communication to piglets; (c) sow carefulness to piglets



490 Fig. 5: Relation between movement disorder and behavioural scores: (a) nest building ($F_{1, 805} = 6.3$; $P = 0.012$); (b) sow communication to piglets ($F_{1, 805} = 3.7$; $P = 0.050$); (c) sow carefulness to piglets ($F_{1, 805} = 7.7$; $P = 0.006$)



493
494 Fig. 6: Relation between body condition score and nest building score ($F_{2, 805} = 3.8$; $P = 0.022$)
495

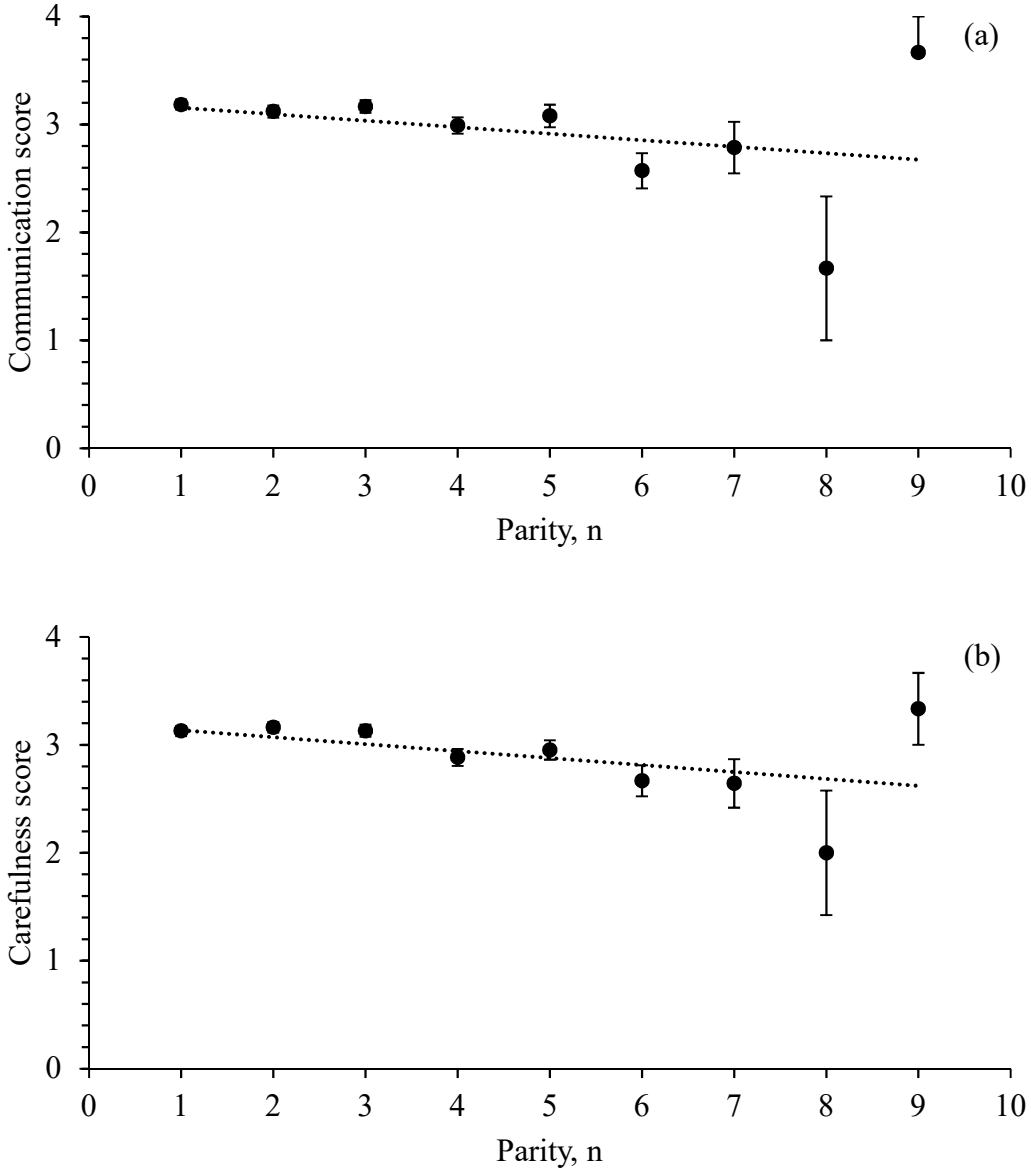
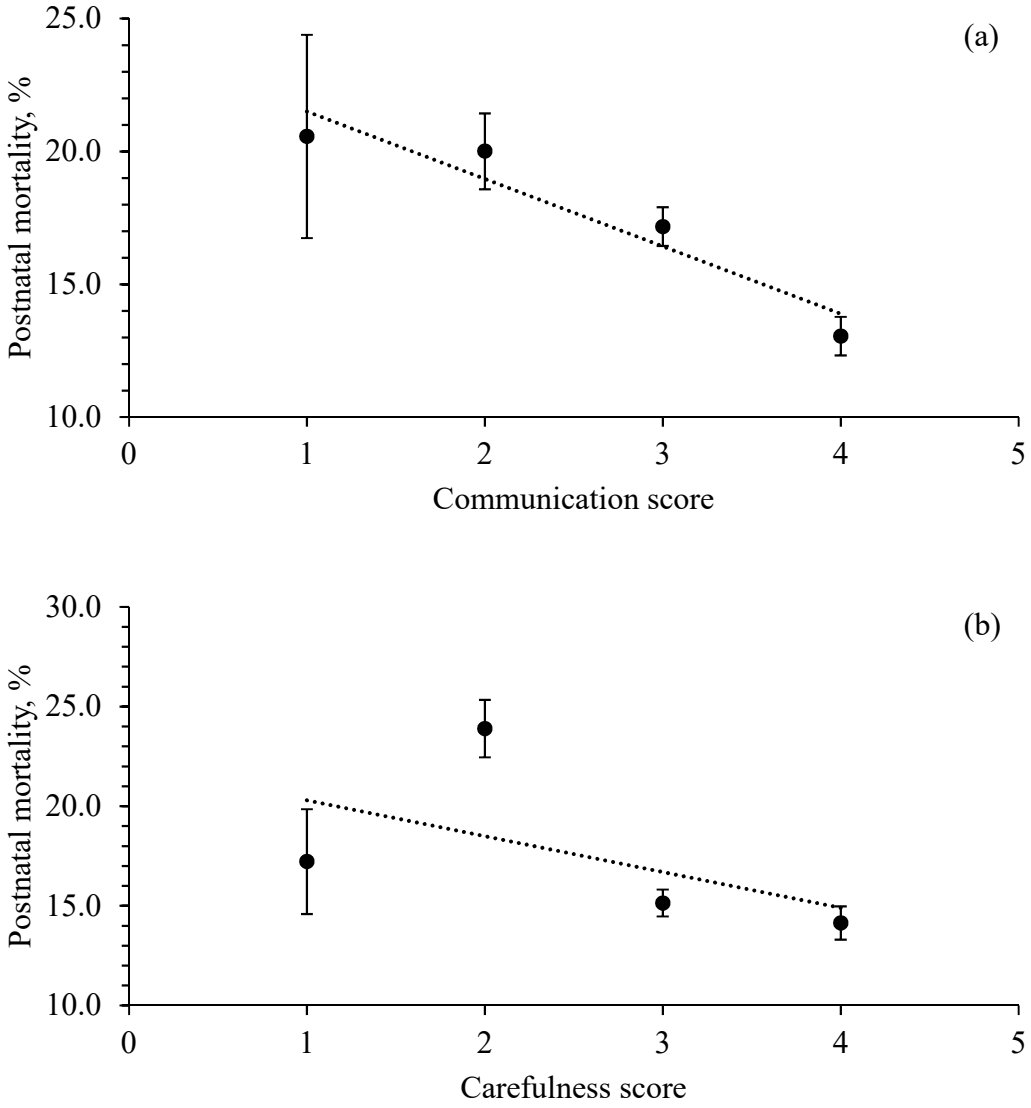
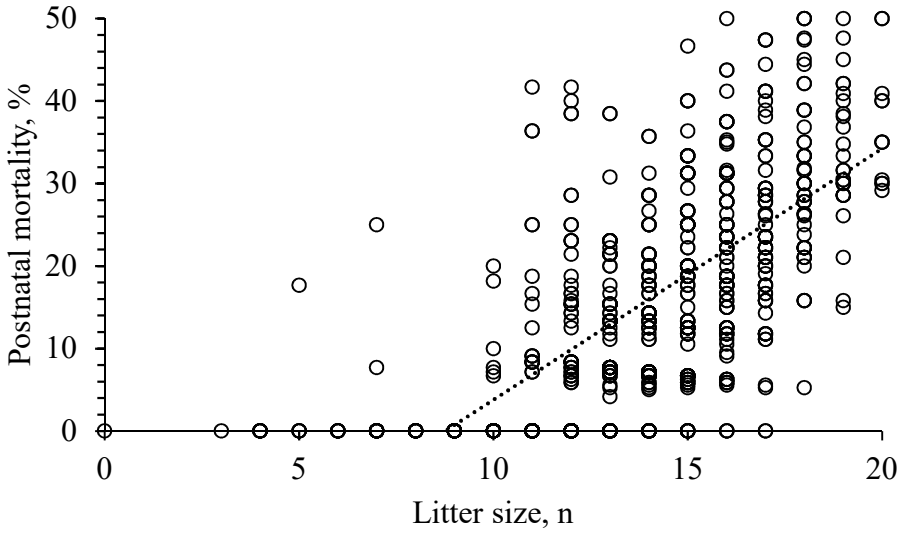


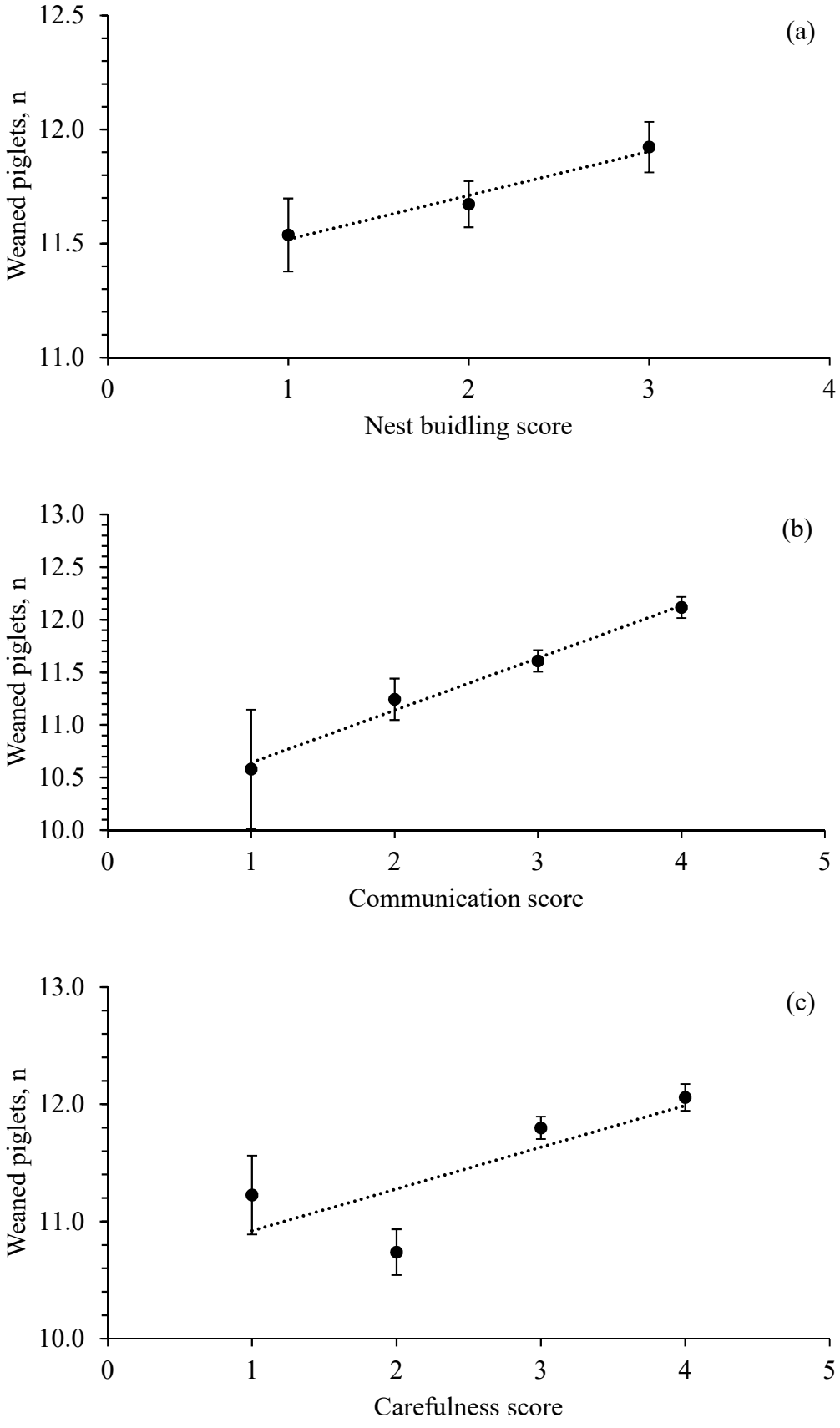
Fig. 7: Relation between sow parity number and behavioural scores: (a) sow communication to piglets ($F_{1, 805} = 14.3$; $P < 0.001$); (b) sow carefulness to piglets ($F_{1, 805} = 15.7$; $P < 0.001$)



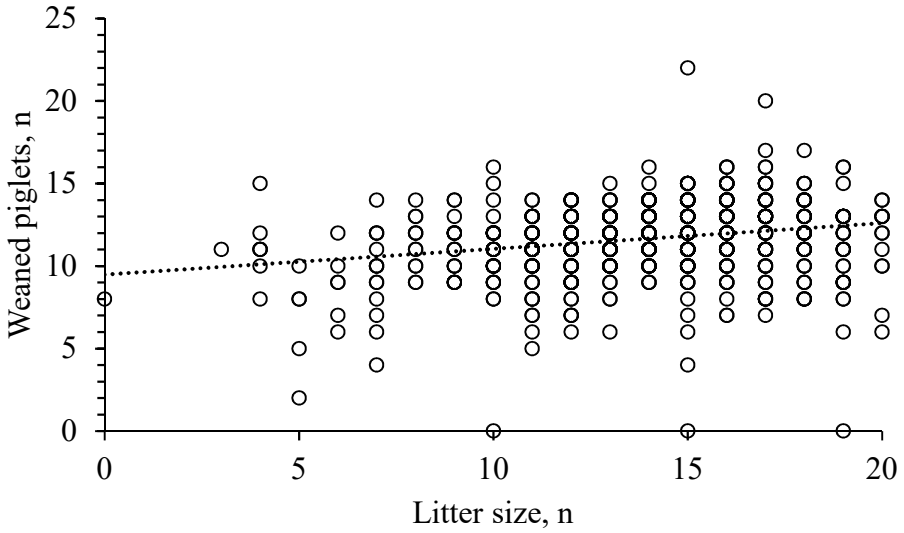
500
501 Fig. 8: Relation between postnatal mortality and behavioural scores: (a) sow communication to piglets
502 ($F_{1, 799} = 13.7$; $P < 0.001$); (b) sow carefulness to piglets ($F_{1, 799} = 6.2$; $P = 0.013$)
503



504
505 Fig. 9: Relation between litter size and postnatal mortality ($F_{1, 799} = 695.1$; $P < 0.001$)
506



507 Fig. 10: Relation between number of weaned piglets and behavioural scores: (a) nest building ($F_{1, 799} =$
508 6.8; P = 0.009); (b) sow communication to piglets ($F_{1, 799} = 14.0$; $P < 0.001$); (c) sow carefulness to
509 piglets ($F_{1, 799} = 6.8$; P = 0.009)



510
511 Fig. 11: Relation between number of weaned piglets and litter size at birth ($F_{1, 799} = 42.1$; $P < 0.001$)
512