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CHARACTERIZATION AND DEVELOPMENT OF THE MALE SHOULDER SHIELD IN AN INTRODUCED WILD PIG POPULATION

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Savannah River National Laboratory®
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EXECUTIVE SUMMARY

A sample of 721 males from an introduced wild pig population in western South Carolina was examined to better describe the unique structure known as the shoulder shield in this species. The shield initially developed as early as 9-12 months of age, and then increased to be found in all adults (36 months of age or older). Growth of the structure began in the central lateral shoulder region and increased to cover an area extending from the posterior neck back to the anterior hips, and from the middorsum down to the proximal margin of the exposed portion of the front leg. The shield dimensions (i.e., length, height and thickness) increased with age, physical size, and body mass of the boar. The thickness varied seasonally, being greatest during the annual peak of conception. The thickness was also positively correlated with the animal's body condition, implying a potential for a nutritional influence affecting that dimension, and possibly also an energy storage function. Injuries indicative of male-male fighting were primarily found on portions of the body covered by the shield. This corroborates the function of this structure as being protective in such male-male aggressive encounters in this species.

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1.0 Introduction

Mature male wild pigs (*Sus scrofa* L.) possess a thickened subcutaneous layer of tissue, commonly referred to as the "shield," which overlies the outermost muscles in the boar's lateral shoulder region. This unique anatomical structure, a secondary sexual characteristic found in this species, serves a reported protective function for males fighting for breeding opportunities with estrous females (Briedermann, 1986; Frädrich, 1984; Snethlage, 1982).

In spite of the fact that the existence of this structure has been known for a long time (Darwin, 1871), only general subjective information exists defining its size and shape. The shield has been described as covering the animal's side from the neck and shoulder area back to the last ribs. However, the only dimension reported for this structure is the shield's thickness, typically ranging up to 20-30 mm (e.g., Barrett, 1978; Choquenot et al., 1996; Giles, 1980; Pullar, 1953). Previously defined as being present in mature boars, the age at which the shield begins to develop and how the development takes place spatially on a boar's body have not been reported. In addition, the shield has been reported to be present during the breeding season, and then to decrease in size or entirely disappear during the rest of the year (Frädrich, 1984; Goulding, 2003). To date, no quantitative data have been published to document such seasonal changes. Finally, the protective function of the shield has been reported for a long time (Briedermann, 1986; Frädrich, 1984; Snethlage, 1982). In spite of this common assertion, no studies on the specific locations of injuries from male-male fighting has been published to confirm this effectiveness of this presupposed function.

The purpose of this study was to both quantitatively and qualitatively define the size, shape and development of the male shoulder shield in a single population of introduced wild pigs. The relationships between the shield data and the animal's age, physical size, mass, and body condition, and seasonal differences would also be assessed. Further, the presence of open wounds and healed scars indicative of male-male fighting was to be studied with respect to the location(s) of these injuries to the shield and relationship to the animal's age. The results of this study would not only better define the male shoulder shield, but would also characterize the role that this structure plays in defense of the boar's body during male-male fighting.

2.0 Methods

The wild pig population used in this study was found on the Savannah River Site (SRS), an 803 km^2 nuclear production and research facility operated by the U. S. Department of Energy and located in Aiken, Barnwell and Allendale counties in the upper coastal plain of western South Carolina, USA. The SRS wild pig population has been in existence for over eight decades. Based on morphological and genetic analyses as well as historical accounts, this population has a mixed feral hog and Eurasian wild boar ancestry (Mayer and Brisbin, 2012).

Between 1984 and 2019, data were collected from a total 721 male wild pigs harvested from the study area during public hunts and subcontract control programs. For each animal taken, the following data were recorded: date collected, age class, head-body length, shoulder height, and total body mass. The head-body length and shoulder height, standard mammalian external linear dimensions, were taken to the nearest mm, and the total body mass to the nearest 0.5 kg. Age class categories included piglet (birth to 8 mo.), juvenile (9-12 mo.), yearling (13-19 mo.), subadult (20-35 mo.), and adult (36 mo. +), and were based on erupted dental patterns, as described in Mayer and Brisbin (2012).

The presence or absence of the shield was recorded or each animal examined. The shoulder shield is a fairly rigid structure, being movable as a unit, located over the underlying connective tissue. Frädrich (1984) noted it could be seen when boars were moving about. Based on preliminary investigations made prior to the initiation of the present study, it was determined that the shield margins were visually evident

and could be generally identified during a close examination of the animal's exterior. This was especially true for subadult and adult animals. For animals which obviously had a shield present, the margins of the structure were initially delineated both visually and physically (i.e., through external palpation of the structure). Small incisions were made as necessary to confirm portions of the structure's edges. The overall margin of the shield were noted using both written descriptions and sketched illustrations on a data sheet. The absence of the structure in animals with no externally discernable presence of a shield was confirmed with short incisions in the central shoulder area.

Once the overall outline of the structure was determined in animals possessing a shield, incisions were made through the entire thickness of the shield along the greatest length and height of the shield. These incisions both enabled the measurement of the length and height of the structure, as well as confirming the presence of the structure along those axes. The shield length (maximum horizontal length of the shield) and shield height (maximum vertical height of the shield) were then measured in a straight line along the surface of the shield. Further, the tissue comprising the shield is macroscopically distinct from both the overlying dermal and underlying connective tissues. Using the two aforementioned incisions, the thickest area of the shield was determined and another short incision made in that area to measure the shield thickness. The shield thickness (greatest straight-line thickness of the shield) was then measured from below the overlying dermal layers inward to the outmost surface of the underlying connective tissue. All three shield linear dimensions were measured to the nearest mm.

To enable a comparison of the animal's body condition with the shield dimensions, a body condition index was calculated as follows: total body mass divided by the statural body size. Statural body size was calculated by multiplying the head-body length by the shoulder height, and then divided by 1,000. The higher the resulting number would indicate animals that have more mass per a standardized size, and therefore would be assumed to be in better body condition.

The animals were examined for the external presence of open wounds and healed scars indicative of male-male fighting (i.e., linear gashes and large punctures). It should be noted that the absence of large predators in the study area would preclude the potential presence of similar injuries inflicted by predation attempts. The general external locations of these injuries on the body (e.g., face, neck, shoulder, front leg, etc.) were also noted. In addition, the relative abundance (i.e., "few/some" or "many/numerous") of wounds/scars was recorded for each animal. The number of locations and relative abundance of these injuries were then correlated with age.

All statistical analyses were performed using the JMP Pro Version 11.2.1 software package (SAS Institute Inc. 2014). Continuous variables were tested for normality using a Shapiro Wilk W test. A Chi Square test was used to determine if a variable differed significantly from the expected/hypothetical probability. An Analysis of Variance was used to determine a regression effect between pairs of variables. A t Test was used to evaluate variables between groups. Statistical significance was accepted at $p<0.05$.

3.0 Results

A total of 254 (35 percent) of the 721 males examined had shoulder shields present. None of the animals in the piglet age class had a shoulder shield. The structure was first evident in the juvenile age class in only one animal (0.8 percent of the sample for that age class). The number and percentage increased successively through the older age classes (i.e., yearlings – 73 animals/63 percent; subadults – 93 animals/99 percent) up through the adult age class, in which all of the 87 animals had a shield present.

In general, the shield begins to develop in the middle region of the shoulder above and slightly anterior to the lateral midline of the front leg (Fig. 3-1). The area covered by the shield increases with an increase in age class, ultimately extending along the animal's side from the base of the neck back to the abdomen in

front of the pelvic region. The greatest height of the structure is in the line with the front leg, where the shield in fully mature animals can extend from the proximal base of the front leg completely across the back. The area where the shield initially begins development in the central portion of the lateral chest ultimately attains the greatest thickness of the structure. The thickness of the shield tapers from a maximum in the central shoulder area down to the margins of the structure in all directions. The margins of the shield in some subadult and most adult boars were evident with a bulge along the ventral-most and anterior-most edge of the structure, with the skin appearing to wrap around the edge of the shield. In general, the areas of shortest linear increase of time develop into the thickest growth of the structure. The central portion of the shield was exceptionally bulging in some adult boars; having a callused appearance with worn-off hairs.

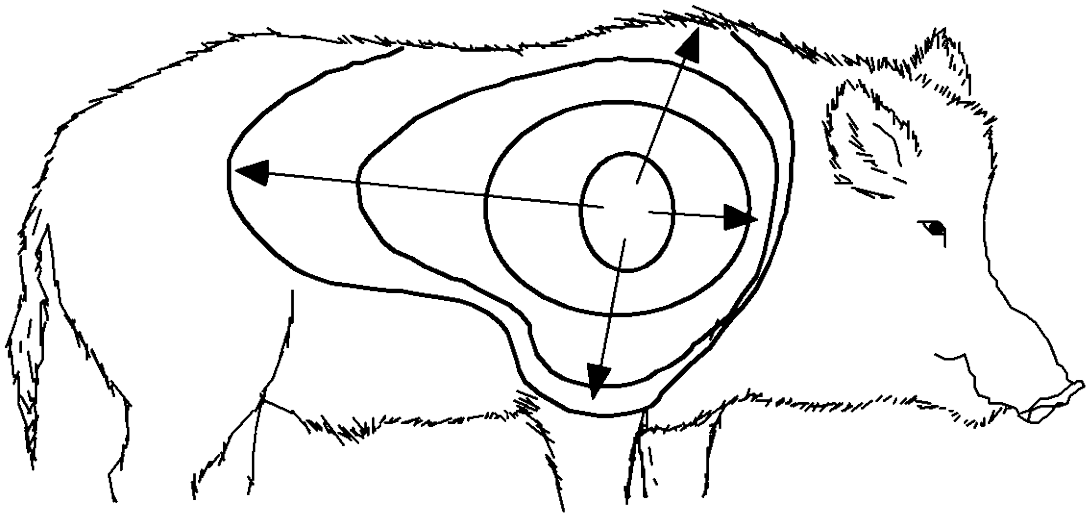

Fig. 3-1. Illustration of the typical progressive development of the shoulder shield's extent in male SRS wild pigs.

The three shield dimensions increased significantly with age (Table 3-1; shield length - F=44.7, df=253, $p\leq$0.0001, shield height - F=29.1, df=253, $p\leq$0.0001, and shield thickness - F=71.6, df=253, $p\leq$0.0001). When the shield begins forming, the structure is greater in height than in length. On average, this dimensional relationship reverses when the shield length reaches about 250 to 255 mm. However, some individuals in each of the age classes had shields where the heights were greater than the lengths. This percent within each age class decreased with an increase in the age class (i.e., yearlings – 42 percent; subadults – 27 percent; adults – 10 percent). All of the shield dimensions were significantly correlated ($p\leq$0.0001) with one another. In addition, all of the shield dimensions were significantly correlated ($p\leq$0.0001) with the two external linear dimensions and the total body mass.

In addition to the actual linear measurements, the percentage of these measurements in comparison to the animal's overall physical dimensions also increased with age (Table 3-1, Fig. 3-2). On average, the shield height overlaid a larger percent of the shoulder height than did the shield length as a percentage of head-body length. The shield length increased to a maximum of 46% of the animal's head-body length, while the shield height was up to 61% of the shoulder height.

The thickness varied seasonally, becoming greatest during the peak of conception (Fig. 3-3). The length and height did not vary seasonally. On average, the shield thickness in adult boars varied up to 5 mm between seasons. Overall, the shield thickness in that age class ranged from a minimum of 3 mm in the summer to a maximum of 48 mm in the fall.

Table 3-1. Summary statistics for male shoulder shield dimensions (in mm) from the wild pig population at the Savannah River Site, South Carolina. The data were also separated age class.

Age Class	Sample Size	Mean	Range	SD
		Shield Length		
Juvenile	1	152	152	-
Yearling	73	260.9	110-610	92.0
Subadult	93	330.5	150-580	110.1
Adult	87	445.6	180-646	106.6
All Age Classes	254	349.2	110-646	128.1
		Shield Height		
Juvenile	1	220	220	-
Yearling	73	255.0	130-376	59.0
Subadult	93	286.1	120-440	69.3
Adult	87	351.4	183-490	73.0
All Age Classes	254	299.2	120-490	78.3
		Shield Thickness		
Juvenile	1	5	5	-
Yearling	73	15.2	7-32	5.7
Subadult	93	21.6	11-33	4.9
Adult	87	28.9	3-48	7.3
All Age Classes	254	22.2	3-48	8.2

In general, all three shield dimension increased significantly with an increase in body condition. However, when analyzed within each age class, only thickness in the yearling (F=5.7, df=72, $p\leq$0.02) and adult (F=9.6, df=86, $p\leq$0.003) age classes increased significantly with body condition. Body condition did not differ significantly between the seasons, either overall or within each of the older three age classes.

The number (percent) of the total locations of the open wounds and healed scars on the bodies of the 122 males found to have these injuries were as follows: face – 5 (2.0), ears – 24 (9.7), neck – 72 (29.0), shoulders – 108 (43.5), front legs – 15 (6.0), flanks – 12 (4.8), hips – 7 (2.8), hind legs – 4 (1.6), and scrotum – 1 (0.4). Summing the percentages of the areas potentially covered by the maximum extent of the shield would account for 192 (77.3 percent) of these injuries. No comparable scars were noted on animals that did not have a developed shoulder shield. The number of locations with injuries on one animal ranged from one to four, and significantly increased with an increase in age ($\chi 2$=18.1; df=119; $p\leq$0.006). The relative abundance of wounds/scars also increased with age; however, this increase was not significant among the age classes ($\chi 2$=4.2; df=2; $p\leq$0.120).

Fig. 3-2. Comparison of the percentage increase of the shield dimensions with age. Shield length is presented as a percentage of head-body length, and shield height is presented as a percentage of shoulder height.

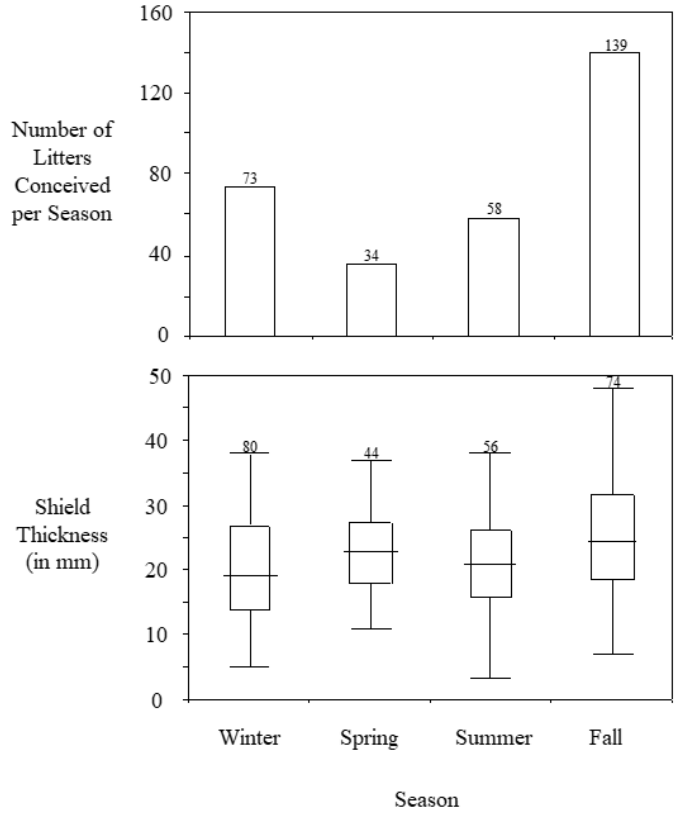

Fig. 3-3. Comparison of the seasonal breeding frequency with the changes in shield thickness among SRS male wild pigs. Data were combined to include all age classes with shields. The conception frequencies were taken from Comer and Mayer (2009).

4.0 Discussion

Contrary to the previously reported presence in only mature, adult or older animals (Choquenot et al., 1996; Giles, 1980; Pullar, 1953; Snethlage, 1982), shoulder shields can be found in male wild pigs as young as 9-12 months of age. Further, males of this species have been documented as producing motile sperm and being sexually active as young as 5-6 months of age (Barrett, 1978; Sweeney et al., 1979). Breidermann (1986) noted that, with the onset of sexual maturity, the shield develops in boars. It is possible then, that the shield could develop in some individuals even younger than 9 months of age. Based on the results of this study, the presence of the shield in that young of an animal would most likely be an uncommon occurrence.

Factors other than sexual maturity and age can also determine the presence or absence of the shield. Barrett (1978) reported that castrated boars at the Dye Creek Ranch, California, lost the shield. None of the males in the present study had been castrated. Further, Diong (1982) noted that feral boars from the Kipahulu Valley on the island of Maui did not even have shoulder shields. No explanation was given for the shield's absence in these males. Other male wild pigs in the Hawaiian Islands have been documented as developing shields (Nichols, 1962). It is possible that the boars examined during Diong's (1982) study were either not fully adult animals (i.e., <36 mo.), examined during the portion of the year of minimal breeding activity, in very poor physical condition, or a combination of these factors.

Although the basic spatial extent of the shoulder shield reported here was similar to that previously described, the present study did extend the maximum coverage of the structure. Earlier reports did not describe the shield as going completely across the shoulders or as far back as the anterior-lateral portion of the hip. In addition, previous studies did not document the fact that the shield's height is initially greater than the length, or that such dimensional relationships can be found even in adult animals. The normal transitional development of the shield had also not been previously described. Although one might assume that such development began in the shoulder region (i.e., because that is the most commonly reported region of the boar's body to be covered by the shield), the specific site of the initial development of the structure had not previously been reported as such.

The only shield dimension that had been reported in the literature was the thickness. This figure varied from 13 up to 51 mm (e.g., Elman, 1974; Jones, 1972). The most commonly reported specific measurement for shield thickness was 25 mm (e.g., Barrett, 1978; Benke, 1973; Kramer, 1971; Nichols, 1962; Wooters, 1987). The maximum observed thickness for specific populations varied from 19 to 51 mm (Jones, 1972; Pullar, 1953).

Aside from the general physical areas occupied by the structure (e.g., "covering the shoulder region"), the shield length and height have not heretofore been reported. Again, one might generally estimate these lengths based on the area typically covered by the shield and the animal's overall external dimensions. However, this study has shown the shield dimensions to be quite variable, with the shield height in some instances being greater than the length, even in adult boars.

Contrary to some previous reports (e.g., Goulding, 2004), the structure was present during the entire year. Although noted in the scientific literature to vary seasonally, no data as to the actual or percentage change in thickness have been reported. The shield has simply been reported to be thickest during the breeding season in Eurasian wild boar (Frädrich, 1984; Goulding, 2004). Unlike many Eurasian wild boar populations that breed only during a defined period of time annually (e.g., Ahmad et al., 1995; Briedermann, 1971; Diong, 1973; Mauget, 1982), the SRS wild pig population breeds year-round. However, a defined peak of breeding occurs during the fall in the SRS population (Fig. 3; Comer and Mayer 2009). Like the wild boar, the shield on SRS wild pigs was thickness during the peak of breeding. However, since the SRS

wild pigs breeds year-round, the shield thickness may not decrease to the extent observed in wild boar. Unfortunately, comparable seasonal or monthly data have not been reported for wild boar.

The shoulder shield has been reported to cause an increase in the shoulder height of boars as compared to sows (Barrett, 1978). One might assume, then, that an increased thickness in the shield would result in an increase in that animal's shoulder height. In contrast to this, the increase in shoulder height within this sample of SRS boars was not strongly correlated with an increase in the shield thickness, either collectively or within each age class (i.e., r^2 ranged from 0.1 to 0.3).

Giles (1980) noted that the shield was thinner in emaciated males. In the present study, shield thickness was shown to be related to the body condition index of the males examined. In addition, the two highest seasonal averages in shield thickness corresponded to the availability of the mast crop in the fall and fresh growth in the spring. The mast crop in the fall provides one of the highest sources of nutrition available to these animals on an annual basis. The peak of reproduction coincides with the availability of that crop, and the success of each year's reproductive effort is largely determined by the abundance of the mast crop (Matschke, 1964). The two lowest seasonal averages in shield thickness occurred during the summer and winter, both periods of lower food availability. The presence of typically abundant soft fruits at the SRS (e.g., *Rubus* spp., *Prunus* spp., and *Vitis rotundifolia*) would make summer a less stressful season than winter (Mayer and Brisbin 2012. Largely composed of adipose tissue (Goulding, 2004), the shield's thickness may be dependent upon the plane of nutrition available to the area's boars at any one point in time. Further, since males can lose up to 25% of their body mass during the peak breeding season due to reduced foraging (Frädrich, 1984, Goulding, 2004), the shield may also provide an energy storage for actively breeding males with lower nutritional ingestion. There may, therefore, be a nutritional as well as a reproductive/hormonal component to determining the thickness of the structure on a seasonal basis, as well as an added energy storage function.

Based on the results from this study, the shield would appear to provide protection from injuries incurred during male-male fighting. Long reported to be the functional purpose of this structure, over three-quarters of the injuries and scars observed in this study were in the area potentially occupied by the shield. This is further corroborated by the lateral fighting stance exhibited by males of this species (Frädrich, 1974, 1984). The potential impact locations of the canine teeth inflicted from such a stance would be centered in the thickest region of the shield. Further, although not quantified, the gashes and punctures seen in that region of the shields in the subadults and adults examined at SRS typically did not even extend through the entire thickness of the structure. Those injuries that did completely penetrate the shield, continued into the outermost layers of underlying muscle, but did not continue into the thoracic and anterior abdominal cavities. Thus, damage to the organs (e.g., lungs and liver) internal to the shield's location was prevented.

5.0 Conclusions

In contrast to the previously reported presence in only mature and older boars, the shoulder shield in male wild pigs was found to begin developing as early as the juvenile age class. By the time the animals reach the adult age class (three years old and older), all of the males had a well-developed shield. Initially the structure is higher than it is long. Ultimately, the length can be up to 1.32 times greater than the height. The shield can be up to 646 mm long, 490 mm in height, and 48 mm thick. The site (i.e., centro-lateral shoulder region) ultimately becomes the thickest area of the structure. The structure was present year-round. The thickness of the structure changed seasonally, being thickness (and assumed to be most protective) during the peak of the breeding season, which would coincide with when most male-male fighting would occur. Based on the locations of scars/wounds from such fighting, the shoulder shield would appear to provide a protective function from serious injury.

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