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History, Management, and Future of Invasive Wild Pigs

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ABSTRACT: Wild pigs are among the most widespread invasive vertebrate species, having been introduced across the globe as a source of food and for sport hunting. Over the last few decades, the growing ecological and economic impacts of wild pigs have precipitated a shift in the perception and management of this species from a desired game animal to a destructive invasive species, resulting in substantial investments in wild pig management. Most notably, in 2014 the National Feral Swine Damage Management Program was established by the U.S. Congress, representing one of the most extensive management programs for a single invasive species in North America to date. This infusion of interest in wild pig control and resources to carry out these programs has spurred technological innovation, resulting in new and enhanced tools for locating, capturing, and removing wild pigs, as well as a surge in research on this species across its range. These investments have resulted in the elimination or presumed elimination of wild pigs from 12 U.S. States in the last decade. However, several significant hurdles remain that must be addressed to achieve long term success in the management of invasive wild pigs. The lack of unified management goals both within and between many agencies is probably the most important factor limiting widespread control efforts, as there is still no standardized legalized classification of this species in the U.S., and some states continue to actively manage wild pigs as a game species. The lack of concordance in management goals underscores the need for better educational programs targeting the public, legislators, and even wildlife professionals. Further, illegal movement of pigs remains a major contributor to the continued establishment of wild pig populations in new areas. As control efforts shift into states with abundant wild pig populations and an entrenched culture of wild pig hunting, new approaches to management, expanded educational campaigns, more unified management goals, and additional investments in control efforts will be needed. While complete elimination of wild pigs from their invasive range is unlikely, adoption of these strategies should facilitate further contraction of their range, benefiting native wildlife, ecosystems, and humans.

KEY WORDS: crop damage, eradication, feral swine, invasive, management, population control, *Sus scrofa*, wild boar, wild pig

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History of the Introduction and Impacts of Invasive Wild Pigs

Non-native wild pigs (*Sus scrofa*) are among the most widespread and abundant vertebrate invasive species globally. Including wild boar within the native range of the species, populations of wild *Sus scrofa* occur on all continents except Antarctica, as well as numerous islands throughout the globe (Barrios-Garcia and Ballari 2012). Across their non-native range, most populations of wild pigs are descendants of domestic pigs. The earliest records of introductions of domestic pigs outside the native range of the species date back to as early as the 11th Century with the importation of pigs to southern Greenland by Norse Colonists (Mayer and Brisbin 2008). However, large scale introductions of domestic pigs in the Americas began in the late 15th century with the exploration and colonization of the Caribbean Islands by European expeditions (Mayer and Beasley 2018, Mayer et al. 2020). In many cases domestic pigs were released onto the landscape to naturally forage, where they established feral populations across much of the New World (Mayer and Beasley 2018, Mayer et al. 2020). Subsequent introductions have occurred across much of the globe, with notable introductions that led to established populations in Australia, South America, Africa, and numerous other regions outside their native range (Skewes and Jaksic 2015, Bengsen et al. 2017, Aschim and Brook 2019, Hegel et al. 2022).

In the U.S., later introductions of wild boar into fenced enclosures in the late 1800s through early 1900s, which escaped and interbred with feral pigs already present on the landscape, led to the introgression of wild boar and domestic pig genes (Smyser et al. 2020, Chinn et al. 2022). Similar introductions of wild boar for hunting or alternative livestock markets have occurred in South America (Skews and Jaksic 2015), Canada (Aschim and Brook 2019), and elsewhere across the globe. As a result, wild *Sus scrofa* in the U.S. and many other parts of their non-native range are referred to as invasive wild pigs (Keiter et al. 2016), and the genetic composition of populations varies widely across their distribution depending on the extent to which wild boar introductions have occurred (Smyser et al. 2020, Smyser et al. 2024).

Following the introduction of Eurasian boar, growing interest in sport hunting of wild pigs resulted in active stocking programs for this species in several states and a general cultural acceptance of wild pigs as a game species (Mayer and Beasley 2018, VerCauteren et al. 2020). These efforts facilitated the widespread distribution of wild pigs across North America, fostering a culture of wild pig hunting that has spanned several generations of hunters. Indeed, wild pigs are the second most harvested big game animal in the U.S. behind white-tailed deer (*Odocoileus virginianus*). Increased desire for local, huntable wild pig populations has spurred illegal translocations of the species

across the U.S. and more broadly across the globe, which is widely recognized as a primary factor facilitating the spread of this species to new areas (Spencer and Hampton 2005, Hernández et al. 2018, Clontz et al. 2023). Illegal translocations, coupled with changing climate, high fecundity (Chinn et al. 2022), and a myriad of other factors led to the rapid expansion of wild pig populations in North America and across the globe, beginning in the 1990s (Bengsen et al. 2017, Lewis et al. 2017). Concurrent with the expansion of wild pig populations, there has been a marked increase in the scope and scale of impacts of wild pigs on anthropogenic and native ecosystems (Barrios-Garcia and Ballari 2012, Keiter and Beasley 2017).

Turning the Tides

With the acceleration of the impacts of wild pigs, there has been a marked shift in the perception of wild pigs from that of a desired game species to a destructive invasive species across much of their range. By the mid-2010s, the U.S. congress established the National Feral Swine Damage Management Program (NFSDMP) to reduce populations of wild pigs in an effort to protect agricultural and natural resources as well as human health and safety. A program of this scale is unprecedented in the management of a single invasive species in North America, which is managed by the United States Department of Agriculture, Animal and Plant Health Inspection Service. Alongside this program there has been a growing effort among private organizations, landowners, and other agencies to control wild pig populations across their distribution. Collectively, these efforts have led to establishment of wild pig control programs across the U.S. and more broadly across the globe where populations of wild pigs occur.

This infusion of interest in wild pig control and resources to carry out these programs has spurred technological innovation, resulting in new and enhanced tools for locating, capturing, and removing wild pigs. For example, innovations in trapping and the recognition of the benefits of whole-sounder removal have resulted in traps producing >80-90% efficiencies (Gaskamp et al. 2021, Lewis et al. 2022, Beasley et al. unpubl. data). Use of aerial removal methods (i.e. via helicopter) has greatly increased the efficiency and scale of many removal programs, and aerial removal has played a pivotal role in several recent eradication efforts (e.g., Parkes et al. 2010, Beasley unpubl. data). The expansion of wild pig control professionals alongside technological developments has also allowed for better integration of multiple techniques to achieve management outcomes previously not feasible. For example, aerial culling using thermal optics (Cox et al. 2023) or use of thermal drones to locate wild pigs paired with aerial shooting of identified pigs is now being used to eliminate elusive or low-density populations not accessible or susceptible to trapping. The influx of resources, tools, and expertise to remove wild pigs, alongside increased recognition of the importance of controlling wild pig populations, has transformed the socioecological landscape of wild pig management across their invasive range in recent decades, with demonstrated results.

Within the first decade of the establishment of the NFSDMP, wild pigs have been eliminated or presumed eliminated (states are considered confirmed eliminated

after two consecutive years with no detections) from 12 U.S. states. Although many of the elimination states had low population sizes and restricted distributions of wild pigs, the rapid elimination of wild pigs from these states is clear evidence that with focused management efforts, clear goals, and the expansion of resources, successful management and in some cases elimination of populations is an achievable outcome. Similar successful outcomes have been achieved on islands and other localized areas (e.g., Santiago Island – Cruz et al. 2005; Pinnacles National Monument – McCann and Garcelon 2008; Santa Cruz Island – Parkes et al. 2010; Saint Vincent Island – Engeman et al. 2024; Jehossee Island – Beasley et al. unpubl. data).

Although statewide elimination of wild pigs is not an achievable goal in many states with abundant and widespread populations in the foreseeable future, efforts across the state of Missouri demonstrate that with sufficient political support, financial resources, stakeholder interest, and partnerships, widespread elimination of wild pigs is feasible, even within states with a longstanding culture of wild pig hunting. In the eight years since the Missouri feral hog elimination partnership program was launched, state and federal partners have successfully eliminated wild pigs from 60% of the areas where pigs were present prior to the initiation of the project, eliminating populations from over two dozen counties across the state (T. Guerrant, pers. commun.). The success of this project should serve as a model for states where wild pigs are widespread and have been present for centuries. Even within most states across the southern U.S., wild pigs are not ubiquitous across the landscape, and thus targeted efforts to remove fringe populations within counties or portions of the state with small or isolated populations could be implemented. However, to date most management is driven by availability of resources within areas experiencing more extensive damages, rather than a focus on systematic range reduction. Widespread adoption of an approach focused on range contraction would require a paradigm shift in management approaches and priorities, as well as expansion of partnerships among state, federal, and private stakeholders. In particular, more support and investment is needed among state agencies to achieve widespread wild pig control in many regions of North America.

Interest in control of wild pigs has also facilitated a renaissance of research on this species, which historically has been understudied compared to other large mammals in North America (Beasley et al. 2018, Beasley et al. 2020). While financial investments in wild pig research remain limited, especially among many state agencies, the growing cadre of research groups conducting applied research on this species has served a critical role in developing, evaluating, and improving management approaches and tools for advancing control efforts by agencies. In part due to the growing collaborations among researchers and managers, shortly after creation of the NFSDMP, the National Wild Pig Task Force was established, representing a technical, scientific, and leadership alliance to aid in management efforts for reducing the impacts of wild pigs in North America. Similar task forces or working groups have now been established in most states, bringing together diverse stakeholders to address key concerns and

challenges in managing wild pigs at more localized scales (Beasley et al. 2018). At an international scale, an ad-hoc working group focused on wild pig issues has been established within the Trilateral Committee for Wildlife and Ecosystem Conservation and Management, facilitating collaboration on wild pig issues among the U.S., Mexico, and Canada (Bergman et al. 2024), highlighting the global implications for more unified management goals of this invasive species.

Despite the success of recent control efforts, the rapid spread of transboundary animal diseases (e.g., African Swine Fever, Classical Swine Fever) within wild boar and wild pig populations across Europe, Asia, and more recently the introduction of African Swine Fever into Hispaniola represents an acute economic threat that underscores the importance of continued expansion in investments and adoption of new approaches to reduce populations of this invasive species. While agricultural damages and control costs are extensive for wild pigs, likely exceeding \$2 billion annually in the U.S. alone, introduction of a transboundary disease has a devastating economic impact on domestic swine industries, representing a significant threat to domestic food security (Brown and Bevins 2018). Current monitoring and mitigation programs are in place to detect and contain any potential disease outbreak in the U.S.; however, this emerging threat underscores the need for more proactive, innovative, and sustained approach to wild pig control, which will require continued investments in new partnerships, a shift in the management culture of wild pigs, and a more unified vision of the legal status of wild pigs among state and federal agencies.

Current and Future Challenges

Despite the success of recent efforts to expand population-level control of wild pigs in North America, several significant hurdles remain that must be addressed to achieve long term success in wild pig management programs. A lack of unified management goals both within and between many agencies is probably the single most important factor limiting the progress and potential for successfully managing invasive wild pigs. Remarkably, across their range in the U.S. there is still no standardized legalized classification of this species (Mayer and Beasley 2018, VerCauteren et al. 2020). Wild pigs are considered a game species in some states, exotic livestock in others, can be live captured and sold through meat markets in at least two states, and yet in others are considered invasive pests and sport hunting of these animals has been outlawed (Smith 2020). Conflating the issue, many states that do not consider wild pigs to be a game species set regulations that essentially manage them as one, which creates confusion among hunters and further compounds the challenges of changing the management culture of this species.

Outside of the NFSDMP, there is considerable variability in wild pig management programs, even within some agencies. For example, there are instances where wild pigs are recognized as an invasive pest and extensively managed on some properties to reduce damages, yet wild pigs on other properties managed by the same agency within the same state are either not managed or there are no clear goals for management activities due to a lack of

clear and unified policies. Further, despite demonstration of the ineffectiveness of bounty systems for controlling wild pigs (Ditchkoff et al. 2017), there are still some agencies that use bounty-based contracts or ineffective strategies that focus on recreational hunting or box trapping to control populations in localized areas. The lack of concordance in management and continued application of ineffective wild pig control strategies by some agencies underscores the need for better educational programs targeting the public, legislators, and even wildlife professionals. Further, despite increased awareness, the illegal movement of pigs remains a major contributor to the continued establishment of wild pig populations in new areas. While several states have progressed new legislation to increase penalties and facilitate enforcement (Smith 2020), further action is needed more broadly across states to stop the movement of wild pigs by humans.

Due to their exceptional reproductive capacity and behavioral plasticity, management of wild pigs in areas with large, established populations is costly, time consuming, and extremely challenging. Consequently, it is imperative that realistic, achievable goals and timelines are set at the outset to guide adaptive management programs. In cases where damage reduction, rather than population elimination, is the goal, it must be recognized that populations can return to pre-control levels within months of the cessation of management activities (Garabedian and Kilgo 2024). Thus, any resources expended on wild pig control must be offset by benefits gained from management activities. Unfortunately, many programs fail to recognize this limitation, spending large sums of money without demonstrated benefits or long-term management outcomes. Further, lapses in federal funding, loss of personnel, and other extraneous factors must be anticipated in designing management programs to ensure populations cannot rebound during gaps in management activities.

Monitoring efforts also are rarely integrated into wild pig management programs, resulting in a lack of understanding of the efficacy of removal efforts or changes in damages in response to control. Such data are critical to facilitate long-term support among politicians and stakeholders, and thus practical and cost-effective monitoring approaches are critically needed to be paired with control efforts to demonstrate success and inform adaptive management approaches (Treichler et al. 2023). Despite its widespread use in highlighting the success of management programs, the number of wild pigs removed alone is not a sufficient benchmark of success. In fact, use of take metrics to highlight program achievements can erode political support for control programs in the absence of concurrent reductions in damages. Instead, managers should implement standard monitoring metrics based on quantitative field-collected data to demonstrate reductions in both population size and damages to stakeholders (e.g., Treichler et al. 2023). It is imperative that such metrics can be easily implemented by management personnel, with minimal additional cost, and can be carried out alongside management activities in order to achieve widespread adoption.

Prior to 2010 there was growing concern that wild pigs would likely continue to expand in numbers and distribution to the limits of where weather and climate would

allow them to survive. Over the last few decades, however, the growing ecological and economic impacts of wild pigs have precipitated a widespread shift in the perception and management of this invasive species, resulting in substantial investments in wild pig management across the U.S. through the NFSDMP and other programs. The success of these programs in eliminating fringe populations throughout many northern U.S. states and multiple islands (VerCauteren et al. 2020, Engeman et al. 2024, Beasley et al. unpubl. data), and reduction in damages in other areas where sustained management programs have been established (Treichler et al. 2023), have transformed the trajectory of wild pig population expansion in the U.S. and invigorated widespread interest in expansion of programs to further reduce damages. However, as control efforts shift into states with abundant and widespread wild pig populations and an entrenched culture of wild pig hunting, new approaches to management, expanded educational campaigns, more unified management goals, and additional investments in control efforts will be needed to continue to contract the range of this species. Further, managers and policy makers must recognize that the cost and effort per pig increases substantially as populations are reduced (McCann and Garcelon 2008), and thus adequate long-term investments in funding, resources, and research must be allocated to management programs. In doing so, while complete elimination of wild pigs from their invasive range is not likely, further contraction of their range should occur, benefiting native wildlife, ecosystems, and humans.

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