



Stakeholder contributions to conservation of threatened Northern Pine Snakes (*Pituophis melanoleucus*, Daudin, 1803) in the New Jersey Pine Barrens as a case study

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Abstract.—The successful management and protection of endangered or threatened species generally falls to state agencies. This paper suggests that while governmental agencies provide the legal, regulatory, and management framework for snake conservation, it is often the universities, conservation organizations, consultants, and concerned citizens that conduct the research needed for conservation efforts. Identification of all the relevant stakeholders and their contributions is important for determining how to manage the threats and enhance population viability. Managing the efforts of volunteers is hampered by the need to protect the locations of sensitive nesting and hibernation habitat, while encouraging protection of the species overall. In this paper we provide a template of the stakeholder categories that are often involved in research, management, and conservation, and describe the types of agencies, organizations and people within each category and their major contributions, using research with Pine Snakes (*Pituophis melanoleucus*). This suite of stakeholders has been successfully involved with Pine Snake research for over 30 years, and helped with examining key environmental and habitat needs. The contributions are synergistic and additive, lending continuity of stakeholder involvement. We also suggest several stakeholder involvement actions that can be useful to a range of conservationists.

Keywords. Environmental management, management framework, public participation, sensitive species, reptiles

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Introduction

Initially, decision-making and managing environmental resources was a top-down approach, where the involvement of the public in research and conservation was largely one way, with governmental agencies providing information to the public. This evolved into two-way communication where agencies also asked the public for their input, perceptions, and concerns. The importance of stakeholders and communities in environmental management was initially acknowledged in the Environmental Protection Agency's risk assessment paradigm, which included the public in the problem formulation phase (USEPA 1992, 1998). Several subsequent authors recognized the importance of a multi-stakeholder frame-

work for environmental management, where a range of stakeholders was involved in goal-setting for a project (Pittinger et al. 1998). The Presidential/Congressional Committee on Risk Assessment and Risk Management (PCCRARM 1997) acknowledged that the National Research Council's (NRC 1983, 1996) risk assessment paradigm required the addition of stakeholders and risk management to the process. Public participation or involvement is usually monitored as the success of the process, or the success of the project (Chess and Purcell 1999), but not the success of stakeholder inclusion.

The realization of the importance of stakeholders in decision-making was empowering, and has led directly to the involvement of stakeholders in every phase of monitoring, assessment, research, and conservation (Bon-

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Fig. 1. Northern Pine Snake (*Pituophis melanoleucus*) hissing when first encountered in the New Jersey Pine Barrens.

ney et al. 2009; Glowinski and Moore 2014). Partly the stakeholder participation derived from analysis of ecosystem services and governance (Paavola and Hubacek 2013). Three major advances followed: 1) stakeholder was defined as all interested and affected parties, including governmental agencies, non-governmental organizations, the private sector, and the general public, 2) stakeholders could identify environmental issues and formulate the questions requiring answers, and 3) a wide range of stakeholders could be involved in all phases of designing and implementing an environmental management project. Although the last is an ideal approach, it is seldom achieved in practice. Stakeholders may be particularly important to predicting or deducing unintended consequences of management. Yet, with decreasing federal, state, and local personnel, and decreasing and limited funding, involving a wide range of stakeholders in projects to help conduct studies and participate in environmental management and conservation is an ideal method of accomplishing more with less, while gaining public support. Citizen science projects, and community participatory research, are becoming more common and more powerful (Bonney et al. 2009; Dickinson et al. 2010). Citizen science is a method of integrating public outreach and scientific data collection locally and regionally (Cooper et al. 2007). An important aspect of citizen science is to gather natural history information that might otherwise go unnoticed (Dickinson et al. 2010). Stakeholder involvement, whether identified as citizen science

or participatory research offers opportunities (Conrad and Hilchey 2011), particularly for conducting long-term studies and monitoring for sustained conservation efforts (see Lawrence 2006).

In this paper we describe the risks faced by Pine Snakes (*Pituophis melanoleucus*) as a case study to identify the types of stakeholders that can be involved in snake research and conservation (Fig. 1). We also give examples of each type, and provide descriptions of the different types of contributions that stakeholders can make that lead to understanding the biology and conservation needs of snakes. Assessing stakeholder participation can lead to increases in the wise use of professionals and volunteers, but can also provide examples of opportunities to engage people and use personnel, and provide models of participation for others engaged in management of natural resources. This is a recently developed, often overlooked approach that can increase the personnel and provide logistic support needed to conduct long-term research. The threats in urban areas are partly offset by the potential for many volunteers. This approach has the added advantage of increasing public awareness, knowledge, and appreciation for snakes in general. The popular jargon for volunteers is citizen scientists (Cooper et al. 2007; Dickinson et al. 2010), but using a range of stakeholders involves more than just volunteers. Including stakeholders in management is particularly important, given the global decline of reptiles in general (Gibbons et al. 2000).

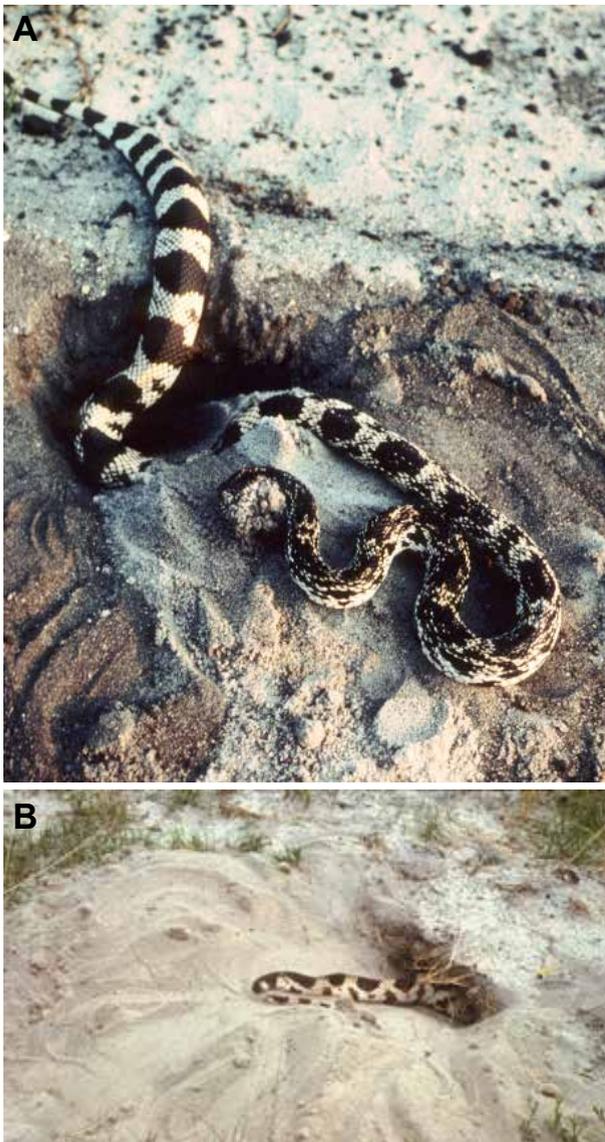


Fig. 2. Female Northern Pine Snakes dig their own nests in the New Jersey Pine Barrens, although in the southern part of their range they do not do so. They bend their neck such that the head forms a scoop capable of bringing sand out the entrance (Fig 2a). While digging their body is hidden below ground, and the dump pile of sand is visible (and serves to attract poachers; Fig 2b).

Background on Pine Snakes: Northern Pine Snakes are large constrictors that reach the northern limit of their range in the New Jersey Pine Barrens. They are among the top-level predators in the region and can grow to almost two meters long (Conant and Collins et al. 1998; Powell et al. 2016; Burger and Zappalorti, unpub. data). This species is declining in many parts of its range, and is not common anywhere. The declines of the species to the south, and its threatened status in New Jersey, make it imperative to understand the factors impacting population levels. The New Jersey population of Northern Pine Snakes is isolated from other populations living to the south by several hundred km (Burger and Zappalorti 2011a, 2016; Powell et al. 2016).



Fig. 3. Typical nesting area of Northern Pine Snakes in New Jersey. They require relatively open areas where there is complete sun penetration to the ground to provide sufficient warmth to the incubating eggs (Burger 1989a, 1991a; Burger and Zappalorti 2011a).



Fig. 4. Female Pine Snakes sometimes remain in their nests for several days after egg-laying is complete, perhaps protecting their clutch from being disrupted by other females that lay in the same nest.

Pine Snakes in the New Jersey Pine Barrens are the only North American snake that excavates their own nest in open-canopy sandy areas, and show high fidelity to these exact nest sites (Burger and Zappalorti 1991, Fig. 2). Open sandy areas with appropriate ground vegetation to provide structure to support excavation, while maintaining sun penetration to the ground, are rare in the Pine Barrens. Usually several females nest in the same open clearing (Fig. 3), and sometimes several females lay eggs in the same nest (Burger and Zappalorti 1991, 1992). The nest tunnel can be more than two meters long. Clutches can be distinguished because females exude a substance that binds the eggs together. Excavation of nests can take several days, and digging females usually rest during the hottest part of the day in the shade of pine trees. Once part of the tunnel is excavated, females sometimes remain in the tunnel during the heat of the day, and continue to do so for a few days after a clutch is laid (Fig. 4). Nesting females and their nests are vulnerable to off-road vehicles (ORVs), poachers, and predators, as are hatchlings (Burger 2006, 2007, Burger et al. 1992, 2007;



Fig. 5. Pine Snakes hibernate in communal hibernacula that can contain up to 30 or more Pine Snakes (Burger et al. 1988; Burger and Zappalorti 2011a, b, 2015, 2016). **Fig. 5a** shows the depth hibernation chambers are below ground, a snake in a natural chamber (**Fig 5b**) and in cement blocks from an old septic chamber (**Fig. 5c**, Pine Snake on right, Black Racer on left).

Burger and Zappalorti 2016). Northern Pine Snakes from the New Jersey Pine Barrens are highly prized by collectors because of their vibrant black and white pattern.

Hatchlings emerge in the late summer or early fall, and find their way to hibernacula by following adult scent trails (Burger 1989a, 1990), or they hibernate in old stump holes or other places. Adults have relatively large territories, and radio-tracked snakes can be found as far as 3–4 km away from hibernation and nesting areas (Burger and Zappalorti 2011a, Zappalorti et al. 2014, 2015).

Snakes spend the winter in communal hibernacula that they modify from old mammal burrows and old stumps, digging long tunnels out into virgin sand, and overwintering in chambers (Burger et al. 1988; Burger and Zappalorti 2011a, 2015, 2016). The snakes usually hibernate a meter or more below the ground in chambers the size of their coiled body (Fig. 5). Traditional hibernacula are used for many years, and several we study have been active for 30 + years. If a hibernaculum is entered by mammalian predators, it may be abandoned for several years, but snakes eventually return to use it (Burger and Zappalorti 2011a). Both sexes show philopatry to hibernation sites, but females are more philopatric than males (Burger and Zappalorti 2015). Once we have

dug up a hibernacula, we rebuilt it with an appropriate chamber and entranceway made of cement blocks that prevent mammalian predators from entering. Our marking and recapture methods have not adversely affected the behavior or survival of the snakes (Burger and Zappalorti 2011b).

Northern Pine Snakes are vulnerable to the usual threats of insufficient food supplies, predators, inclement weather, and finding hibernation sites (this is especially true for hatchlings), but they also face human disturbance, wanton killing, mortality on roads, and poaching. They are vulnerable due to habitat loss and fragmentation, and human activities that lead to local extirpations (Golden et al. 2009; Burger and Zappalorti 2011a; 2016). It is for this reason that the involvement of a full range of stakeholders (including the public) is necessary and important to the conservation of this large snake. Involvement of stakeholders is an important aspect of the Pinelands National Reserve management (New Jersey Pinelands Commission 2009).

Materials and Methods

The objectives of this series of studies of Pine Snakes, which has spanned over 40 years, are to 1) examine the

breeding and hibernation biology of Pine Snakes, 2) understand the threats faced by Pine Snakes, and gather information helping to preserve them, 3) understand the possible role of contaminants, 4) conserve Pine Snake populations in their preferred habitats, and 5) educate the public about the importance and role of Pine Snakes in the Pine Barrens ecosystem. Over the last 30 years as it became clear that people, organizations and agencies wanted to contribute, and to take part in a research and conservation efforts to conserve Pine Snakes. Our intent is to describe the various contributions of different organizations and people to serve as an example for other short or long-term studies with reptiles, whether threatened or not. All procedures were completed under appropriate state permits and a Rutgers University protocol approval (E86-017).

Results

Types of stakeholders: Understanding the biology of species, and collecting data for management and conservation traditionally fell to governmental agencies and universities. However, many different categories of stakeholders now participate and fund species conservation and management. Table 1 lists the categories that are relevant for Northern Pine Snakes, and that have participated in Pine Snake research and conservation activities to a greater or lesser degree. A general description of each stakeholder type follows, and may be useful for other species of conservation concern (Table 1). This represents a suite of stakeholders that may be involved in many different types of environmental studies.

Stakeholder contributions to Pine Snakes conservation: Within each stakeholder type there are different organizations, groups, and individuals that contribute to research and conservation of Pine Snakes in the New Jersey Pine Barrens. Some stakeholder groups contribute positively, without any negative effects, while others can have both positive and negative effects on Pine Snakes (usually not the same people). Tables 2 and 3 list the threat types, and the roles of stakeholders’ in conservation and research in the New Jersey Pine Barrens. The references in Table 3 generally relate to Northern Pine Snakes in the New Jersey Pine Barrens (or from other regions), and not to other congeners. Much of the information available for Pine Snake life history and behavior comes from either university studies, or those funded by state agencies or industry, or a combination thereof, with the help of volunteers (Fig. 6).

Discussion

Stakeholder involvement: Federal and state agencies (resource and regulatory) are usually thought of as determining the status and trends of animals, protecting and conserving them, regulating or permitting their use, and conducting research that leads to conservation and management. With limited and sometimes declining resources, agencies must set priorities, and different agencies may have conflicting priorities (i.e., promoting multiple use vs protecting resources). While State involvement has been valuable for Pine Snake conservation, there are other groups that play critical roles in research and conservation. These roles are essential

Table 1. Types of stakeholders that can participate in research and conservation. Not all species, populations, or communities will have this full range of stakeholders.

Type	Definition
<i>Independent Scientist (university, museum, other)</i>	Scientist engaged in designing and implementing research projects, leading to public talks, publication and dissemination of results, and in some cases, to regulations or adaptive management.
<i>Natural Resource Agency</i>	State, federal, or local agency responsible for managing a biological resource (a species, population, community, natural area, preserve, or ecosystem)
<i>Management Agency</i>	State, federal, or local agency responsible for managing a resource other than biological one (e.g., water authorities)
<i>Regulatory Agency</i>	State, federal, or local agency responsible for developing and enforcing regulations that pertain to a species, population, community, or ecosystem (e.g., park, refuge), as well as media resources (e.g., water).
<i>Conservation Organization</i>	Non-governmental agency (NGO) with a conservation mission to protect species, populations, communities, or ecosystems, including endangered and threatened species. Can be national, state, or local.
<i>Other Non-governmental Agency</i>	Any other NGO with a vested interest in the species, population, community, or ecosystem, either directly or indirectly.
<i>Environmental Justice Community</i>	Any identifiable environmental justice community that is interested or affected by the resource; usually involves low income or minority communities.
<i>Public</i>	The general public, not otherwise engaged in any of the above categories, that is interested and affected by the existence of a wildlife resource and the opportunity to experience it.
<i>Consultant</i>	Business specifically set up with expertise to address environmental questions posed by governments, industry, or developers.
<i>Industry</i>	Local or regional industry that overlaps in some way with a resource, through land, air, or water, or directly with a species or community.
<i>Developer</i>	Entity that develops or changes the local or regional land use, usually for residential or commercial activities.



Fig. 6. Volunteers of all ages are involved in our Pine Snake research, and the handling and measuring of snakes contributes to their education, and results in their providing information about conservation to their families, friends, classmates, and others. Following hibernation studies, the children (and adults) put the snakes back into their hibernation chambers.

because the NJDEP, Endangered and Nongame Species Program has insufficient resources to gather data on all the threatened and endangered species in the state. The trend of decreasing resources may continue.

Engaging the members of conservation organizations and the public in research activities has the added advantage in that they often become committed to continued work, to spreading conservation information, and to specifically protecting Pine Snakes (and other snakes). For many naturalists and conservationists, working with state and university scientists provides a unique and rare opportunity to work with endangered or threatened species, which is both rewarding and thrilling, while contributing to essential conservation knowledge. Allowing children, especially teenagers, to participate results in disseminating information and enthusiasm to their classmates and friends (Fig. 6). It also increases their awareness of the importance of Pine Snakes and preserving their environments.

The inclusion of stakeholders that participate in data collection can result in connecting people to information about the species around them (Lawrence 2006), as well as increasing and expanding scientific literacy (Bonney et al. 2009). These are valuable goals, particularly for snakes, which often are feared (and therefore killed or discouraged from urban areas). Partnerships among different agencies and conservation organizations can lead to both improved conservation of species, and to increased collaboration among entities that will benefit future conservation efforts (Bidwell and Ryan 2006). Stakeholder involvement can have the added benefit of demonstrating the adverse effects of some species (Young et al. 2013), such as raccoons, that have increased because of human provision of food in urban environments, especially on sensitive, threatened Pine Snakes. More case studies on stakeholder involvement in species conservation in urban areas could lead to some general principles of involvement. For example, people living along canals could

monitor and track water snake numbers or their nest success, or people living near parks could track the number or habitat use of local snakes. Others in the public could record the location and date of turtle nests, of local species, or place protective cages over nests to prevent predation. In all cases, volunteers should coordinate with scientists and local agencies (Fig. 7).

Problems with involving stakeholders in conservation of a threatened species: There are several issues in involving many different stakeholders: 1) Protection of sensitive areas for Pine Snakes, 2) Protecting information about sensitive locations, 3) Conflicts among and within stakeholder groups, and 4) Securing help for field work when needed. In addition, illegal activities threaten the Pine Snake populations. Each will be discussed below.

The locations of sensitive areas for Pine Snakes need to be protected because they can be exposed to snake collectors that poach eggs, gravid females, and all Pine Snakes they encounter. With 6-digit GPS locations available on cell phones, this has become critical. Participants must be aware of the need to protect location data. In some years we have lost 40 % of our Pine Snake nests to poachers; the average was 29 %/year (Burger et al. 1992; Burger and Zappalorti 2011a). This is in addition to losses to natural predators such as foxes, raccoons, and skunks. It is imperative that everyone actively helping with Pine Snake work and conservation be aware of the potential, and avoid intentional or inadvertent disclosure of the location of nesting and hibernating snakes. This includes cautioning volunteers to avoid putting any information on social media that could indicate such locations, and warning them to turn off the GPS on their cameras and cell phones. People readily agree with this, but often are not aware of the problem. We are combating poaching by removing clutches before poachers have a chance to collect them. We hatch the eggs in the laboratory, and replace the hatchlings in their original nests after they

Stakeholder contributions to conservation of threatened Northern Pine Snakes

Table 2. Main threats faced by Pine Snakes in the New Jersey Pine Barrens and Opportunities for Stakeholder Involvement. These are not exhaustive, but provide examples of major threats or risks to the snakes.

Threat Type	Major Threat	Opportunity for Stakeholder Involvement
<i>Habitat Loss</i>	Development	Mainly NJDEP, Pinelands Commission, Public pressure on agencies. Public can protect snakes, leave habitat where possible on their properties.
	Forestry practices	Mainly NJDEP (Parks and Forests), Pinelands Commission, Public pressure on agencies, conservation organizations work to affect optimization for different sensitive species. Scientists of all stakeholder groups develop information on Pine Snake habitat needs to lobby Parks and Forests; public lobby for Pine Snakes. Conservation organizations and other publics can lobby for restrictions of off-road vehicles to reduce mortality.
	Infrastructure development	NJ Department of Transportation (DOT). NJDEP (Endangered Species and Nongame Project) influence DOT and work to build under-highway passages. NJDEP collect information on road-killed Pine Snakes to identify sensitive regions. Public can report Pine Snakes dead on the roads with their locations to the NJDEP database.
	Fire	Natural fires originally set back succession, providing open areas for Pine Snakes to nest and hibernate. Management of fires prevents the natural creation of open areas. State agencies (in collaboration with Pinelands Commission) can manage controlled burns (or forest cutting) to create open areas; conservationists and the public can lobby for creation of open areas, and can volunteer for such management actions.
<i>Human Disturbance</i>	Off-road vehicles	Conservation organizations, scientists, and the public pressure state and local officials, including NJDEP (ENSP [Endangered and Nongame Species Program], PF [Parks and Forests]) and law enforcement to manage off-road vehicles to reduce mortality on snakes and other wildlife, while providing for legitimate off-road recreational activity at levels which do not threaten natural resources.
	Poaching	NJDEP, law enforcement (both ENSP and PF) to monitor sensitive nesting and hibernation areas during peak activity times (spring, early summer nesting season, fall). Conservation organizations and private citizens to pressure government agencies and Pinelands Commission to enforce laws. Citizens can stop poachers when they see them, and raise awareness among neighbors about poaching.
<i>Predators</i>	Natural predators	Scientists from all stakeholder categories need to monitor natural predation rates to determine if actions by NJDEP are required. Public can report any incidences of predation on Pine Snakes to NJDEP database.
	Enhanced natural predators	Scientists from all stakeholder categories need to monitor whether there are increases in natural predators that are due to availability of food; state agencies, Pinelands Commission, and others conduct educational programs to explain the importance of not feeding animals, or leaving food available.
	Human commensals	NJDEP, Pinelands Commission and conservation organizations can educate the public about the threats from dogs and other pets to natural ecosystems, including snakes. All stakeholders need to make the effects of releasing pets into the wild known to the general public.
<i>Prey Base</i>	Population variations	NJDEP (ENSP and PF) and Pinelands Commission can fund and encourage studies on variations in prey populations, and the relationship to habitats and fragmentation. This information could be used to address habitat and development restrictions. To better provide prey for Pine Snakes, the public should not control rodents on undeveloped property that they own.
<i>Management Needs</i>	Lack of enforcement	NJDEP, law enforcement to ensure that personnel are used effectively to maximize protection during peak Pine Snake activity Periods. Conservation organizations and public to reinforce these needs. Public can report any infractions.
	Lack of key information	While NJDEP and Pinelands Commission require specific information on habitat needs and threats that pose a risk to populations, university scientists and other scientists have a responsibility to conduct studies to address specific needs. Public volunteers can help in monitoring, assessments, and conservation studies with time, money, and expertise. They can volunteer for research projects to allow long-term studies to continue.
	Lack of personnel and money	Conservation organizations and the public to lobby government agencies to devote more personnel and money to protection and conservation of Pine Snakes and other sensitive Pinelands Species. Industry and developers can set aside some funding for necessary assessments and monitoring of projects and mitigations to determine efficacy. Public can contribute to research and conservation projects.
	Education about Pine Snakes	All stakeholders can play a role in education, but public advocates (conservation organizations, Pinelands Commission) can continue to include Pine Snake conservation as part of their educational programs. All volunteers can educate their neighbors, friends, and family about the role of Pine Snakes and their threatened status in the state.



Fig. 7. Volunteers contribute directly to conservation efforts by helping to remove trees that are obstructing sun penetration to nests or hibernation sites (**Fig. 7a**), or taking data on snake behavior (**Fig. 7b**).

have shed (and we remain until they have emerged, dispersed, and are no longer visible; Fig. 8).

The number of NJDEP conservation officers and Park Police has declined, and numbers are inadequate to effectively cover all the areas that need to be patrolled for the range of species protected under their responsibility. Although there are key seasons for Pine Snake activity, some of the hotspots are not close together, making it more difficult to patrol them and apprehend poachers. Many of the nesting areas have been known for many decades, and poachers regularly check them, including putting out “sucker boards” for snakes to hide under (where they can readily find them to poach).

Conflicts among stakeholder groups: There can be conflicts among stakeholder groups, even among state agencies, and these should be acknowledged (Young et al. 2013). The Department of Environmental Protection has a number of divisions that have different mandates with respect to habitats and the animals within them. For example, the Endangered and Nongame Species Program (ENSP) is charged with protection of all animal species, except for fish and game species. The Division of Parks and Forestry (PF) is charged with managing the forests, which can include cutting, special use permits, and other activities. In some cases the activities conflict with the protection of habitat for a species, such as Pine Snakes. Pine Snakes require open areas for nesting and for hibernation sites (Burger and Zappalorti 1986, 2011a), but these need to be close to suitable forest for foraging and summer dens (Burger and Zappalorti 1988b, 1989). Cutting large swaths of forest removes effective habitat, results in fragmentation, and churns up potential nesting areas. Pine Snakes do not nest in sugar sand, nor in sand with many dense roots, but prefer some roots from *Hudsonia* to stabilize the soil (Burger and Zappalorti 1986, 1988a). However, removal of small areas of trees can open the canopy and be optimal for Pine Snakes (Burger and Zappalorti 2011a), as well as for other snakes (Webb et al. 2005).

The pressures within each agency can also differ. For example with Pine Snakes, ENSP desires to keep off-road vehicles (ORVs) away from sensitive areas (nesting, hibernation) to avoid habitat destruction, and direct mortality, and would keep ORVs out of the forest during peak snake movement and activity periods (spring, nesting, fall). By contrast ORV users petition Parks and Forests to allow them to use ORVs in the forests at other times. Off road vehicle users have strong lobbying groups. Agency management is likely to listen to a vociferous group with many members. However, ORVs churn up nesting areas, killing eggs and hatchlings, and making habitat unusable for nesting, and they also unintentionally run over basking or moving snakes because large Pine Snakes are cryptic and invisible to a motorbike moving through narrow forest trails at excessive speeds (Burger et al. 2007).

Conclusions

Key contribution of stakeholders to conservation:

Including a variety of stakeholders who have a strong interest in the conservation of a rare plant or wildlife species typically has a positive outcome. A good example of stakeholder cooperation was the planning and writing of a comprehensive management and recovery plan for the Gopher Tortoise (*Gopherus polyphemus*), which was subsequently listed as a state “threatened” species (Florida Fish and Wildlife Conservation Commission 2012). Input from expert Gopher Tortoise stakeholders provided their years of knowledge and experience which was included in the recovery and management plan (Ashton and Ashton 2008). This case, however, did not have as inclusive a group of stakeholders, including non-governmental agencies (NGOs) and the general public.

Our case study illustrates how a range of stakeholders can aid in research and conservation of Pine Snakes in a number of ways, and help ensure that long-term studies provide the information needed for their continued protection. The various stakeholders we cooperated with have contributed markedly to conserving Pine Snake

Stakeholder contributions to conservation of threatened Northern Pine Snakes

Table 3. Agencies and entities that directly contribute to research and conservation of Pine Snakes in New Jersey. The examples given relate to Pine Snakes and are used to provide an indication of the ways stakeholders can participate, having a positive or negative effect (+/-).

Type	Example	+/-	Contribution
<i>Independent Scientist</i>	Rutgers University, Other universities or colleges, museums	+	Design, oversee, and implement research and conservation on Pine Snakes, leading to publication in refereed literature and provision of information to the public. Train students, both graduate and undergraduate, and organize volunteers to participate in research projects (Burger et al. 1987, 1991; Burger 1989b, 1990, 1991a,b, 1998a,b, 2006; Burger and Gochfeld 1985; Rudolph et al. 2007; Miller et al. 2012).
<i>Resource Agency</i>	NJ Department of Environmental Protection (NJDEP), Endangered and Nongame Species Program	+	Responsible for listing species (endangered, threatened, species of special concern), and gathering information where needed to protect the species and enhance populations, if needed. Pine Snakes are listed as threatened in NJ, and the ENSP has had to respond to delisting calls by developers (the state prevailed). Lead evaluations of the status of all nongame species, and oversee and engage in research, including snakes (Burger and Zappalorti 1988a, b, 1989, 1992; Schwartz and Golden 2002; Golden and Jenkins 2003; Golden et al. 2009). NJDEP also bans ORVs on public lands (NJDEP 2002).
	NJDEP; Division of Parks and Forests	+	Responsible for administering NJ state parks and forests. Bass River State Forest and Wharton State Forest have been involved with actively preventing off-road vehicles on nesting and hibernation sites, and habitat manipulation to improve nesting habitat (Burger et al. 2007; Burger and Zappalorti 2011a, b).
	NJ Natural Heritage Program	+	Lists and catalogues all sightings of endangered, threatened, and special concern species. Information is useful to federal and state agencies, consultants, and others. Exact locations of Pine Snakes are not disclosed generally to other that state or federal agencies.
	Pinelands Commission of the Pinelands National Reserve	+	Responsible for administering the Pinelands National Reserve, including protecting habitat for threatened and endangered species, such as the Pine Snake (NJPC 2009).
<i>Other Agency</i>	Ocean County Department of Emergency Services	+	Provide facilities and office space for snake research (Burger and Zappalorti 1988).
<i>Regulatory Agency</i>	NJ Department of Environmental Conservation, Law enforcement	+	Responsible for enforcing state endangered species laws. Pine Snakes are heavily poached by snake collectors in some years (Burger and Zappalorti 2011a, b).
<i>Conservation Organization</i>	New Jersey Conservation Foundation	+	Major mission is the protection and conservation of NJ's species, populations, communities, and ecosystems. Engage in independent and collaborative research with Pine Snakes, protection of Pine Snakes on their properties, organizes volunteers to help with research projects. Provide funding where possible. Mobilize interest in conservation measures and influence protective laws and regulations. Provide expertise and volunteers to aid in conservation, such as placing barriers to ORV traffic on nesting and hibernation sites (Burger et al. 2007).
	Pineland Preservation Alliance	+	Dedicated to upholding the tenets of the (NJ) Pinelands Preservation Act, and protecting the plants and animals of the Pinelands; provides volunteers to assist in research and conservation projects, especially protecting sensitive areas from illegal off-road vehicle use.
	The Nature Conservancy	+	Work to conserve species and habitats; fund projects (Burger and Zappalorti 2015; Zappalorti et al. 2015).
	New Jersey Audubon	+	Provide volunteers to assist in research and conservation projects.
<i>Other Non-governmental agencies</i>	Outdoor hiking clubs: Burlington County Naturalists, Batona Trail Club	+/-	Report sightings of rare species, assist with filling in knowledge gaps in distribution for rare species.
<i>Environmental Justice Communities</i>	Some retirement communities	+/-	Some retirement communities are on low/fixed incomes; some retirees fear snakes, do not protect them, and kill them on sight; dogs can become predators. The original residents of the Pine Barrens ("Pineys"), who had small farms in the pines, protected Pine Snakes because they eat rats and mice. They left places for them to nest at the edges of fields (Burger and Zappalorti 2011a).
<i>Public</i>	Naturalists	+	Gather information, produce reports and books about animals or habitats (field guides; Conant and Collins 1998; Boyd 1991).

Table 3 (continued). Agencies and entities that directly contribute to research and conservation of Pine Snakes in New Jersey. The examples given relate to Pine Snakes and are used to provide an indication of the ways stakeholders can participate, having a positive or negative effect (+/-).

Type	Example	+/-	Contribution
	Conservationists, hunters.	+/-	Volunteer to help with research projects, help build hibernacula and collect data on life history characteristics. Help monitor populations (Gerald et al. 2006a, b). Hunters maintained hunting lodges in the Pines, keeping open areas around their lodges which are used by Pine Snakes for nesting and hibernation sites.
	Buck Run Hunt Club, Burrs Mill Hunt Club	+	Provide access and volunteers to help with research and conservation of Pine Snakes. Help build hibernacula and provide information on nesting sites and timing of nesting. Maintain open nesting areas for snakes (Burger and Zappalorti 1986, 1991; Zappalorti and Burger 1986; Burger et al. 1988).
	Other recreationists	+/-	Hikers, photographers, and others that walk through the Pine Barrens forests or roads. Usually protective of snakes, but may inadvertently kill or injure snakes. All foot and vehicular traffic within the pines can kill or injure snakes, and carry invasive seeds, leading to habitat changes.
	Retirement communities	+/-	Some retirees are protective of Pine Snakes, while others are afraid, and discourage, injure, or kill them.
	Traffic	-	There is significant mortality on paved roads, and on the sand roads that pass through the forest. Some people aim their cars toward the snakes, deliberately killing them (Himes et al. 2002; Golden et al. 2009).
	Off-road vehicle enthusiasts	-	Some recreationists (ORVs) make trails in the pines or on nesting areas, disrupting nests and killing snakes or destroying the underground nests (running over them; Burger et al. 2007).
	Snake enthusiasts and poachers	+/-	Snake enthusiasts help protect snakes and contribute time and money to snake research and conservation. Poachers can be a problem (poaching of nests averaged 29%/year, but was as high as 40%, Burger et al. 1992).
<i>Consultants</i>	Companies and scientists	+/-	Professionals that bid for work from state agencies and industry to census, monitor, or study species. Also conduct un-paid scientific studies. Contract work for the state always provides useful information (Zappalorti and Burger 1986; Zappalorti et al. 2014, 2015).
	Herpetological Associates	+	Consulting firm dedicated to providing sound scientific information to agencies, conservation organizations, and industry about amphibians and reptiles. Also conducts independent herpetological research (Zappalorti and Burger 1986; Burger and Zappalorti 2011a).
<i>Industry</i>	Varied	+/-	Provide funding for studies on their lands that they wish to develop; such funding results in information on nesting, hibernation sites, movement, and activity ranges (Gerald et al. 2006a, b).
<i>Developers</i>	General contractors	+/-	If in appropriate habitat, need to conduct an assessment of Pine Snake presence and abundance, depending upon contractor can be positive or negative; can produce important information on Pine Snakes (Zappalorti et al. 2015; Burger and Zappalorti 2011a), or can census at the wrong times or with the wrong methods.
	Builders Association of NJ	-/+	Challenged the threatened status of Pine Snakes; request delisting of rare species. Provide funding for state-required threatened or endangered species studies on proposed development site (Golden et al. 2009).

populations in New Jersey. They did so by volunteering to aid with research and conservation projects, educating the public about the role and importance of Pine Snakes in the Pinelands ecosystem, aiding in enforcement of laws and regulations, and providing funds for specific research tasks. For example, volunteers helped our research by searching for nest sites, and aiding with hibernation and radio-tracking studies. They greatly aided conservation efforts by cutting small groups of trees to provide open nesting habitat, removing herbaceous cover to increase the suitability of nesting areas, and adding logs to provide hiding places for hatchlings (Fig. 7). We note in passing that our project started before Pine Snakes were listed as a threatened species by the State of New Jersey, and it was our data (aided by stakeholders) that contributed to their listing.

We suggest that other herpetological studies can be greatly improved with the inclusion of stakeholders (Fig. 9). Each stakeholder group has the potential to contribute in many ways. State and county governmental agencies should be encouraged to enact laws and regulations to provide protection for herpetological communities, as well as to provide surveillance and law enforcement. The involvement of state agencies and NGOs has persuaded landowners to allow researchers to conduct studies on their land, and to consider easements or the purchase of land to provide wildlife corridors in connecting critical habitats. Land managers, either government agency, NGO, or private interests have directly aided in targeted conservation activities. In doing so they became aware of partnerships in field conservation to improve habitat (e.g., removal of vegetation or invasive species), prevent



Figure 8. Several Pine Snake females often nest in the same nest. Here we (R. Zappalorti and J. Burger) have removed four clutches (note they are bound together, making it possible to identify the eggs of three different females). Once females lay eggs, they exude a liquid that binds the eggs together. This partly prevents other females from disrupting the clutch and accidentally removing them to the outside while they are digging their own side chambers.

ORV entry (adding fencing, building berms, or other barriers), or educate the public about the importance of protecting Pine Snakes within their ecosystems.

NGOs can disseminate information through newsletters and programs on conservation needs, solicit volunteers from their organizations, and encourage contributions of money, equipment and time. Indirectly NGOs can advocate for state and local government to enact protection measures (laws, regulations), and provide conservation officers. By their example, NGOs can demonstrate the criticality of conservation for endangered or threatened species.

Many other organizations and individuals can also directly contribute to conservation of reptiles. For example, companies can provide volunteers and educate their employees about the importance of a range of species. Awareness of the plight of reptiles might result in managers altering the timing of activities (e.g., reduction of activity during critical nesting periods), and enhancement of vigilance throughout the year to avoid unnecessary harm. Companies can also develop a culture of ongoing contributions of research funds or volunteer assistance with field research and conservation.

Individuals can volunteer to aid projects, provide funding for projects, advocate at local, state and federal

levels to protect reptile communities, and provide local information not necessarily known by others. Some people have historical knowledge of populations, nest and hibernation sites used, and changes in predator (or prey) abundance in a particular habitat. In one particular example, the site engineer at a hazardous material cleanup site became aware of both gestating, state-endangered female Timber Rattlesnakes (*Crotalus horridus*) and nesting Pine Snakes, and mentioned their presence to an adjacent non-profit conservation landowner. An innovative approach to enhancing the rattlesnake gestation and Pine Snake nesting sites was developed and implemented as part of the hazardous material cleanup. A permit was obtained for this new plan, and it was actually less expensive than the original remediation plan which would have ruined the gestation and nesting areas with unnecessary tree plantings.

In all the above examples, individuals are key. People working for governmental agencies, NGOs, businesses, and other organizations, as well as volunteers, can all contribute to advancing research and conservation of reptiles.

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Figure 9. Sometimes many volunteers are necessary for a project, either digging up a hibernation site (**Fig 9a**), clearing open areas for sun penetration, or digging up an old septic line to prevent collapses and injuries to snakes.



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Stakeholder contributions to conservation of threatened Northern Pine Snakes



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