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Conserving Orthoptera in the wild: lessons from *Trimerotropis infantilis* (Oedipodinae)

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Orthopteran species are increasingly threatened with extinction in the wild. I review the state of orthopteran conservation in the wild, focusing on unique challenges facing these efforts. To provide a basis for discussion, I first review conservation efforts for *Trimerotropis infantilis*, the Zayante bandwinged grasshopper, which was the first orthopteran given official protection under the U.S. Endangered Species Act. I then address the principal challenges for orthopteran conservation. Successful conservation of Orthoptera in the wild will require motivation for conservation action, availability of basic biological information, and development of applied management programmes.

Keywords: orthopteran conservation; *Trimerotropis infantilis*; habitat conservation planning.

Introduction

All species – and the communities that they compose – are increasingly threatened by human disturbance, habitat loss, and extirpation. Orthoptera are no exception. Around the world, at least four orthopteran species have already been lost. *Conozoa hyalina*, the California Central Valley grasshopper and *Neduba extincta*, the California Antioch Dunes shieldback katydid are extinct. *Leptogyllus deceptor*, the Oahu deceptor bush cricket, is considered extinct in the wild (IUCN, 1996). Even widespread pest species are susceptible. During the 1800s, swarms of *Melanoplus spretus*, the Rocky Mountain locust, plagued much of the western United States. Following a natural population decline in the 1880s, disturbance from agriculture and cattle extirpated remaining populations. By the early 1900s, *M. spretus* appeared to be extinct (Lockwood and DeBrey, 1990). Other species may soon join this list. The 1996 *Red List of Threatened Animals* (IUCN, 1996) includes 66 orthopteran species classified as critically endangered, endangered or vulnerable, while three more are considered to be conservation dependent (summarized in Table 1, listed in Table 2). Species on this list are found in over 25 countries across Europe, Asia, Australia and North America (WCN, 1996). Additional species may be threatened in Africa and South America but we lack documentation of their status. Preservation of these and other Orthoptera will require effective conservation.

What can we do to prevent additional extinction in the wild? Insect conservation has received increased attention over the last few years (see Gaston *et al*., 1993; Samways, 1994). However, little attention has been paid to the specialized challenges of orthopteran conservation. I examine three issues crucial to successful conservation of Orthoptera: motivation for conservation efforts, availability of basic biological information and development of applied management programmes. I begin with a case study of *Trimerotropis infantilis*, the Zayante bandwinged grasshopper, the only orthopteran with legal protection under the US Endangered Species Act. Conservation efforts for *T. infantilis* provide pertinent examples for subsequent discussion of orthopteran conservation.

Case study of *T. infantilis*

Description of T. infantilis *and its habitat*

Trimerotropis infantilis Rentz and Weissman (Oedipodinae) is endemic to sandstone outcrops in the Santa Cruz Mountains of central coastal California. The species was described in 1984 from specimens collected

Table 1. Summary of threatened orthopteran species by IUCN (1996) categories

IUCN category	Number of orthopteran species
Critically endangered	8
Endangered	8
Vulnerable	50
Conservation dependent	3

Table 2. Threatened Orthoptera species from the *1996 Red List of Threatened Animals* (IUCN, 1996)

Species name	IUCN category	Countries
Acrididae		
Acrolophitus pulchellus	Vulnerable	USA
Appalachia arcena	Vulnerable	USA
Chloaeltis aspasma	Vulnerable	USA
Chorthippus acroleucus	Vulnerable	Hungary and Romania
C. hyalina	Extinct	USA
Miramella irena	Vulnerable	Hungary and Romania
Odontopodisma montana	Vulnerable	Hungary and Romania
Odontopodisma rubripes	Vulnerable	Hungary
Schayera baiulus	Critically endangered	Australia
Spaniacris deserticola	Conservation dependent	Mexico and USA
Spharagemon superbum	Vulnerable	USA
Stenobothrodes eurasius	Vulnerable	Hungary and Romania
Trimerotropis infantilis	Endangered	USA
Trimerotropis occidentaloides	Endangered	USA
Trimerotropis occulens	Endangered	USA
Zubovskia banatica	Vulnerable	Hungary and Romania
Eumastacidae		
Eumorsea pinaleno	Vulnerable	USA
Psychomastix deserticola	Vulnerable	USA
Gryllidae		
Caconemobius howarthi	Vulnerable	USA
Caconemobius schauinslandi	Vulnerable	USA
Caconemobius varius	Vulnerable	USA
Cycloptilum irregularis	Vulnerable	USA
L. deceptor	Extinct in the wild	USA
Neonemobius eurynotus	Conservation dependent	USA
Oecanthus laricis	Endangered	USA
Thaumatogryllus cavicola	Vulnerable	USA
Thaumatogrylius variegatus	Vulnerable	USA
Rhaphidophoridae		
Daihinibaenetes arizonensis	Vulnerable	USA
Macrobaenetes kelsoensis	Vulnerable	USA
Macrobaenetes valgum	Vulnerable	USA
Pristoceuthophilus sp.	Vulnerable	USA
Tasmanoplectron isolatum	Vulnerable	Australia
Utabaenetes tanneri	Vulnerable	USA
Stenopelmatidae		
Ammopelmatus kelsoensis	Vulnerable	USA
Ammopelmatus muwu	Vulnerable	USA
Deinacrida fallai	Vulnerable	New Zealand
Deinacrida heteracantha	Vulnerable	New Zealand
Deinacrida rugosa	Vulnerable	New Zealand

Table 2. Continued

Species name	IUCN category	Countries
Stenopelmatidae *continued*		
Stenopelmatus cahuilaensis	Vulnerable	USA
Stenopelmatus navajo	Vulnerable	USA
Stenopelmatus nigrocapitatus	Conservation dependent	USA
Tetrigidae		
Bienkotetrix transsylvanicus	Vulnerable	Hungary and Romania
Tetrix sierrana	Vulnerable	USA
Tettigidea empedonepia	Critically endangered	USA
Tettigoniidae		
Austrosaga spinifer	Vulnerable	Australia
Baetica ustulata	Vulnerable	Spain
Banza nihoae	Vulnerable	USA
Belocephalus micanopy	Vulnerable	USA
Belocephalus sleighti	Vulnerable	USA
Conocephaloides remotus	Vulnerable	USA
Hemisaga elongata	Critically endangered	Australia
Hemisaga lucifer	Vulnerable	Australia
Hemisaga vepreculae	Vulnerable	Australia
Idiostatus middlekaufi	Critically endangered	USA
Isophya harzi	Vulnerable	Hungary and Romania
Ixalodectes flectocercus	Critically endangered	Australia
Kawanphila pachomai	Endangered	Australia
Metrioptera domogledi	Vulnerable	Hungary and Romania
Nanodectes bulbicercus	Critically endangered	Australia
N. Extincta	Extinct	USA
Neduba longipennis	Critically endangered	USA
Onconotus servillei	Vulnerable	Hungary and Romania
Pachysaga munggai	Vulnerable	Australia
Pachysaga strobila	Critically endangered	Australia
Phasmodes jeeba	Vulnerable	Australia
Psacadonotus insulanus	Endangered	Australia
Psacadonotus seriatus	Vulnerable	Australia
Sagapedo	Vulnerable	Armenia, Austria, Azerbaijan, Bulgaria, China, Czech Republic, France, Georgia, Germany, Hungary, Italy, Kazakhstan, Kyrgyzstan, Romania, Russia, Slovakia, Spain, Switzerland, Tajikistan, Turkmenistan, Ukraine, Uzbekistan and Yugoslavia
Throscodectes xederoides	Endangered	Australia
Throscodectes xiphos	Endangered	Australia
Windbalea viride	Vulnerable	Australia
Zaprochilus ninae	Vulnerable	Australia

near the town of Felton, Santa Cruz County, California, USA. Female adults are approximately 20 mm long and males are approximately 15 mm long, making *T. infantilis* one of the smallest members of the genus *Trimerotropis*. A prominent black eye band contrasts with the greyish-white frons against the grey to light brown body. The tegmina are marked with two, usually distinct, crossbands. The hindwings are pale yellow at their base and transparent. Hind tibia are blue (Rentz and Weissman, 1984). When flushed, *T. infantilis* flies 1–5 m; males crepitate during flight. *T. infantilis* may be found from May to October, with peak abundance and activity of adults during July and August (R. Morgan, unpublished; R. White, unpublished). Preferred food plants and oviposition requirements are unknown.

Trimerotropis infantilis only occurs in isolated patches of habitat called sand parkland. Sand parkland is typified by sparsely vegetated sandstone ridges and saddles with scattered ponderosa pine (*Pinus ponderosa*) (Fig. 1). Rapid drainage, ridge-top exposure and sparse ground cover (generally < 20%) result in a warmer and drier microclimate than that in surrounding habitats (Marangio, 1985; W.B. Davilla, unpublished). Sand parkland is a unique component of a habitat mosaic of maritime chaparral and ponderosa pine forest that is collectively known as the Zayante sand hills ecosystem (Griffin, 1964; R.F. Holland, unpublished). Sand parkland and the rest of the Zayante sand hills ecosystem dramatically contrast with the mesic mixed evergreen and coast redwood forests that dominate the region.

The sand parkland community, of which *T. infantilis* is part, is remarkably diverse. The flora includes at least 90 annual and perennial forbs and grasses that appear specifically adapted to the xeric conditions on sand parkland. Many of these plants are rare or endemic to sand parkland; others represent geographically disjunct populations (Thomas, 1961; Griffin, 1964; W.B. Davilla, unpublished; R. Morgan, unpublished). Two plant species are currently listed as endangered (US Fish and Wildlife Service, 1997). The sand parkland fauna includes several unique insect species. Another endangered species, *Polyphylla barbata*, the Mount Hermon June beetle, is found there, along with a localized subspecies of *Euphilotes enoptes*, the dotted blue butterfly, *Philanthus nasalis*, the Antioch sphecid wasp and *Colletes kincaidi*, Kincaid's solitary bee (US Fish and Wildlife Service, 1997).

Figure 1. Sand parkland on South Ridge near Quail Hollow Quarry, Santa Cruz County, California (Photo by J. Hoekstra, 1997).

Status of T. infantilis

Extensive surveys conducted from 1989 to 1997 have identified only eight populations of *T. infantilis*. Three of the populations are in patches of sand parkland surrounding the Quail Hollow Quarry; these populations are the focus of the principal conservation efforts discussed below. Three other populations were found nearby: one in a county park and two on the perimeter of another quarry. The seventh and eighth populations are on outlying patches of sand parkland that are privately owned (J.M. Hoekstra, unpublished; D. Pereksta, personal communication). The locality where the type specimens were collected has been mined and that population is believed to be extinct.

Trimerotropis infantilis is primarily threatened by habitat destruction and degradation. Historically, patches of sand parkland covered approximately 240 ha (Marangio and Morgan, 1987). Commercial sand mining and urban development reduced sand parkland to fewer than 80 ha (D. Lee, unpublished), thus restricting available habitat for *T. infantilis*. Populations on the remaining patches of sand parkland are threatened by continued sand mining and residential developments. Hikers and horses are degrading sand parkland habitat by trampling plants and compacting or disturbing the soil. Additionally, exotic vegetation is invading the habitat, threatening the integrity of the plant community on which *T. infantilis* must feed (US Fish and Wildlife Service, 1997). The anthropogenic threats to *T. infantilis* are compounded by the unavoidable risk of stochastic extinction of small populations.

Concern for the precarious status of this species was first raised by Dr David Weissman, who petitioned the US Fish and Wildlife Service to list *T. infantilis* as an endangered species under the Endangered Species Act on 16 July 1992. Following an evaluation of the species' status, the US Fish and Wildlife Service designated *T. infantilis* as an endangered species on 24 January 1997 (US Fish and Wildlife Service, 1997). (At the same time, the US Fish and Wildlife Service gave similar protection to *P. barbata*, which occupies similar habitats.) This designation makes it illegal to 'harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct' toward *T. infantilis* (Section 3(18) of the Endangered Species Act, 16 USC 1531–44, 87 Stat. 884).

Current conservation efforts

At the time of writing, the only active conservation effort for *T. infantilis* was a habitat conservation plan implemented by the operators of Quail Hollow Quarry. The habitat conservation plan defines habitat protection, management and restoration actions intended to preserve three populations of *T. infantilis* around the quarry. In return, the quarry operators have received an incidental take permit that exempts them from liability for any *T. infantilis* that may be killed or displaced by legal quarry operations.

The habitat conservation plan preserves, in perpetuity, three patches of sand parkland that support populations of *T. infantilis* around Quail Hollow Quarry. To protect *T. infantilis* from the threat of sand mining, the 4.5 ha North Ridge and 8.3 ha West Ridge parcels are being placed in conservation easements held by the quarry operators. The easements will protect the parcels from mining and restrict human access to prevent other disturbances. The 13.2 ha South Ridge parcel, which contains the best quality sand parkland, is being sold to the public (Fig. 1). Long-term management of the three protected parcels is planned because habitat degradation continues to threaten the Quail Hollow Quarry populations. Exotic plants invading sand parkland will be eradicated. Public access onto the South Ridge parcel will be restricted to minimize disturbance by foot and horse traffic (Thomas Reid Associates, unpublished). (This restriction has apparently become a contentious issue that may significantly affect the success of the conservation plan (D. Pereksta, personal communication).) Finally, a revegetation programme has been implemented to repair damage in protected habitat areas and to reclaim quarry habitat after completion of mining. Where disturbed sand parkland does not recover naturally, local seeds and topsand will be used to recreate a native plant assemblage.

The quarry operators, US Fish and Wildlife Service and other interested parties hope that the habitat conservation plan will preserve the three populations of *T. infantilis*, and provide additional habitat which might be colonized in the future. Because this plan was implemented only months ago, it is too early to determine its success.

At the time of writing, there were no active efforts to conserve the other populations of *T. infantilis*. The operators of another sand quarry have drafted a habitat conservation plan, but no suitable habitat remains on the property. Therefore, it is uncertain whether the plan would actually protect any populations of *T. infantilis*. (The quarry operator likely developed the plan simply as a regulatory formality to pre-empt any future regulatory actions.) The population in the county park is protected from habitat destruction, but no plan for controlling habitat degradation exists. Other populations of *T. infantilis* on private property could receive protection if a county-wide conservation plan is developed or if the properties are purchased by the public. Such actions are being contemplated (D. Pereksta, personal communication).

Discussion

Conservation of any species is challenging. The threat of extinction lends a sense of urgency to research, planning and decision making. As a result, conservation biology is a science conducted under pressure and with only limited information. Orthopteran conservation faces similar challenges, but with some unique complications. I classify these under three headings: (1) support for orthopteran conservation, (2) basic biology and (3) applied biology. To maintain a focus on conservation of Orthoptera, I will not address more general principles of conservation biology such as reserve design, minimum viable population sizes or conservation law. Such issues are discussed in detail elsewhere (e.g. Pyle *et al.*, 1981; Soulé, 1987).

Support for orthopteran conservation

When seeking support for conservation of Orthoptera, the principal challenge is to overcome cultural preconceptions. Orthoptera is a broadly recognizable taxon. Most people can readily identify a grasshopper or cricket. However, orthopteran morphology and ecology are poorly understood, even by many biologists. As a result, species of legitimate conservation concern may be summarily equated with more common and widespread species. The preconception of Orthoptera as pests may be the greatest challenge to overcome. For centuries, humans have been affected by plagues of locusts and grasshoppers. Today, our efforts to combat these pests are institutionalized in agencies such as the Centre for Overseas Pest Research and the US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS). A full discussion of Orthoptera as pests versus conservation subjects can be found in accompanying papers.

How can we overcome preconceptions and garner support for orthopteran conservation efforts? One approach is publicity. Increased scientific attention, both in the field and in the literature, to rare and unique Orthoptera will improve recognition of orthopteran diversity and threats thereto. People must know that a problem exists before they can be motivated to solve it. Conservation laws, such as the US Endangered Species Act, offer another source of support for orthopteran conservation efforts by mandating protection for threatened and endangered species. Unfortunately, such laws are not in effect everywhere and they only give protection to formally listed species. Orthopteran species currently at risk of extinction require active conservation efforts, but almost all lack legal status as protected species.

The case study of *T. infantilis* provides two examples of ways in which support for conservation efforts was successfully gained. First, the habitat conservation plan for *T. infantilis* at Quail Hollow Quarry was backed by a fortuitous alliance of parties with diverse interests. Several years before *T. infantilis* was even recognized as an endangered species, proposed expansion of the sand quarry was opposed by neighbouring residents who feared their water supply would be affected. Opposition to quarry expansion was also voiced by local botanists and environmentalists who wanted to preserve the sand parkland community. Both parties supported conservation of *T. infantilis* at Quail Hollow Quarry because protecting this species would simultaneously protect their own interests. Other orthopteran conservation efforts may similarly benefit if the needs of the species coincide with other interests.

Second and most importantly, Dr David Weissman demonstrated that individuals can have extraordinary influence on the success of conservation efforts. His petition to list *T. infantilis* as an endangered species catalysed the entire conservation effort for this species by raising awareness of the status of *T. infantilis*. In addition to prompting the formal listing of *T. infantilis* as an endangered species, Dr Weissman's petition attracted the support of quarry neighbours and local environmentalists. Their support, in turn, led to an agreement with the quarry operators that is the basis of *T. infantilis* conservation at Quail Hollow Quarry.

Basic biology

The foremost complication for conservation of Orthoptera is the limited availability of natural history and ecological information about the species at risk. A large literature addresses widespread pest species, but the rare, localized and endemic Orthoptera are poorly studied. As a result, conservation is limited by the validity of assumptions and generalizations extrapolated from other species. Furthermore, few if any of the people involved in conservation of an orthopteran species are likely to have any familiarity or expertise in orthopteran biology. This was certainly true for *T. infantilis*. With the exception of Dr Weissman and anonymous reviewers of the listing documents, no-one directly involved in either the listing or habitat conservation planning process had previous experience with Orthoptera.

The case of *T. infantilis* highlights the kind of information that must be available if conservation is to be successful. The food plants and oviposition requirements of *T. infantilis* are unknown. Without such basic information, we cannot develop specific management plans that protect and maintain these resources. Nor can we be certain that habitat restoration efforts will provide adequate resources to establish new populations of *T. infantilis*. Suppose, for example, that *T. infantilis* is limited by availability of suitable substrate for oviposition; efforts to restore native vegetation without regard to the soil architecture may be wholly ineffectual from the grasshopper's perspective. I certainly recognize that preservation of intact habitat is a logical and necessary part of any conservation strategy and that if it proves effective my point is moot. However, should habitat preservation prove insufficient for maintaining a population or if discrete populations or habitat patches are difficult to delineate for protection, basic biological information will be critical in designing effective management interventions.

Orthopteran conservation will also derive significant benefits from investigations into more general aspects of orthopteran ecology. The principal gap in our knowledge is an understanding of the ecological factors that lead to habitat specialization and endemism. Several questions exemplify some of the issues needing attention. Why do some species within a genus have highly restricted distributions while others are widespread and common? Do specialized or endemic Orthoptera share particular morphological, behavioural or ecological traits? Are such traits indicative of key ecological factors that should be considered in conservation efforts?

Valuable research has been done by orthopterists (c.f. Rentz and Weissman, 1981; Weissman, 1984; Samways, 1997), but more is needed. I hope this paper will encourage interested biologists to pursue further study of orthopteran ecology. Even small efforts promise to make substantial contributions.

Applied biology

After decades of research and practice, we possess sophisticated methods for forecasting and controlling orthopteran pests. Phenological and meteorological models can predict the timing and intensity of locust and grasshopper outbreaks (e.g. Rainey, 1989; Kemp and Dennis, 1991). Chemical and biological applications can help control them (e.g. *Nosema locustae*). Because of the obvious threats such control programmes could pose to rare and endangered orthopterans, we must strive to minimize the impacts of such programmes on non-target species. At the same time, we may also be able to adapt some of these technologies to benefit endangered orthopteran populations directly. For instance, if phenological models can predict a pest outbreak, they should also be able to predict a crash in a threatened population, thereby enabling proactive conservation measures. Similarly, investigations into the dynamics of biological control agents may identify factors that slow the spread of an orthopteran pathogen or reduce its lethality. Such factors could be exploited by conservation biologists to reduce the risk that pathogens and parasites may pose for threatened orthopteran populations. These ideas may seem far-fetched, but they warrant exploration.

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