Documentation of Disturbance-Dependent Threatened and Endangered Species on U.S. Army–Europe Training Areas in Bavaria

Submitted to:
Installation Management Agency – Europe (IMA-EURO)
Heidelberg, Germany

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# Disturbance Dependent T&E Species

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1 INTRODUCTION

The preservation of native biodiversity is a common goal of many organizations around the globe, including the U.S. Department of Defense (DoD). To that end, the Installation Management Agency, Europe (IMA-EURO) funded this study to examine the potential effects of U.S. Army training activities on biodiversity in the German state of Bavaria. Given growing emphasis on the European Union’s Natura 2000 legislation, the effects of training on threatened and endangered species were of particular interest.

Biodiversity has been variously defined. In a comprehensive context, biodiversity includes “the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning . . .” (Noss and Cooperrider 1994). Recognizing that healthy, diverse ecosystems provide realistic, sustainable training resources, the U.S. DoD has become an advocate of maintaining biodiversity on its training lands. Goals established by the 1996 DoD Instruction 4715.3 include (1) maintaining or restoring remaining native ecosystem types across their range of variation, (2) maintaining or re-establishing viable populations of all species native to an installation’s areas of natural habitat, (3) maintaining evolutionary and ecological processes, such as disturbance regimes, hydrological processes, and nutrient cycles, and (4) managing over sufficiently long time periods for changing system dynamics.

As the DoD Instruction recognizes, some degree of disturbance is natural and often necessary for normal ecological functioning. Disturbance is a primary cause of spatial heterogeneity in ecosystems and plays a crucial role in maintaining biodiversity (White and Jentsch 2001). Disturbance that is heterogeneous in its nature, intensity and distribution may create patches of habitat representing a continuum of ecological succession. As species vary widely in their habitat needs, these patches may be colonized by a variety of organisms. Biodiversity is thus maximized where spatially heterogeneous, moderate levels of disturbance occur (Fox 1979).

Some species are “disturbance-dependent”, i.e., they require early or subclimax successional conditions for survival. The elimination of disturbance and the successional variation that it causes may result in the elimination of some species. The value of apparently destructive military activities has been noted in eastern Germany where the departure of the Soviet army and concomitant removal of disturbance following the fall of the Berlin Wall now threatens the biodiversity of former training areas such as Jüterbog (Brandenburg), Oberlausitz (Saxony) or Döberitzer Heide near Berlin (see e.g. Beutler 2000, Wanner et al. 2002, Tschöpe et al. 2002). Likewise, following cessation of maneuver-related disturbance, the former U.S. Army training areas at Hainberg and Tennenlohe (both in Bavaria) are experiencing shifts in biodiversity, including the loss of some threatened and endangered species (Jentsch 2001, Beyschlag et al. 2002, Jentsch et al. 2002).

Based on reviews of threatened and endangered species surveys of the major training areas in Germany, a number of species were identified that have a high likelihood of being disturbance dependent. These include various amphibians such as the yellow-bellied toad (Bombina variegata) and the natterjack toad (Bufo calamita),
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various insects such as the blue-winged grasshopper (*Oedipoda caerulescens*) and the dune tiger beetle (*Cicindela hybrida*), and numerous plants such as gray hairgrass (*Corynephorus canescens*), fringed gentian (*Gentianella ciliata*), mudwort (*Limosella aquatica*), and shepherd’s cress (*Teesdalia nudicaulis*).

2 OBJECTIVE

The objective of this effort was to utilize rigorous scientific and statistical methods to determine if the above-named threatened and endangered species are truly disturbance-dependent, and, if so, to determine, inasmuch as possible, the nature and degree of required disturbance.

3 DESCRIPTION OF THE SURVEY AREAS

The research took place at four U.S. Army training areas in the German state of Bavaria. Hohenfels and Grafenwöhr are considered major training areas (MTA’s) capable of supporting battalion and brigade-sized maneuvers and weapons training. Freihölser Forst and Klosterforst are considered local training areas (LTA’s) suitable for individual and crew weapons proficiency training at the platoon level. As a general rule, training activities at the MTA’s is more frequent and more intense than activities at the LTA’s.

3.1 Hohenfels Training Area (HTA)

The Hohenfels Training Area (HTA) is approximately 16,000 ha in size. It supports force-on-force maneuver training at the battalion level. No live fire takes place at HTA.

The training area is located in the administrative district of the Upper Palatinate (Oberpfalz). It is approximately 30 km northwest of Regensburg in the ‘Oberpfälzer Jura’ and belongs to the natural region of the ‘Mittlere Frankenalb’. Frankenalb is comprised of layers of Upper Jurassic sediments. Changes in the calcium content of the sea water that once covered the area and the incorporation of up to 40 % magnesium resulted in the formation of the hard dolomite. By the onset of the Cretaceous period, the entire area had become dry land and then suffered erosion and Karst formation. The soils in the training area are mostly loams derived from weathered limestone or dolomite. The common name of the soils is Braunerde or “brown soil”. Dolomitic sands are also present.

Average precipitation is between 650 mm and 700 mm per year. Drainage is predominantly internal, with much of the water entering the karst system. With the exception of one stream approximately 1 km in length, there are no naturally-occurring perennial water bodies at HTA. However, training activities create many small to moderate-sized puddles that may be filled with water for days or weeks depending on annual precipitation patterns.
3.2 Grafenwöhr Training Area (GTA)

Grafenwöhr Training Area is approximately 23,000 ha in size. It supports training and qualification for armor, infantry and aviation weapons. The weapons training may take place at static locations or from moving vehicles on multi-purpose range complexes using established roads. In 1988, the Combat Maneuver Training Center (CMTC) Live-Fire area, comprising approximately 2500 ha, was established which allows cross-country maneuvers at the company level with live firing into the established impact area.

GTA is located in the administrative district of the Upper Palatinate (Oberpfalz). The training area is located between the towns Auerbach, Vilseck and Grafenwöhr. The western third of the training area belongs to the natural unit of the "Nördliche Frankenalb". The central and eastern part is within the "Oberpfälzer Hügelland". The two basic geological formations Franconian Jurassic (Frankenalb) and Upper Palatine Hills (Oberpfälzisches Hügelland) are separated by the Freihung fault zone. Soils in the western part of the training area are derived from Jurassic sediments. Large portions of the central and southern areas are characterized by Upper Cretaceous deposits. The eastern part of GTA is mainly Triassic sandstone and sandy soils. Although the sands generally drain rapidly, finer textured layers beneath the sands may retain water.

Populations of blue-winged grasshopper, the dune tiger beetle and shepherd’s cress are known to occur on the sandy soils of the eastern portion of the training area. The yellow-bellied toad and natterjack toad are known to occur in the western portion of the training area where the calcareous/loamy soils retain water in ephemeral puddles. The natterjack toad is common in the sandy soils in the eastern part of the training area.

3.3 Freihölser Forst Local Training Area (FF)

The Freihölser Forst Local Training Area is located approximately 16 km north of Hohenfels Training Area and 5 km southeast of the town of Amberg in a forested area known as "Freihölser Forst" within the administrative district of Upper Palatinate (Oberpfalz). The LTA consists of approximately 138 ha situated in the Central Franconian Jurassic at the border of the Upper Palatine Hills.

Due to intensive training activities with heavy combat tanks and other all-terrain vehicles in the 1960’s, large areas were converted into denuded sand deserts characterized by severe erosion problems. In 1970, the Training Area was subdivided into a western German Federal Army section and an eastern US Army section. Attempts to reforest the area were initiated by the German Federal Forest Service in the late 1970’s. In 1993/94, the US Army carried out a large-scale revegetation program resulting in almost complete elimination of large, barren sandy areas. This condition has been largely preserved until today due to the fact that the training intensity has been maintained at a much reduced level. It is currently used primarily as a staging and logistics point for units arriving or training at HTA. The open character of large areas is threatened by shrub invasion and increasing crown density of the reforested areas. However, large areas with sand meadows and open sand soil can still be found.
3.4 Klosterforst Local Training Area (KF)

Klosterforst is situated northeast of Kitzingen in the administrative district of Lower Franconia (Unterfranken). The Klosterforst local training area comprises approximately 1,088 ha in the foreland of Steigerwald. The LTA is used primarily for light maneuver and ground troop training exercises.

Mixed layers of sand and gravel deposits from the Main River and former sand dunes characterize the subsoil. Sand dunes deposited during Pleistocene are mainly found in the central and northern parts of the training area. Klosterforst lies within one of the largest dune areas within the administrative district of Kitzingen. Where the sands are mixed with loam, they can retain water in ephemeral puddles.

Prior to military use, the “Klosterforst” was largely forested. When the military acquired the area following World War II, approximately 100 ha were cleared and have remained open since that time.

The local training area supports rather large populations of the blue-winged grasshopper and the dune tiger beetle in highly diversified sandy grasslands.

4 METHODS

Due to differences in the biology and ecology of the species surveyed, methods used to survey them also differed by species. In general, survey plots for each species and each training area were distributed as evenly as possible along a spectrum of surface disturbance from near zero to near 100%. For each species, approximately 20% of the survey plots were established in areas corresponding to 0-20% disturbance, and another 20% were established in each of four remaining disturbance categories corresponding to 21-40%, 41-60%, 61-80% and 81-100% disturbance. Inasmuch as possible, the plots also represented a spectrum of 0-100% bare ground. Plot locations were selected so that the level of disturbance and bare ground within each plot was as uniform as possible. All plots were established in areas where the target species occurred or would likely occur if disturbance or lack thereof created a suitable habitat. All plots were subjectively placed on areas with similar soils, woody overstory, slope position, aspect, etc. Hence, the primary differences between plots were vegetation density and the amount of bare ground resulting from surface disturbance.

Surveys were conducted during the spring and summer of 2004. All plots were located with a global positioning system (GPS) and photographed so that they could be revisited as necessary.

Disturbance was estimated or measured at each survey plot using methods described below for each species. Disturbance was defined as physical disturbance to the soil surface where the disturbance vector could be definitively determined. In the case of vehicular disturbance, the observer was required to be able to define the class of vehicle and/or the direction of travel. The mere presence of bare ground was not sufficient to be defined as disturbance.
4.1 Yellow-bellied toad and natterjack toad

The yellow-bellied toad (Figure 1) is considered severely endangered (category 2) on the German Red List (Rote Liste) and endangered (category 3) on the Bavarian Red List. It is listed in Annex II of the European Union’s Flora-Fauna-Habitat (FFH) Directive, requiring the establishment of specific preserves for its protection. It is also listed in Annex IV of the FFH Directive, requiring strict protection, and is especially protected by German Federal Nature Protection Act which prohibits the disturbance, harm or killing of the species without good cause. The natterjack toad (Figure 2) is considered endangered (category 3) on both the German and Bavaria Red Lists. It is listed in Annex IV of the FFH Directive and is especially protected by the German Federal Nature Protection Act.

The yellow-bellied toad and natterjack toad utilize similar habitats for breeding. Both require ephemeral pools of shallow water with limited vegetation. To minimize interspecific competition, the yellow-bellied toad is active primarily during the day and the natterjack toad at night. We originally planned to survey the yellow-bellied toad and the natterjack toad in 50 puddles at both HTA and GTA, for a total of 100 puddles. The survey was to be repeated at the same puddles on two subsequent dates, thus producing 300 total samples for each species. Unfortunately, the spring of 2004 was relatively dry, and it was determined that the puddles used for breeding might disappear prior to the second and third sampling periods. Thus, the sampling scenario was changed to include 300 puddles (150 each at HTA and GTA) that were all sampled during the first sampling period.

![Figure 1. The yellow-bellied toad gets its name from its yellow belly (right).](image)
During the respective reproductive seasons at HTA and GTA, the populations of both toad species were sampled in each plot. Sampling for the yellow-bellied toad took place during daylight and sampling for the natterjack toad was conducted at night to ensure maximum activity for the two species, respectively. The populations were sampled by counting all visible and audible adults. Visible and audible adults of all other non-target amphibians known to occur in similar habitats were also counted and quantified by species.

The surface area of each puddle was measured and survey data from each puddle were subsequently converted to the number of individuals per m$^2$ of surface area. Puddles were only considered if they ranged between 4 and 100 m$^2$. Prior to sampling the puddles, the degree of physical disturbance was visually estimated as 0-20%, 21-40%, 41-60%, 61-80% or 81-100%. The apparent age(s) of disturbance was also recorded. Age categories were none, recent, 1-2 years old, and older than 2 years and were based on the visual condition of the soil surface, the presence of dead or dying plants from the current year, and the degree of reestablishment of new plants. The percent cover for bare ground, plant litter, algae, and higher vegetation was visually estimated on a Daubenmire scale of 0%, 1-4%, 5-24%, 25-49%, 50-74%, 75-95% and ≥95%. Air temperature, water temperature and water depth were also recorded.
4.2 Blue-winged grasshopper and dune tiger beetle

The blue-winged grasshopper (Figure 3) is listed as endangered (Category 3) on the German Red List and severely endangered on the Bavarian Red List. It is not listed in the EU’s FFH Directive, but requires special protection under Germany’s Federal Nature Protection Act. The dune tiger beetle (Figure 4) is on the early warning list for Bavaria, but has not yet been placed on the Red List. However, it requires special protection under Germany’s Federal Nature Protection Act.

To quantify the populations of blue-winged grasshopper and dune tiger beetle along a disturbance gradient, sandy grassland communities were selected at the four training areas included in the study. For the blue-winged grasshopper, 50 plots were established at FF, 35 at HTA, 15 at GTA, and 76 plots were established at KF for a total of 176 plots. For the dune tiger beetle, 50 plots were established at FF, 10 at HTA, 15 at GTA, and 76 plots at KF for a total of 151 plots. Plot size was 5m x 10m.

At FF, GTA and KF the same plots were used for both species. However, at HTA these species do not share the same localities. During the respective reproductive seasons at the four training areas, the populations of both species were sampled in each plot. The populations were sampled by counting all visible adult individuals. Information regarding larval stages was recorded separately. Sampling occurred during daylight hours when the insects are normally active. Sampling was limited to times when temperatures exceeded 18°C and cloud cover was minimal to ensure maximum activity. Visible and audible adults of all other readily identifiable non-target grasshoppers and ground beetles known to occur in similar grassland habitat were counted and quantified by species. Counts were repeated twice at approximately 2-week intervals.

To determine the level of disturbance and the level of bare ground associated with each plot, transects were established perpendicular to the short (5m) end of each plot. The transects were spaced 1m apart and ran parallel to the long side (10m) of the plot for a total of 6 transects, each 10 m in length. The presence or absence of disturbance was recorded at 1m intervals along each transect (66 points per plot). The apparent age(s) of disturbance was also recorded. The presence or absence of bare ground was recorded at the same points. Quantification of percent disturbance and percent cover took place several hours prior to population sampling to allow insects disturbed by the quantification process to return to the plots. Air temperature and cloud cover were also recorded.
4.3 Shepherd’s Cress, Mudwort and Fringed Gentian

Shepherd’s cress (Figure 5) is listed as endangered (Category 3) on the Bavarian Red List. It is known to prefer sandy, acidic grasslands (Schultze-Motel 1986, Oberdorfer 1990). Fifty survey plots were established in suitable habitat at GTA; an additional 50 plots were established at FF. Inasmuch as possible, the plots were evenly distributed along a gradient from 0 to 100% disturbance.
Mudwort (Figure 6) is listed as endangered (Category 3) on the Bavarian Red List. Fringed gentian (Figure 7) is listed as endangered on the German Red List and is on the early warning list for Bavaria. It requires special protection under Germany’s Federal Nature Protection Act. Both species occur commonly in grasslands with loamy or clayey soils (Oberdorfer 1990, Rothmaler 1994, Rosenbauer 1996). Mudwort generally occurs along the margins of ephemeral puddles, while fringed gentian prefers drier grasslands. Suitable habitat, where the species were known to occur, was identified at both HTA and GTA and 50 plots were established per species per location.

Survey plots for these 3 species were circular with a radius of 3m, giving an area of approximately 28.3m². The degree of physical disturbance in each plot was visually estimated as 0-20%, 21-40%, 41-60%, 61-80% or 81-100%. The apparent age(s) of disturbance was also recorded as recent, 1-2 years old, or older. The percent cover for bare ground, plant litter, non-vascular plants (algae, mosses and lichens) and vascular plants was visually estimated on a Daubenmire scale of 0%, 1-4%, 5-24%, 25-49%, 50-74%, 75-95% and >95%.

All individuals of the target species were counted in their respective plots. Any other threatened and endangered plant species occurring on the plots were also quantified by species.

Figure 5. Shepherd’s cress.
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Figure 6. Mudwort.

Figure 7. Fringed gentian.
4.4 Gray Hairgrass

Gray hairgrass (Figure 8) is listed as endangered on the Bavarian Red List. It is known to prefer sandy, acidic grasslands with loose sand (Oberdorfer 1990, Rothmaler 1994, Conert 1998, Wörz 1998). Sandy, acidic grassland areas were selected at GTA, KF and FF to represent a range of disturbance from near zero to near 100%. Within these areas, 29 plots were established at GTA, 21 plots at KF and 50 plots at FF.

Plot size was 5m x 5m. To determine the level of disturbance and the level of bare ground associated with each plot, transects were established perpendicular to one end of each plot. The transects were spaced 1m apart, for a total of 6 transects, each 5 m in length. The presence or absence of disturbance was recorded at 1m intervals along each transect (36 points per plot). The apparent age(s) of disturbance was also recorded. The presence or absence of bare ground was recorded at the same points.

Figure 8. Gray hairgrass typically occurs in sandy soils.
5 RESULTS AND DISCUSSION

5.1 Yellow-bellied toad

The yellow-bellied toad is widely distributed at HTA and can be found in practically all the areas where armored maneuver training takes place. Numbers at GTA were limited, perhaps due to differences in soil type or the date of sampling. Hence, only data from the 150 plots at HTA were used in the analysis. The yellow-bellied toads exhibited a statistically significant preference for disturbance levels above 40% (Figure 9). There was an apparent preference for disturbance greater than 80%, but the density of toads was not significantly greater than areas with 41-60% surface disturbance.

Figure 9. Density of yellow-bellied toads as a function of visible surface disturbance at Hohenfels Training Area, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.
The breeding season for the yellow-bellied toad generally begins in April and may continue as long as suitable habitat is available (Nöllert and Günther 1996). For breeding purposes, the yellow-bellied toad prefers shallow bodies of water with little vegetation and high exposure to the sun. Such puddles are generally warm due to insolation, but dry up rather quickly with the onset of warmer weather. Few other amphibian species utilize this habitat, so competition is minimal (Möller 1993).

Historically, the natural habitat of the yellow-bellied toad was probably found along major rivers and their tributaries (Nöllert and Günther 1996). Seasonal flooding and concomitant scouring of the river banks and flood plains created ideal breeding habitat for the yellow-bellied toad. Today, however, flooding of most large rivers is limited by man-made flood-control structures. Hence, much of the natural habitat has been lost, and secondary habitats such as open-mine pits and military training areas have increased in importance (Jedicke 1992, Möller 1993). Figure 10 shows a typical habitat for the yellow-bellied toad at Grafenwöhr Training Area.

Figure 10. Typical habitat for the yellow-bellied toad at Grafenwöhr Traning Area, Germany.
5.2 Natterjack toad

Whether the sampling strategy missed the primary breeding season at HTA, or whether few individuals occur there at all, few natterjack toads were recorded at HTA. Hence, only data from the 150 plots at GTA were included in the statistical analysis. The results from GTA show a distinct preference for very high levels of surface disturbance (Figure 11).

The natterjack toad lives in dry areas but, like the yellow-bellied toad, the natterjack requires pools of water for breeding, and prefers shallow pools with minimal vegetation (Günther and Meyer 1996, Sinsch 1998). Breeding generally takes place in April. However, the breeding pools must retain water until late summer to ensure successful reproduction (Günther and Meyer 1996). As with the yellow-bellied toad, the historic natural habitat of the natterjack toad was probably found along major rivers and their tributaries where seasonal flooding scoured the river banks and flood plains, thus providing the essential habitat (Nöllert and Günther 1996). Today’s flood-control practices have eliminated much of the natural disturbance, relegating the natterjack toad to secondary habitats such as open-mine pits and military training areas (Jedicke

Figure 11. Density of natterjack toads as a function of visible surface disturbance at Grafenwöhr Training Area, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.

The natterjack toad lives in dry areas but, like the yellow-bellied toad, the natterjack requires pools of water for breeding, and prefers shallow pools with minimal vegetation (Günther and Meyer 1996, Sinsch 1998). Breeding generally takes place in April. However, the breeding pools must retain water until late summer to ensure successful reproduction (Günther and Meyer 1996). As with the yellow-bellied toad, the historic natural habitat of the natterjack toad was probably found along major rivers and their tributaries where seasonal flooding scoured the river banks and flood plains, thus providing the essential habitat (Nöllert and Günther 1996). Today’s flood-control practices have eliminated much of the natural disturbance, relegating the natterjack toad to secondary habitats such as open-mine pits and military training areas (Jedicke
1992, Möller 1993). Figure 12 shows a typical habitat for the natterjack toad at Grafenwöhr Training Area.

![Figure 12](image)

**Figure 12.** Typical habitat used by the natterjack toad at Grafenwöhr Training Area, Germany.

### 5.3 Blue-winged grasshopper

The blue-winged grasshopper was surveyed at HTA, GTA, FF and KF. The statistical analysis revealed significant interactions between locations, so the locations were analyzed separately. At HTA, there were also significant statistical interactions between sample dates. Hence, at that location, the sample dates were also evaluated separately. At GTA, the density of blue-winged grasshoppers was significantly greater in areas where surface disturbance exceeded 60% (Figure 13). At FF, there was a significant preference for 60-80% disturbance (Figure 14). And at KF, the preference was for areas with 80-100% disturbance (Figure 15). At HTA, few adult grasshoppers had emerged at the first survey date (Figure 16). Two weeks later, at the second survey date, the adults exhibited significant preference for areas with 60-80% disturbance. At the final survey date, preference had shifted to 80-100% disturbance, although the density was not significantly different from 60-100% disturbance.
Figure 13. Density of blue-winged grasshoppers as a function of visible surface disturbance at Grafenwöhr Training Area (GTA), Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.

Figure 14. Density of blue-winged grasshoppers as a function of visible surface disturbance at Freihölser Forst (FF) Local Training Area, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.
Figure 15. Density of blue-winged grasshoppers as a function of visible surface disturbance at Klosterforst (KF) Local Training Area, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.

Figure 16. Density of blue-winged grasshoppers as a function of visible surface disturbance at Hohenfels Training Area (HTA), Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.
Adult blue-winged grasshoppers generally prefer warm, dry, sandy areas with sparse vegetation. Typical habitats in Germany include early successional, nutrient-poor, sandy grasslands (Schlumprecht and Waeber 2003). Dry grasslands in Germany are seldom maintained in an early successional state; thus habitat for the blue-winged grasshopper is uncommon and transient. Where military maneuvers occur on such grasslands, they are kept in an early successional stage and become ideal habitat for the blue-winged grasshopper. Figure 17 represents a typical habitat for the blue-winged grasshopper at the Klosterforst (KF) local training area.

Figure 17. Typical habitat used by adult blue-winged grasshoppers at Klosterforst Local Training Area, Germany.

5.4 Dune tiger beetle

The dune tiger beetle was surveyed at KF and FF. There was no statistical interaction between locations or survey dates, so the data were combined for analysis. The beetle was not found in areas with less than 40% disturbance (Figure 18). Although there was a trend toward greater numbers of beetles with higher levels of
disturbance, there was no statistically significant difference between any of the disturbance categories beyond 40%.

As its common name implies, the dune tiger beetle also prefers open sandy habitats. Although the adult beetles are excellent flyers, they spend most of their time on the ground. The adults prey on other species and prefer minimal vegetation in order to detect prey, which they can do from a distance of 20-30 cm (Trautner and Detzel 1994). Minimal vegetative cover also promotes insolation of the soil surface. The adult beetles are most active when the surface soil temperature is between 34 and 42 °C (Trautner and Detzel 1994). Historically, the species was probably most abundant in sandy soils along rivers, beaches and sand dunes (Horion 1941) where periodic disturbance by wind and water removed encroaching vegetation. Sand quarries, as well as heavily grazed pastures and intensive vehicular traffic on sandy soils, now provide suitable habitat. Figure 19 represents typical habitat for the dune tiger beetle at KF.
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Figure 19. Typical habitat utilized by the dune tiger beetle at the Klosterforst (KF) local training area, Germany.

5.5 Shepherd´s Cress

Shepherd’s cress was surveyed at GTA and FF. There was no statistical interaction between locations, so the data were combined for analysis. The data showed no statistical difference in density of shepherd’s cress between disturbance levels of 0 to 80% (Figure 20). The density of shepherd’s cress was significantly less in areas with >80% disturbance. Initially, the data led to the conclusion that shepherd’s cress is not dependent on disturbance. However, further evaluation of the data and study sites has led to an alternative conclusion. As indicated previously, the working definition of “disturbance” required the surveyors to list an area as disturbed only if they could see specific evidence of the disturbance vector. In areas where succession and natural healing processes have obscured such evidence, the site could not be listed as disturbed. Shepherd’s cress occurs primarily in dry, nutrient-poor, acidic grasslands (Schultze-Motel 1986). Such meadows persist only where disturbance is able to periodically set back the natural successional process. The fact that physical surface disturbance was not always apparent in plots where shepherd’s cress occurred, is not evidence that the plot was undisturbed. It implies only that the disturbance was of an age such that physical evidence was no longer visible. Figure 21 is typical of habitat where shepherd’s cress is found.
Figure 20. Density of shepherd’s cress as a function of visible surface disturbance at Grafenwöhr (GTA) and Klosterforst (KF) training areas, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.

Figure 21. Shepherd’s cress habitat at Grafenwöhr Training Area (GTA), Germany.
5.6 Mudwort

Mudwort was surveyed at HTA and GTA. There was no statistically significant interaction between locations, so the data were combined for analysis. The distribution of mudwort exhibited a clear statistical preference for areas with 80-100% surface disturbance (Figure 22). It was absent in areas with less than 40% disturbance. As the common name implies, mudwort occurs in the muddy margins of small ephemeral pools with loamy or clayey soils (Rothmaler 1994). Such pools or puddles occur abundantly on military training lands where tracked and wheeled vehicles create ruts. Typical habitat is shown in Figure 23.

![Bar chart showing density of mudwort as a function of visible surface disturbance at Hohenfels (HTA) and Grafenwöhr (GTA) training areas, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.]

**Figure 22.** Density of mudwort as a function of visible surface disturbance at Hohenfels (HTA) and Grafenwöhr (GTA) training areas, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.
5.7 Fringed gentian

Fringed gentian was surveyed at HTA and GTA. Similar to shepherd’s cress, there were no significant differences in the density fringed gentian among disturbance levels up to 80% (Figure 24). Density of the gentian declined significantly in the 81-100% disturbance level. While shepherd’s cress prefers sandy soils, the fringed gentian occurs more often on loamy or clayey soils (Rothmaler 1994). At the training areas, it occurred most often in the ecotone between grassland and forest where they experience partial sunlight. As with the shepherd’s cress the numerical data do not support the contention that fringed gentian is disturbance-dependent. However, the fact that it occurs in locations along a successional trajectory from grassland to forest, implies that it requires disturbance that is several years old where physical evidence of disturbance may no longer be visible. Figure 25 illustrates a typical habitat where fringed gentian is found.
Disturbance Dependent T&E Species

Figure 24. Density of fringed gentian as a function of visible surface disturbance at Hohenfels (HTA) and Grafenwöhr (GTA) training areas, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.

Figure 25. Fringed gentian habitat at Grafenwöhr Training Area (GTA), Germany.
5.8 **Gray Hairgrass**

Gray hairgrass was surveyed at GTA, KF and FF. There was no statistical interaction between locations, so the data were combined for analysis. There was significantly greater density of gray hairgrass on plots representing levels of disturbance greater than 40% (Figure 26). The greatest density of gray hairgrass was present on plots representing 61-100% disturbance, but the difference was not significantly different from plots representing 41-60% disturbance.

![Figure 26](image)

*Figure 26. Density of gray hairgrass as a function of visible surface disturbance at Grafenwöhr (GTA), Freihölser Forst (FF) and Klosterforst training areas, Germany. Bars with the same letter are statistically similar to each other with a 95% level of probability.*

Gray hairgrass prefers sandy, acidic grasslands (Wörz 1998). This biotope developed from sand dunes following the end of the last glacial period about 10,000 years ago. Vegetation was naturally sparse and blowing sand was common. As the climate changed, the vegetation became more dense. In recent times, the dry grasslands have been kept open only through human intervention in the form of deforestation (Philippi 1970), grazing animals (1992), and military training. These dry acidic grasslands on sandy soils are among the most endangered biotopes in Europe (Quinger and Meyer 1995). Gray hairgrass is a common plant where the grasslands have persisted. Figure 27 is typical of gray hairgrass habitat at FF.
6 CONCLUSIONS

All eight of the surveyed species exhibited some degree of disturbance dependence. Both amphibians and both insects exhibited statistically significant preference for highly disturbed areas. Density of the yellow-bellied toad was highest where visible surface disturbance exceeded 40%; the natterjack toad reached highest density where disturbance exceeded 80%. At both training areas surveyed, both amphibians depend on ruts and other maneuver-related damages that provide ephemeral puddles with minimal vegetative cover on which the amphibians depend for reproductive success.

The adults of both insects, the blue-winged grasshopper and the dune tiger beetle, are adapted to sparse grasslands, and exhibited a statistically significant preference for areas with 41 to 100% visible surface disturbance. Dry grasslands are an early successional biotope. If left undisturbed, the grasslands would eventually convert to shrublands or forests. Military vehicular disturbance which limits plant cover is important for maintaining the open character of the grasslands where the insects can thrive.

Among the surveyed plant species, mudwort exhibited a statistically significant affinity for areas with loamy or clayey soils and with 81-100% visible surface
disturbance. Gray hair grass prefers sandy soils and achieved greatest density at all visible surface disturbance levels above 40%. The dry, acidic grasslands on which it occurs is one of the most endangered biotopes in Germany and, in the absence of herds of grazing ungulates, is maintained in an early successional condition only by human disturbance.

Numerically, shepherd’s cress and fringed gentian did not exhibit preference for highly disturbed areas. To the contrary, their density was significantly less in areas with greater than 80% surface disturbance. However, both species occur in the ecotone between grasslands and forests. They do not have an affinity for highly disturbed areas, nor do they occur within the late-successional forests. Instead, they seem to prefer areas with historic disturbance. Our observations suggest that shepherd’s cress prefers areas where disturbance is 4-6 years old, while fringed gentian prefers areas where disturbance is 6-10 years old, although the methods employed did not allow quantification of the observation.

The results support the contention that the diversity and abundance of threatened and endangered species is enhanced by military training disturbance on these training areas. While all eight of the studied species exhibited affinity for disturbed areas, their preferences varied by the degree and age of the disturbance. Large portions of each training area remain virtually untouched, thus favoring disturbance-averse species; other areas are heavily disturbed, favoring disturbance-dependent species such as the ones investigated in the present study. The rich habitat mosaics created on the training areas include the two extremes as well as a continuum of disturbance between them, thus providing suitable habitat for a very large number of species. The cessation of military training on these training areas would undoubtedly result in the loss of threatened and endangered species and overall biodiversity.
7 LITERATURE CITED


APPENDIX I. Data forms
8.1 Data form for the yellow-belled toad and the natterjack toad

**Disturbance Hypothesis** (Amphibians sampling)

<table>
<thead>
<tr>
<th>Target species:</th>
<th>Amphibians</th>
<th>Installation (^1):</th>
<th>Pond No.:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveyor:</td>
<td></td>
<td>Date &amp; time:</td>
<td></td>
</tr>
<tr>
<td>Weather conditions:</td>
<td></td>
<td>Pond and photo position</td>
<td></td>
</tr>
<tr>
<td>Temperature:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Precipitation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud cover (^2):</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Coordinates (^3):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N:</td>
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<td>E:</td>
<td></td>
</tr>
<tr>
<td>Apparent disturbance class:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O 0-20 %</td>
<td>O 21-40 %</td>
<td>O 41-60 %</td>
<td>O 61-80 %</td>
</tr>
<tr>
<td>Size:</td>
<td>m(^2)</td>
<td>max. Depth:</td>
<td>cm</td>
</tr>
<tr>
<td>Shade (^4):</td>
<td>%</td>
<td>Water temp.:</td>
<td>°C</td>
</tr>
<tr>
<td>Vegetation cover (Daubenmeyer scale) (^5):</td>
<td>Age class of disturbance (%) (^6):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bare ground:</td>
<td></td>
<td>None:</td>
<td>%</td>
</tr>
<tr>
<td>Litter:</td>
<td></td>
<td>Recent:</td>
<td>%</td>
</tr>
<tr>
<td>Algae:</td>
<td></td>
<td>1-2 years:</td>
<td>%</td>
</tr>
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<td>Plants:</td>
<td></td>
<td>Older:</td>
<td>%</td>
</tr>
<tr>
<td>Count of target species:</td>
<td></td>
<td>Other endangered / important species:</td>
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<td>Bombina variegata:</td>
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<tr>
<td>Endangerment (^8):</td>
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</tbody>
</table>

---

1. HTA, GTA, FF, KF
2. clear (< 10%), scattered (11-50%), cloudy (51-90%), overcast (> 91%)
3. WGS 84 / UTM
4. Estimate percentage of time per day the pond is shaded.
5. 0 (0 %), 1 (1-4 %), 2 (5-24 %), 3 (25-49 %), 4 (50-74 %), 5 (75-94 %), 6 (> 94 %)
6. Estimate percentage of each disturbance class (must add to 100% !)
7. Kind of disturbances, origin of pond, degree of succession, soil properties, etc.
8. Apparent or future endangerment of present situation, if necessary
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# 8.2 Data form for the blue-winged grasshopper and dune tiger beetle

**Disturbance Hypothesis (Grid sampling)**

<table>
<thead>
<tr>
<th>Target Species ¹</th>
<th>Installation ²</th>
<th>Plot Nr.:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveyor:</td>
<td>Count of Survey:</td>
<td>Date:</td>
</tr>
</tbody>
</table>

**Weather Conditions:**
- Temperature:
- Precipitation:
- Cloud cover:

**Coordinates ³:**
- E
- N

**Aspect ⁴:**

**Slope ⁵:**

**Orientation of Plot and photo position:**

**Apparent Disturbance Class:**
- 0-20 %
- 21-40 %
- 41-60 %
- 61-80 %
- 81-100%

**Age Class of Disturbance (%) ⁶:**
- None
- Recent
- 1–2 years
- Older

**Plot History ⁷:**

**Count of Target Species:**

**Other endangered / important Species:**

---

1. Genus (written out)
2. HTA, GTA, FF, KF
3. WGS 84 / UTM
5. Estimation of degrees
6. Estimate percentage of each apparent disturbance class (must add to 100 %)
7. Kind of disturbances, degree of succession, exposure to sun / shade, soil compression, cover with mosses or lichens
8. Apparent or future endangerment of present situation, if necessary
### Vegetative Cover (V) and Disturbance (D):

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<thead>
<tr>
<th></th>
<th>V</th>
<th>D</th>
<th>V</th>
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</tbody>
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- **Yes**
- **No**
### 8.3 Data form for shepherd’s cress, mudwort and fringed gentian

**Disturbance Hypothesis** (Circle sampling)

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<th>Target species:</th>
<th>Installation ¹:</th>
<th>Point No.:</th>
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</thead>
<tbody>
<tr>
<td>Surveyor:</td>
<td>Date &amp; time:</td>
<td></td>
</tr>
<tr>
<td>Coordinates ³:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N:</td>
<td>E:</td>
<td></td>
</tr>
<tr>
<td>Apparent disturbance class:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O 0-20 %</td>
<td>O 21-40 %</td>
<td>O 41-60 %</td>
</tr>
<tr>
<td>Size: m²</td>
<td>Shade ⁴: %</td>
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</tr>
<tr>
<td>Vegetation cover (Daubenmeyer scale) ³:</td>
<td></td>
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</tr>
<tr>
<td>Bare ground:</td>
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<td></td>
</tr>
<tr>
<td>Litter:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algae:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plants:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age class of disturbance (%) ⁵:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None: %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recent: %</td>
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<tr>
<td>1-2 years: %</td>
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<tr>
<td>Older: %</td>
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<td></td>
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<tr>
<td>Count of target species:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other endangered / important species:</td>
<td></td>
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<tr>
<td>Plot history, remarks ⁷:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endangerment ⁸:</td>
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</tr>
</tbody>
</table>

1. HTA, GTA, FF, KF  2. clear (< 10%), scattered (11-50%), cloudy (51-90%), overcast(> 91%)  
3. WGS 84 / UTM  4. Estimate percentage of pond that is shaded at noon.  
5. 0 (0 %), 1 (1-4 %), 2 (5-24 %), 3 (25-49 %), 4 (50-74 %), 5 (75-94 %), 6 (> 94 %)  6. Estimate percentage of each disturbance class (must add to 100% !)  
7. Origin of site, kind of disturbances, soil properties, degree of succession/shading, etc.  8. Apparent or future endangerment of present situation, if applicable
### 8.4 Data form for gray hairgrass

**Disturbance Hypothesis** (Grid sampling)

<table>
<thead>
<tr>
<th>Target Species ¹:</th>
<th>Installation ²:</th>
<th>Plot Nr.:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveyor:</td>
<td>Count of Survey:</td>
<td>Date:</td>
</tr>
</tbody>
</table>

**Weather Conditions:**
- Temperature:
- Precipitation:
- Cloud cover:

**Coordinates ³:**
- E
- N

**Aspect ⁴:**

**Slope ⁵:**

**Orientation of Plot and photo position:**

**Apparent Disturbance Class:**
- 0-20 %
- 21-40 %
- 41-60 %
- 61-80 %
- 81-100 %

**Age Class of Disturbance (%) ⁶:**
- None
- Recent
- 1–2 years
- Older

**Plot History ⁷:**

**Count of Target Species:**

**Other endangered / important Species:**

---

1. Genus (written out)
2. HTA, GTA, FF, KF
3. WGS 84 / UTM
5. Estimation of degrees
6. Estimate percentage of each apparent disturbance class (must add to 100 %)
7. Kind of disturbances, degree of succession, exposure to sun / shade, soil compression, cover with mosses or lichens
8. Apparent or future endangerment of present situation, if necessary
### Vegetative Cover (V) and Disturbance (D):

<p>| | | | | | | | |</p>
<table>
<thead>
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<td>V</td>
<td>D</td>
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<td>D</td>
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<td>D</td>
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</tbody>
</table>

+ Yes
- No