

ELEMENT STEWARDSHIP ABSTRACT
for

Centaurea maculosa

Spotted Knapweed

To the User:

Element Stewardship Abstracts (ESAs) are prepared to provide The Nature Conservancy's Stewardship staff and other land managers with current management-related information on those species and communities that are most important to protect, or most important to control. The abstracts organize and summarize data from numerous sources including literature and researchers and managers actively working with the species or community.

We hope, by providing this abstract free of charge, to encourage users to contribute their information to the abstract. This sharing of information will benefit all land managers by ensuring the availability of an abstract that contains up-to-date information on management techniques and knowledgeable contacts. Contributors of information will be acknowledged within the abstract and receive updated editions. To contribute information, contact the editor whose address is listed at the end of the document.

For ease of update and retrievability, the abstracts are stored on computer at the national office of The Nature Conservancy. This abstract is a compilation of available information and is not an endorsement of particular practices or products.

Please do not remove this cover statement from the attached abstract.

Authors of this Abstract:

Teresa Mauer, Mary J Russo (Revision), Margaret Evans (Revision)

©

THE NATURE CONSERVANCY

1815 North Lynn Street, Arlington, Virginia 22209 (703) 841 5300

The Nature Conservancy
Element Stewardship Abstract
For *Centaurea maculosa*

I. IDENTIFIERS

Common Name: Spotted Knapweed

General Description:

The following description of *Centaurea maculosa* is taken from Munz and Keck (1973) and Roche et al. (1986).

C. maculosa is a biennial or short-lived perennial composite with a stout taproot. It has 1-20 slender, upright stems, 3-10 dm tall, most branching in the upper half. Seedling leaves form a rosette; stem leaves are canescent, the lower once or twice pinnately divided into linear or lanceolate lobes on each side of center vein, tapered at both ends, the broadest part above the middle to 10 cm long and 3 cm wide; the upper with fewer lobes or entire, becoming smaller up the stem to less than 1 cm long. Heads are solitary, terminal, egg-shaped to oblong, 1.5-2.5 cm broad and 1.3cm tall. The involucre is pale and 1-1.4 cm high. Phyllaries are not spiny but have obvious veins, the lower and middle bracts egg-shaped, green to brown, all with a dark pectinate tip and the upper margin fringed with 5-7 pairs of cilia. The slender tubular flowers are whitish to pink or purplish; the marginal florets somewhat enlarged. Seeds are oval, brown to black with pale lengthwise lines; the pappus copious and whitish.

C. maculosa resembles other species in the genus, including *C. diffusa* (diffuse knapweed), *C. nigra* (black knapweed), *C. jacea* (brown knapweed), *C. nigrescens* (short-fringed knapweed), and *C. trichocephala* (featherhead knapweed). The best way to distinguish *C. maculosa* is by the dark tips and fringed margins of its phyllaries. All of these species are capable of becoming serious weed problems.

II. STEWARDSHIP SUMMARY

III. NATURAL HISTORY

Habitat:

A native of Europe, *C. maculosa* was accidentally introduced to North America most likely in the 1890s in alfalfa seed from Asia Minor (Maddox 1979). Spotted knapweed was collected in Victoria, B.C. in 1893 (Moore and Frankton 1974). It is assumed that soil carried on ships as ballast and unloaded in the port transported knapweed seed to this site at that time (Roche et al. 1986). Although the earliest collections of *C. maculosa* are from coastal areas of British Columbia and Washington, evidence of observed densities and directions of spread suggest it has moved into Washington more rapidly from the east (Roche et al. 1986). This species was abundant in Montana before it became common in Washington (Roche et al. 1986).

Approximately 1.5 million ha of pasture and rangeland in Washington, Montana, Idaho, Oregon and California are infested with knapweed, and it threatens 10.7 million ha in western Canada (Harris and Cranston 1979). Inceptisol soils are susceptible to spotted knapweed invasion in western Canada (Harris and Cranston 1979). In 1988, Alberta reported 145 sites of scattered individuals (Ali 1988). British Columbia reported that 100,000 acres were presently occupied by *Centaurea* species, and 2.7 million acres could potentially be infested. Diffuse knapweed accounted for 75% of that total area infested, with spotted knapweed accounting for the second largest area (Cranston, 1988). In Montana spotted knapweed occupies 4.7 million acres (Lacey 1988), the largest area in one state or province. There it appears best adapted to well-drained, light-textured soils that receive summer rainfall, including habitats dominated by Ponderosa pine and Douglas fir, as well as foothill prairie habitats with bluebunch wheatgrass, needle-and-thread, and Idaho fescue (Chicoine 1984). In Washington, spotted knapweed rates third among the state's knapweeds, with four percent of the total acreage. It is reported in 19 counties, with a total area of 10,777 ha. Ninety-two percent of the spotted knapweed is found in three northeastern counties (Roche and Roche 1988). Thirty-nine percent (4,253 ha) grows on land classified as industrial, including gravel pits, stockpiles, power lines, grain elevators, railroad, and equipment yards. These are strategic seed distribution points (Roche and Roche 1988). Seventeen percent occurs on pasture, range, and timbered range, and sixty-eight percent of this pasture-range-timbered range total is on pasture (Roche and Roche 1988). In the counties that reported few infestations, the plants were almost exclusively along roads or in urban areas. In central Washington, it is often associated with irrigation, preferring areas of high available moisture, including areas of deep soil with threetip sagebrush/fescue and roadsides receiving runoff (Roche et al. 1986). *C. maculosa* occurs statewide as individuals or small colonies in North Dakota, and on at least 32 sites in 10 counties in Utah. In Oregon, it grows on 121,600 acres in 23 counties. Spotted knapweed seems to occur along the more mesic margins of the range of the more widely distributed diffuse knapweed (*Centaurea diffusa*) (personal communication, Larry Larson).

Reproduction:

The biology and North American distribution of spotted knapweed are described in Reed and Hughes (1970), Moore (1972) and Watson and Renney (1974). Seeds germinate in fall and early spring. Thirty percent of seeds may be viable after eight years of burial (Davis and Fay 1991). Seedlings form rosettes which may produce 1-7 flowering stems the following spring. Marked plants in the Glacier National Park area in Montana have been observed to persist in the rosette stage for four years or longer before bolting (Tyser, personal observation, in Tyser and Key 1988). Plants may flower only once, or up to three years in succession, and perennial plants may have up to 20 flowering stems. Each plant produces 4-5 capitula in the first year (range 1-25), and 8-15 capitulas (range 1-89) in succeeding years. In central Oregon capitula are visible on the plants in late June; flowers open from mid/late July until mid August. Knapweeds are cross pollinated by insects, but are also self-compatible (Lack 1982).

Estimates of the mean number of achenes (seeds) per capitula range from 9-37 in the literature (Watson and Renney 1974, Schirman 1981, Harris 1980b, Maurer et al in prep). Variations in numbers of stems, capitula, and seeds have been observed between sites and years, and were attributed to seasonal differences in precipitation (Schirman 1981). Up to 146,000 seeds per

square meter have been reported using calculations based on seed capitula density and seed numbers (Schirman 1981). Dispersal is generally passive, occurring in late summer (but may continue throughout the fall, winter and spring), as seeds are shaken from drying capitula. The short pappus and weight of the seed (1.7 mg) keep dispersal distances relatively short; seeds generally fall within a 3-12 dm radius of the parent plant (Roche et al 1986). Existing populations spread outward at the perimeter and downwind (Roche et al 1986). Movement over greater distances requires transport by rodents, livestock, vehicles, or hay or commercial seed (Roche et al 1986).

Spotted knapweed seeds may germinate over a wide range of soil depths, soil moisture content and temperatures (Spears et al 1980, Watson and Renney 1974). Seed dormancy may be induced by exposure to light (Watson and Renney 1974)? Seedlings emerging early in the season (April and May) have a high probability of survival and reproduction in the following year. Those emerging in June and July have a low survival rate and almost no stem production the following season (Schirman 1981). Schirman (1981) estimated that survival of only about .1% of seed production is required to maintain stands at observed plant densities in highly disturbed areas.

In seed sowing studies Roze et al (1984) found that rosettes and bolting plants appeared on plots sown at densities as low as 208 seeds per m². Numbers of bolted plants were lower in plots with higher seed and rosette densities, possibly due to intraspecific competition. At low densities, the average number of capitula per plant tended to increase, although differences were not significant for the number of plots used in this study.

Lateral root-sprouting in *C. maculosa* may result in rosettes that may remain attached to the parent for an indefinite length of time, but expansion of a colony is primarily dependent upon seed production (Tyser and Key 1988).

The competitive superiority of this species suggests preadaptation to disturbance (Roche et al 1986). The initial invasion of spotted knapweed, like other noxious weeds, is correlated highly to disturbed areas. Once a plant or colony is established though, it may invade areas that are relatively undisturbed or in good condition with gradual, broad, frontal expansion (Tyser and Key 1988, Lacey et al 1991). This invasion is associated with a decline in the frequency of some species and a decline in species richness overall (Tyser and Key 1988). Widespread invasion of spotted knapweed often results from overgrazing. It has a low palatability, as it contains a bitter compound cnicin (Roche 1990). As the native grasses and forbes are continually eaten, the food reserves of their roots are depleted, and they are less able to compete with the knapweed (Roche 1988). The knapweed is highly adept at capturing available moisture and nutrients, and it quickly spreads, choking out other vegetation (Roche et al 1986). As the network root system of the native species is lost, replaced by the taproot of the knapweed, the water storage capacity of the soil decreases (Roche 1988), and soil erosion increases (French and Lacey 1983, in Tyser and Key 1988). Lacey et al (1988) compared two elements of erosion on plots that were 90% bunchgrasses to plots that were 85% spotted knapweed. The average total runoff from the bunchgrass plots was 23%, and the average

sediment yield was 39 pounds per acre. The total runoff from the knapweed plots averaged 36%, and the total sediment yield averaged 114 pounds per acre.

Although the quality of the land being invaded does not seem to be able to exclude spotted knapweed, it probably does effect the rate of spread of the infestation. In a study conducted in Glacier Nation Park, the front of a *C. maculosa* colony advanced by 10 meters in three years ((Tyser and Key, 1988). In another study, also conducted in Montana, the front of a colony advanced 14 meters in four years (Lacey et al 1991).

IV. CONDITION

V. MANAGEMENT/MONITORING

Management Requirements:

Most literature on controlling knapweed has focused on reestablishing valuable range, pasture, or cropland. None has looked at the problem from the point of view of restoration ecology, with the intent of restoring the native community.

Spotted knapweed is increasing in its range and frequency in western North America. It is important to monitor whatever means of control are used in order to determine the efficacy of the efforts and the effects of control upon the larger community.

The extent of infestation can be monitored with either low altitude aerial photographs or permanent photo plots. A permanent line transect should be established so that plant and/or stem density can be measured. The transect should extend outside the colony in order to measure the direction and rate of change in the size of the colony. If biological control agents are used, sticky traps and capitula dissection should be used to monitor insect populations, attack rates, and seed losses.

There are several methods of control for this species. It is important to determine and document the methods most effective for different sized infestations, different communities, and the specific characteristics of the site, including soil type, exposure, drainage, and degree of disturbance, human or otherwise.

Control of this species is receiving considerable attention by state agencies as well as colleges and universities in Oregon, Washington, Idaho and Montana. This species is very aggressive. In addition to the effects it could have on elements, control of this species is mandated by county and state agencies. In most states and provinces it is under the "A" weed list for eradication.

Several grasses and forbs, most of them non-native, have been used to explore the possibility of replacing *Centaurea* species by the seeding of a competitor. A. H. Bawtree, Provincial Range Specialist in British Columbia cited a group of studies from which he recommended the application of picloram at no more than 6 oz. per acre followed by fall seeding of crested wheatgrass (Bawtree 1988). An Oregon State University study found six species--Palestine orchardgrass, Berber orchardgrass, Nangeela subterranean clover, Mt. Baker subterranean

clover, and Covar sheep fescue--that over the course of six years were able to establish themselves and outcompete yellow starthistle (*Centaurea solstitialis*) (Johnson 1988). A two-year study of four grasses--Paiute orchardgrass, Covar sheep fescue, Critana thickspike wheatgrass, and Ephriam crested wheatgrass--found that the greater the biomass produced by the grass, the more it reduced the number of diffuse knapweed (*Centaurea diffusa*) seedlings. The species are listed in the order of their effectiveness. The researcher also indicated that those species whose growth period overlap the growth period of diffuse knapweed would be more effective at competing for moisture and nutrients (Larson, 1988).

Mowing is a method of control that would be possible only in areas that are not too rocky or steep, or without shrubs. If mowed in the early flowering state, the plants will usually regrow and produce abundant late season seeds. Those mowed even the same day as florets appear out of the bud have enough energy to produce seed. Among those mowed within ten days after flowerheads opened, none produced more than four filled seeds per head, and the greatest viability of these filled seeds was 57%, reached nine days after the flowerhead opened. Although these results indicate that mowing greatly reduces the seed set, a well established seed bank, such as would be present on a large or severe infestation, would most likely be able to compensate for this loss. Mowing would probably be a way to control populations, but not eradicate them.

No detailed research on vegetation response to knapweed control exists in the literature. The use of seeded or planted native bunchgrass species has not been explored. No studies have explored control by timed removal of flower capitula. Most studies have been designed to tackle infested areas on a large scale, and scale might prohibit removal of capitula by manual methods. However, relatively small areas that might be encountered on TNC preserves may be more amenable to this sort of management. Documented successful control in small areas by capitula removal would add valuable new information to the control literature.

Chemical and biological control have been proposed for spotted knapweed, and most of the control literature addresses these two categories:

Herbicides--*C. maculosa* can be controlled with picloram (4-amino- 3,5,6-trichloropicolinic acid) and 2,4-D but there are problems. Control by 2,4-D is temporary since it does not prevent germination from seeds in the soil. Picloram persists in soils but in 4 years, enough is lost from a .4-.6 kg/ha treatment to allow germination and reinfestation (Harris and Cranston 1979). The costs of applying picloram are estimated at \$37/ha, and are prohibitive for very large infested areas (Maddox, 1979).

Biological--Four insect species have been introduced into North America for biological control of knapweeds. Two gall flies, *Urophora affinis* and *Urophora quadrifasciata* (Diptera: Tephritidae) (Maddox 1982, Story and Anderson 1978, Harris 1980 a and b, Myers and Harris 1980, Berube 1980) and a moth, *Metzneria paucipunctella* (Lepidoptera: Gelechiidae) attack seed capitula (Englert 1971, Myers personal communication). A beetle which attacks the roots, *Shenoptera jugoslavica* (Coleoptera: Buprestidae) has also been introduced more recently (Zwolfer 1976).

U. affinis lays its eggs into young buds of *C. maculosa*. Egg hatch is synchronized with rapid growth of the receptacle in which each larva forms a gall. The seeds are not destroyed directly, but the diversion of nutrients to the gall reduces seed production by the plant as a whole (Harris 1980b). One generation of flies per season is usual, but a small proportion of the population completes a second one. Reported percentages of capitula attacked range from 10-50%, with up to 97% reduction in seed numbers per capitula.

U. quadrifasciata lays its eggs into florets inside more mature buds. Both species of *Urophora* can coexist in the same capitula. Some studies (Harris 1980) have found that *U. quadrifasciata* may attack capitula missed or more lightly-attacked by the earlier-attacking *U. affinis*, and result in a higher overall attack rate among capitula.

Metzneria paucipunctella lays eggs at the base of spotted knapweed buds and a young larva bores into the capitula after hatch. It feeds first on florets, then directly on seeds and does not form a gall. Establishment of this species has been somewhat difficult and increase has been slower than the fly species.

Female Sphenoptera beetles oviposit at the base of *C. maculosa* rosettes, and first instar larvae feed externally on plant tissues. After the first molt, the larva enters the plant tissue and mines into the root. A gall forms as the rosette terminates aestivation and resumes growth. The larva overwinters in the rosette root and pupates the next spring in a pupal chamber in the root crown. Adult beetles emerge and feed on knapweed leaves, adding to the root damage imposed by larvae.

Insects are available from USDA sources and could be released in target areas as a first step for control with relative ease and at no or little cost. Seed capitula attack percentages seem to rise quickly within a few years, but noticeable decreases in reproductively mature plants will take longer because of seed bank reserves and dormancy. This method, though slower, may be desirable because of minimal disturbance to soil and surrounding vegetation.

Other methods of control should be explored:

Mowing--although this would not be feasible in rocky, or sagebrush areas, in some knapweed stands with little other vegetation it might be possible to mow the plants just after most flowering has ended but before seeds have matured. This would make regrowth unlikely since moisture levels late in the season are probably too low for continued growth, but would offer a possible advantage of reducing reserves for flowering the following year.

Hand Removal--by August, in central and eastern Oregon, soils are often dry and dusty, and it may be possible to pull up a large number of seedlings, rosettes and reproducing plants in a small infested area. However, effects of soil disturbance on knapweed seed germination are not well documented. Even if seed germination of knapweed were not a problem, colonization by other weed species may be.

Hand Clipping--This method might alleviate the soil disturbance problem outlined above. Again, this would probably be feasible only in small infested areas. Timing would be the same as mowing and the stems and capitula would be removed from the area. Again, control might be slower, due to continued emergence from seedbank reserves.

Burning--although no literature specifically mentioned this as a control method for knapweed, it might be considered in areas with enough surrounding vegetation or litter to carry a controlled burn. Often however, dense stands of knapweed have little surrounding vegetation, possibly due to allelopathy. Litter from the previous year's stems often decays or scatters during the current season, but it may accumulate in very dense stands and create more favorable burning conditions.

VI. RESEARCH

Management Research Programs:

Identify infestations on or near preserves. Experiment with manual control methods.

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

Bibliography:

Berube, D.E. 1980. Interspecific competition between *Urophora affinis* and *U. quadrifasciata* (Diptera: Tephritidae) for ovipositional sites on diffuse knapweed (*Centaurea diffusa*: Compositae). *Z. Angew. Ent.* 90:299-306.

Berube, D.E. and P. Harris. 1978. Bud size selection by ovipositing *U. affinis* and *U. quadrifasciata* in B.C. pp 210-217 in Proceedings of the knapweed symposium (Oct 6-7, 1977; Kamloops, B.C.).

Berube, D.E. and J.H. Myers. 1982. Suppression of knapweed invasion by crested wheatgrass, *AGROPYRON CRISTATUM*, in the dry interior of British Columbia. *J. Range Management* 35(4):459-461.

Berube, D.E. and J.H. Myers. 1983. Reproductive isolation between *Urophora affinis* and *U. quadrifasciata* (Diptera:Tephritidae) in British Columbia. *Can. J. Zool.* 61:787-791.

Chicoine, T.K. 1984. Spotted knapweed (*Centaurea maculosa* L.): Control, seed longevity and migration in Montana. MS Thesis Montana State University. Bozeman, Mont. 96 pp MIN 25-8430038.

Englert, W.D. 1971. *Metzneria paucipunctella* (Gelechiidae, Lepidoptera): a potential insect for the biological control of *Centaurea STOEBE* in Canada. CIBC Report Weed Projects of Canada No. 28.

- Fletcher, R.A. and A.J. Renney. 1963. A growth inhibitor found in *Centaurea* spp. *Can. J. Pl. Sci.* 43:475-481.
- French, R.A. Lacey, J.R. 1983. Knapweed: its cause, effect and spread in Montana. Circular, Mont State Univ Coop Ext Serv. Bozeman: The Service. Number 307.
- Harris, P. 1980a. Establishment of *Urophora affinis* Frfld. and *Urophora quadrifasciata* (Meig.) (Diptera: Tephritidae) in Canada for the biological control of diffuse and spotted knapweed. *Z. Angew Entomol J Appl Entomol.* 89 (5):504-514.
- Harris, P. 1980b. Effects of *Urophora affinis* Frfld and *U. quadrifasciata* (Meig) (Diptera:Tephritidae) on *Centaurea diffusa* Lam. and *C. maculosa* Lam. (Compositae). *Z. Angew. Ent.* 90:190-201.
- Harris, P. and R. Cranston. 1977. Prospective cost-benefits for the biological control of diffuse and spotted knapweed in B.C. pp 276-285 in *Knapweed Symposium*.
- Harris, P. and R. Cranston. 1979. An economic evaluation of control methods for diffuse and spotted knapweed in Western Canada. *Can. J. Pl. Sci.* 59:375-382.
- Hubbard, W.A. 1975. Increased range forage production by reseeding and the chemical control of knapweed. *J. Range Management* 28:406-407.
- Lack, A. 1976. Competition for pollinators and evolution in *Centaurea*. *New Phytologist* 77:787-792.
- Lack, A.J. 1982. Competition for pollinators in the ecology of *Centaurea SCABIOSA* L. and *Centaurea nigra* L. I. Variation in flowering time. *New Phytologist* 91:297-308.
- Maddox, D.M. 1982. Biological control of diffuse knapweed (*Centaurea diffusa*) and spotted knapweed (*Centaurea maculosa*) in Washington, Montana, Idaho, Oregon, California. *Weed Sci.* 30 (1): 76-82. ill.
- Maddox, D.M. 1979. The knapweeds: their economics and biological control in the Western States, U.S.A. *Rangelands* 1(4):139-141. ill.
- Maurer, T.A., P.B. McEvoy, and C. Cox. 1985. Establishment and increase of three biological control agents on spotted knapweed in central Oregon. (in preparation).
- Moore, R.J. 1972. Distribution of native and introduced knapweeds (*Centaurea*) in Canada and the United States. *Rhodora* 74:331-346.
- Muir, A.D. and W. Majak. 1983. Allelopathic potential of diffuse knapweed extracts. *Can J Plant Sci.* 63 (4):989-996.

- Myers, J.H. and D.E. Berube. 1983. Diffuse knapweed invasion into rangeland in the dry interior of British Columbia. *Can J Pl Sci* 63(4):981-988.
- Myers, J.H. and P. Harris. 1980. Distribution of *Urophora* galls in flower heads of diffuse and spotted knapweed in British Columbia. *J. Applied Ecology* 17:359-367.
- Myers, J.H., P. Harris, B. Rawlek and W.W. Bennett. in prep. Establishment and adaptation of *Metzneria paucipunctella* (Gelechiidae, Lepidoptera) as a biological control agent on spotted knapweed in British Columbia. manuscript.
- Peschken, D.P. 1979. Biological control of weeds in Canada with the aid of insects and nematodes. *Z. Angew. Ent.* 88:1-16.
- Roze, L.D., B.D. Frazer and A. McLean. 1984. Establishment of diffuse and spotted knapweed from seed on disturbed ground in British Columbia, Canada. *J. Range Management* 37(6):501-502.
- Roze, L.D. 1981. The biological control of *Centaurea diffusa* Lam. and *C. maculosa* Lam. by *Urophora affinis* Frauenfeld and *U. quadrifasciata* Meigen (Diptera:Tephritidae). Ph.D. thesis. University of British Columbia.
- Schirman, R. 1981. Seed production and spring seedling establishment of diffuse and spotted knapweed. *J. Range Management* 34:45-47.
- Spears, B.M., S.T. Rose, and W.S. Belles. 1980. Effect of canopy cover, seedling depth, and soil moisture on emergence of *Centaurea maculosa* and *C. diffusa*. *Weed Research* 20:87-90.
- Story, J.M. and N.L. Anderson. 1978. Release and establishment of *Urophora affinis* (Diptera: Tephritidae) on spotted knapweed in western Montana. *Environ Entomol.* 7 (3): 445-448.
- Story, J.N. and R.M. Nowierski. 1984. Increase and dispersal of *Urophora affinis* (Diptera: Tephritidae) on spotted knapweed in western Montana. *Environ Entomol.* 13 (4): 1151-1156.
- Varley, G.C. 1937. The life-history of some trypetid flies, with descriptions of the early stages (Diptera). *Proc. Royal Ent. Soc. (London)* 12:109-122.
- Varley, G. C. 1947. The natural control of population balance in the knapweed gall-fly (*Urophora JACAENA*). *J. Animal Ecology.* 16:140-187.
- Watson, A.K. 1972. The biology and control of *Centaurea diffusa* Lam. and *Centaurea maculosa* Lam. M. Sc. Thesis. University of British Columbia.
- Watson, A.K., and A.J. Renney. 1974. The biology of Canadian weeds. 6. *Centaurea diffusa* and *C. maculosa*. *Can J. Plant Sci.* 54:687-701.

Zwolfer, H. 1976. Investigations on *Shenoptera (Chilostetha) jugoslavica* Obenb. (Col:Buprestidae), a possible biocontrol agent of the weed *Centaurea diffusa* Lam. (compositae) in Canada. *Z. Angew. Ent.* 80:170-190.

Zwolfer, H. 1979. Strategies and counterstrategies in insect population systems competing for space and food in flower heads and plant galls. *Fortschritte der Zoologie* 25:331-353.

IX. DOCUMENT PREPARATION & MAINTENANCE

Edition Date: 87-23-01

Contributing Author(s): Teresa Mauer, Mary J Russo (Revision), Margaret Evans (Revision)