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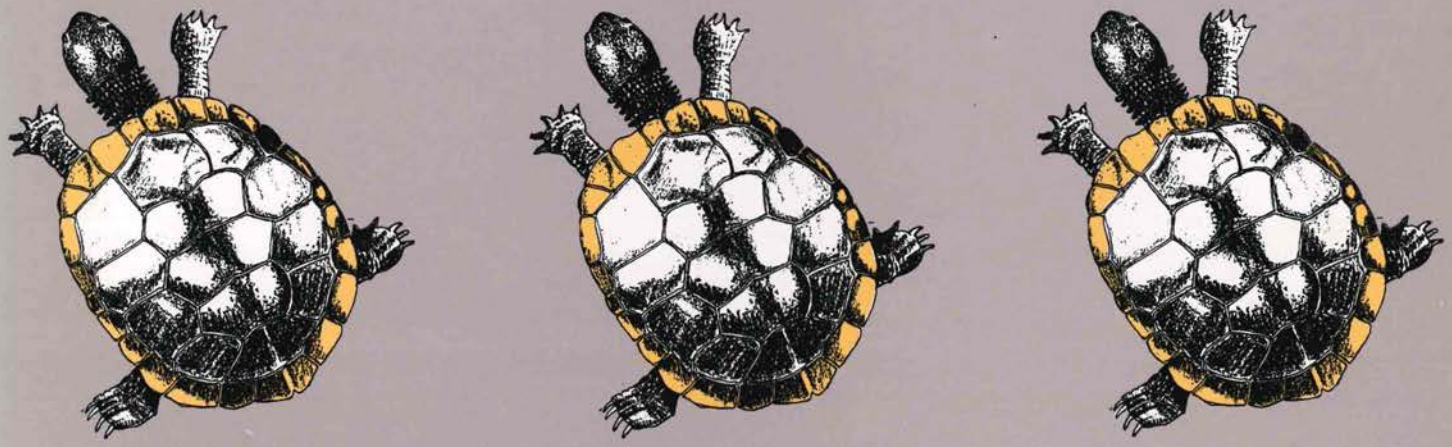

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WESTERN AUSTRALIAN WILDLIFE MANAGEMENT PROGRAM NO. 6

The Western Swamp Tortoise

by

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FOREWORD

Western Australian Wildlife Management Programs are a series of publications produced by the Department of Conservation and Land Management (CALM). The programs are produced in addition to Regional and Conservation Reserve Management Plans to provide detailed information and guidance for the management and protection of certain exploited, rare or threatened species (e.g. kangaroos, Noisy Scrub-bird, *Eucalyptus rhodantha*) or groups of those species (e.g. Endangered flora of the Northern Forest Region).

This program is the 6th in the series and is concerned with one species of endangered animal, the Western Swamp Tortoise (*Pseudemydura umbrina*). It provides a brief summary of research information on the species, a discussion of the general approach to its conservation and prescribes management actions to ensure the survival of *Pseudemydura umbrina*.

ACKNOWLEDGEMENTS

Many people and organizations have contributed to the conservation of the Western Swamp Tortoise since it was rediscovered in 1953. We can not thank all of these people and organizations here, but we would like particularly to acknowledge the following:

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SUMMARY

The Western Swamp Tortoise (*Pseudemydura umbrina*) is the most endangered vertebrate in Australia. Since its rediscovery in 1953 it has declined from over 100 animals located in two nature reserves to about 30 animals in one nature reserve, plus a small captive colony. The endangered status of the Western Swamp Tortoise can be explained by a combination of factors: a very small geographic range, most of which has been converted to agricultural, industrial or urban use; protection of only marginal habitat solely in two small nature reserves; a specialised biology that includes dependence on a rare habitat, a wholly carnivorous diet, low fecundity and slow growth rates, mitigated to some extent by great longevity; increasing aridity, a factor compounded by the marginal nature of the remaining habitat and which will become worse if current climatic predictions are correct; and the presence of exotic predators, particularly the European Red Fox.

This management program, which will operate from 1990 to 2000, aims to ensure that the Western Swamp Tortoise persists by creating at least two viable populations in the wild. It incorporates five main strategies: population monitoring; management of the nature reserves to maintain and improve the tortoises' habitat, to prevent external factors reducing water availability or water quality, to eliminate or greatly reduce predation and to prevent emigration; intervention in the reproductive biology of the species to increase recruitment by captive breeding, with the eventual release of captive-bred animals to the wild; identification, purchase and, where necessary, rehabilitation of additional suitable habitat; and a public education program.

1. BACKGROUND

1.1 Taxonomy and Relationships

The first Western Swamp Tortoise known to science was sent to the Vienna Museum in 1839 by the Austrian, J.A. Ludwig Preiss, who collected in Western Australia from 1839 to 1841. It is not known where this specimen was collected - it was simply labelled 'New Holland'. The specimen remained in the Museum undescribed until 1901 when it was named by Siebenrock, a well-known herpetologist of his day. Siebenrock provided further details and comments on the species in 1907. No further specimens were collected until 1953 when two were found near Warbrook, only 30 km north-east of the centre of the city of Perth. These were described as a new species, *Emydura inspectata*, by Glauert (1954), but this was shown to be a synonym of *P. umbrina* by Ernest Williams (1958) of Harvard University.

The correct scientific name of the Western Swamp Tortoise is *Pseudemydura umbrina* Siebenrock 1901.

Several vernacular names have been used. After its rediscovery it was generally known to Western Australians as the Short-necked Tortoise to distinguish it from *Chelodina oblonga*, a long-necked species, which is the only other fresh water tortoise in the south-west. 'Tortoise' is the traditional name used for freshwater chelids in most of Australia, while 'turtle' is usually reserved for species with flippers on their front legs. The name Western Swamp Tortoise was proposed as an Australia-wide name, since there are many other 'short-necked' tortoises in three other genera of Australian Chelids - *Emydura*, *Elseya* and *Rheodytes* - and this name has been used consistently in numerous scientific and popular publications for over two decades (Burbidge 1967, 1981, 1984, 1987a, 1987b; Burbidge and Friend 1988). Recently some people have used the name Western Swamp Turtle, since turtle is more consistent with usage for fresh water testudinids in some other parts of the English-speaking world.

Tortoises and turtles belong to the order Testudines, which has two living sub-orders, the

Pleurodira (side-necked families) with only two extant families, and the Cryptodira (hidden-necked families), to which most living species belong. The Pleurodiran family Chelidae, to which *Pseudemydura* belongs, has been spelled Chelydridae, Chelyidae and Cheluidae by various authors because of uncertainties about the spelling and derivation of the type genus, which is *Chelus* of South America. The Chelidae is restricted to Australia, New Guinea and some adjacent islands, and South America.

A relict species, apparently little changed since the Miocene, *Pseudemydura umbrina* is the only member of its genus and has no close relatives among other members of the Chelidae (Burbidge 1967; Burbidge *et al.* 1974; Gaffney 1977), which is a primitive Gondwanan testudinid family with at least 25 species in Australia (several species are currently undescribed) and a further 21 in South America. *P. umbrina* is so different from other members of the family that a separate sub-family, the Pseudemydurinae, has been proposed for it (Gaffney 1977; Gaffney and Meylan 1988). The only fossil records of *Pseudemydura* are a portion of a skull and a pygal bone from the Miocene Riversleigh deposits of north-west Queensland, which show only slight differences from modern specimens (Gaffney *et al.* 1989).

1.2 History

Following the interest generated by the rediscovery of a presumed extinct species so close to Perth, the Government of the day, aided by a public appeal for funds, created two Class A nature reserves that protected much of its remaining habitat. These are Ellen Brook Nature Reserve of 65 ha, situated on the west side of Highway One 2 km north of Upper Swan, and Twin Swamps Nature Reserve of 155 ha, located on the south side of Warbrook Road and the east side of the Midland Railway, about 5 km north-north-west of Ellen Brook Nature Reserve. Both reserves are vested in the National Parks and Nature Conservation Authority and managed by the Department of Conservation and Land Management.

The Western Swamp Tortoise is considered to be the most endangered vertebrate animal in Australia. Its rediscovery and, later, the rediscovery of the Noisy Scrub-bird, were instrumental in raising public awareness about the conservation of the Western Australian fauna at a time when there was a fraction of the interest in environmental matters that we take for granted today. The Noisy Scrub-bird has been a conservation success story, having been brought back to relative abundance from the verge of extinction (Burbidge *et al.* 1986; Burbidge and Friend 1988), but the Western Swamp Tortoise has continued to decline in numbers and is now critically endangered.

The Western Swamp Tortoise has been declared as fauna that is 'likely to become extinct or is rare' under Section 14(2)(ba) of the Western Australian Wildlife Conservation Act 1950. It is on the Australian Council of Nature Conservation Ministers' List of Australian Endangered Vertebrates (Burbidge and Jenkins 1984), is listed as 'Endangered' in the IUCN Amphibia-Reptilia Red Data Book (Groombridge 1982), is included in the World Checklist of Threatened Amphibians and Reptiles (Goombridge 1988), is on the IUCN Red List of Threatened Animals (Wilcox 1988), is on Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and has been given a priority rating of '1' in the Action Plan for Tortoises and Freshwater Turtles (IUCN/SSC 1989).

1.3 Biology and Ecology

Aspects of the biology and ecology of the Western Swamp Tortoise have been described by Lucas (1963) and Burbidge (1967, 1981, 1984, 1987a, 1987b). Studies commenced shortly after it was rediscovered. Initially, Dr David Ride, then Director of the Western Australian Museum, coordinated field searches and kept a captive colony in the back yard of his Nedlands home. Then, in 1963 at the request of the Fauna Protection Advisory Committee (the forerunner of the Western Australian Wildlife Authority and today's National Parks and Nature Conservation Authority), Professor A.R. Main of the University of Western Australia initiated and supervised a project by several Zoology Honours Degree students, one of whom is the senior author (see Lucas 1963). In 1964 the senior author commenced his Ph.D. studies with Professor Main on *Pseudemydura* and, for comparison, two other southern Western Australian long-necked tortoises, *Chelodina oblonga* and *C. steindachneri*. Sometime after completing his thesis (Burbidge 1967) the senior author started work as a Research Officer with the Department of Fisheries and Fauna in 1968. Less intensive studies on the Western Swamp Tortoise were conducted during the 1970s with research studies becoming more detailed again through the 1980s as it became clear that the species was declining in numbers.

Western Swamp Tortoises inhabit ephemeral swamps with a clay or sand over clay soil. They have been recorded only from scattered localities in a narrow (3 to 5 km wide) strip of the Swan Coastal Plain with largely alluvial soils, roughly parallel with the Darling Scarp, running from Perth Airport at

Guildford to near Pearce Royal Australian Air Force Base at Bullsbrook. Anecdotal information (Burbidge 1967, 1981) suggests that their stronghold was the clay soils of the Swan Valley, the first part of Western Australia developed for agriculture. Almost all this land is now cleared and either urbanised or used for intensive agriculture or the extraction of clay for brick and tile manufacture.

The Western Swamp Tortoise has unusual and specialised ecological relationships. After the swamps fill in June or July they can be found in water, feeding when water temperatures are high enough (14°C). They are carnivorous, eating only living food such as insect larvae, crustaceans and small tadpoles. As the swamps warm in spring and swamp life becomes plentiful, the tortoises' food intake increases and fat supplies are laid down for the forthcoming summer. When the swamps are nearly dry and water temperatures rise above 28°C, usually in November, the tortoises leave the water to aestivate during the summer and autumn. Aestivation refuges vary with the soil type: at Ellen Brook Nature Reserve they are naturally-occurring holes in the gilgai clay, while at Twin Swamps Nature Reserve most aestivate under *Banksia* leaf litter or fallen branches, but a few find holes in the ground dug by other animals or left by a rotting tree root.

Pseudemydura is not territorial and individuals do not appear to have a fixed home range, using all suitable habitat in the nature reserves. At Twin Swamps Nature Reserve movements of up to 500 m have been recorded in two weeks. At Ellen Brook Nature Reserve the area of suitable habitat is much smaller and movements are correspondingly shorter.

Twin Swamps animals have been found up to 600 m outside the reserve boundary, especially in dry years, suggesting that there may have been movements between swamps some distance apart before habitats in the area were fragmented by clearing.

Females lay three to five hard-shelled eggs of *ca* 35 x 20 mm in an underground nest in November or early December. The Western Swamp Tortoise is the only known species in the world that digs the nest chamber with the front feet (Kuchling unpublished). Only one clutch per year is produced; in most other Australian chelids multiple clutching is the norm. Hatchlings emerge the following winter, about 180 days after laying. Growth in juveniles is slow and varies considerably from year to year as well as within age-classes. Consequently, age to sexual maturity varies from animal to animal and also varies from year to year depending on seasonal conditions - the lower the annual rainfall the shorter the swamp life and the slower the growth. Age to sexual maturity at Twin Swamps Nature Reserve varies from 6.5 to 14 years, with a mean of 11 years while at Ellen Brook Nature Reserve the mean is probably around 15 years with less variation.

In some tortoises and turtles sex is determined by incubation temperature. There are few data relating to sex determination in Australian chelid tortoises, but available data from both laboratory and field studies indicate that sex is genetically-determined (Bull *et al.* 1985, Georges 1988, Thompson 1988, Palmer-Allen and Beynon 1990). Histological examination of Western Swamp Tortoise hatchlings that died in 1989 also suggests that sex is genetically determined.

1.4 Population Estimates

Three estimates of population size are available: KTBA (known to be alive) and two estimates calculated from mark and recapture data using the Jolly (Jolly 1965; Seber 1982; Krebs 1989) method and the Manley and Parr method (Manley and Parr 1968). These estimates are presented in Tables 1 and 2.

Table 1.
Western Swamp Tortoise Population data - Ellen Brook Nature Reserve.

Year	No. captured	KTBA#	Jolly estimate	Jolly* 95% cl	Manley & Parr
1963	4	27	-	-	-
1964	9	27	15	9-53	63
1965	3	23	14	4-56	63
1966	4	21	7	5-11	21
1967	2	21	27	5-174	40
1968	5	21	12	7-19	25
1969	1	20	8	-	20
1970	3	21	30	8-119	-
1971	0	20	-	-	-
1972	6	21	16	6-26	24
1973	0	23	-	-	-
1974	2	24	14	6-26	46
1975	3	23	15	7-28	33
1976	9	22	26	13-50	26
1977	3	21	13	-	21
1978	8	21	18	11-24	29
1979	4	20	11	-	20
1980	8	22	19	11-28	27
1981	8	23	16	11-20	25
1982	10	23	29	16-46	29
1983	5	22	32	13-60	48
1984	10	26	69	26-159	90
1985	7	21	32	15-56	40
1986	2	18	21	9-39	18
1987	6	19	17	11-18	22
1988	5	21 ~	38	14-89	-
1989	17	17+2	-	-	-

- can not be calculated from available data
KTBA = known to be alive
* 95% confidence limits
~ Taken into captivity in 1988 until fox-proof fence completed

KTBA data under-estimate the size of Western Swamp Tortoise populations, particularly in recent years, since only a small proportion of tortoise are captured in any one year. (If an animal that has not been captured for some years is re-captured KTBA increases for the intervening years.) For these reasons KTBA population estimates are usually considered to be reasonably reliable only for periods five years or more before the last sample.

Estimates from mark and recapture data have also proved to be unreliable indicators of Western Swamp Tortoise population size both because of the small populations and because of the small proportion of animals captured each year. Because of these factors the estimates often fluctuate markedly from year to year and the confidence limits for the Jolly method are large. Nevertheless they are included in Tables 1 and 2 because they confirm the general trends revealed by the KTBA data.

Table 2.
Western Swamp Tortoise Population data - Twin Swamps Nature Reserve.

Year	No. captured	KTBA#	Jolly estimate	Jolly 95% cl	Manley & Parr
1963	1	54	-	-	-
1964	4	75	5	-	288
1965	9	96	117	66-335	270
1966	65	100	135	68-193	123
1967	25	74	56	35-61	147
1968	17	61	64	32-85	67
1969	8	57	64	43-71	91
1970	26	58	51	37-56	70
1971	27	51	46	27-58	70
1972	15	39	37	21-50	60
1973	13	32	77	25-213	54
1974	8	26	25	14-36	80
1975	8	21	21	10-32	29
1976	4	18	16	12-19	23
1977	9	17	25	12-60	21
1978	9	15	10	7-22	36
1979	6	8	3	-	12
1980	2	4	3	3-4	4
1981	3	4	3	-	4
1982	3	4	4	4-5	4
1983	4	4	3	3-5	4
1984	3	3	-	-	3
1985	1	1	0	-	0
1986	0	0	0	-	0
1987	0	0	0	-	0
1988	0	0	0	-	0
1989	0	0	0	-	0

- can not be calculated from available data
Known to be alive
* 95% confidence limits

In an attempt to overcome the shortcomings discussed above population data were lumped for two- and three-year periods. The results of the estimates from these data are given in Table 3. The lumped data produce more even results but the trends in population size remain much the same. It is also noteworthy that the estimates from the two techniques are similar when lumped data are used, suggesting that the differences between the estimates using annual data are, as suggested above, a consequence of the small proportion of animals captured each year rather than anything else.

Population estimates at Twin Swamps Nature Reserve show that numbers there have dropped from a high of over 100 in the mid-1960s, to about 50 in the early 1970s, to near extinction by 1985. The population at Twin Swamps must now be considered to be extinct.

At Ellen Brook Nature Reserve numbers have never been as high as at Twin Swamps Nature Reserve. The KTBA data suggest that numbers have remained fairly static at around 20 to 30. It is unclear whether numbers may have dropped in recent years.

Table 3.
Western Swamp Tortoise Population estimates from lumped data

Year	ELLEN BROOK Jolly estimate	ELLEN BROOK Manley & Parr	TWIN SWAMPS Jolly estimate	TWIN SWAMPS Manley & Parr
A. Data from each two-year period lumped.				
1963-64	-	-	-	-
1965-66	9	9	37	-
1967-68	18	18	94	98
1969-70	20	28	67	64
1971-72	16	21	54	55
1973-74	14	18	45	41
1975-76	26	39	25	26
1977-78	18	20	21	21
1979-80	19	20	9	9
1981-82	31	33	4	4
1983-84	67	78	4	4
1985-86	28	36	-	0
1987-88	26	25	-	0
1989	-	-	-	-
B. Data from each three-year period lumped.				
1963-65	-	-	-	-
1966-68	11	12	67	83
1969-71	20	28	62	61
1972-74	13	16	56	54
1975-77	26	39	25	25
1978-80	20	21	13	13
1981-83	31	32	3	4
1984-86	61	60	-	0
1987-89	-	-	-	-

The numbers of animals in captivity at July 1990 were:

Adult males:	8
Adult females:	5
Sub-adults and hatchlings:	17

These figures exclude 6 females from Ellen Brook Nature Reserve that will be returned to the wild in 1991 once the fox-proof fence is completed.

1.5 Captive Breeding

Captive breeding has been attempted in a low-key, non-interventionist way ever since Western Swamp Tortoises were first kept at Perth Zoo in 1964 (Spence *et al.* 1979). Success was, however, very low with only four animals still living from 26 that hatched between 1966 and 1977.

In 1979 the three adult females from the Zoo population were transferred to the Western Australian Wildlife Research Centre for more intensive husbandry and the use of interventionist techniques in obtaining and incubating eggs. During the first year three eggs were obtained by oxytocin inducement and incubated artificially. Two hatchlings were obtained, but both died in their first year. In 1980 19 eggs were produced and artificially incubated; six of these hatched, but again the hatchlings did not survive for more than a few months. This work did, however, show that eggs could still be produced by the captives and demonstrated that the hatching of *P. umbrina* eggs is triggered by a drop in incubation temperatures; if the incubation temperature is maintained the embryos develop to hatchling size but do not hatch and eventually die. This adaptation presumably prevents hatchlings emerging before winter.

No further eggs were produced by the captive animals until 1987.

In 1987 Dr Gerald Kuchling arrived at the University of Western Australia from Austria to work with Professor S.D. Bradshaw on the hormonal control of reproduction in the Oblong Tortoise *Chelodina oblonga*. Later he asked the Department of Conservation and Land Management if he could help with captive breeding in *Pseudemydura*, a suggestion that was welcomed. The development of techniques for the examination of the female reproductive tract using ultra-sound scanners was a breakthrough, enabling measurements to be made of egg follicle development for the first time (Kuchling 1989). Previously it was not known whether eggs were being developed until ovulation had taken place and the shell had been laid down. Even then, palpation in Western Swamp Tortoises is difficult because of the small leg openings between the carapace and plastron, and the only certain method of counting eggs was via the use of radiography.

In 1987 seven eggs were obtained from two captive females. These eggs were incubated artificially, but none hatched, the embryos dying at an early stage of development. The reasons for this are not clear: recent research suggests that the most likely explanation is poor quality eggs caused by inadequate nutrition of the females that produced them.

Also in 1987 the Department of Conservation and Land Management and the Zoology Department of The University of Western Australia developed a budget for a two and a half year captive breeding project and sought and obtained funds from the World Wide Fund for Nature, Australia (previously World Wildlife Fund Australia), the Australian National Parks and Wildlife Service, the Nature Conservation and National Parks Trust Account and the Department of Conservation and Land Management. The project has been carried out by Dr Gerald Kuchling, now a Research Fellow at Zoology Department, The University of Western Australia, utilising tortoises kept at Perth Zoo and at the Department of Conservation and Land Management's Wildlife Research Centre. Perth Zoo and the Department of Conservation and Land Management have supported the project with staff and with additional funds and The University of Western Australia has provided facilities and financial administration. Perth Zoo has obtained external sponsorship for the construction of new facilities for the captive tortoises and hatchlings. The project has been supervised and coordinated by the Western Swamp Tortoise Captive Breeding Project Management Committee of Dr Andrew Burbidge, (Conservation and Land Management, chair), Mr John DeJose (Perth Zoo) and Professor Don Bradshaw and Dr Gerald Kuchling (Zoology Department, The University of Western Australia).

The new breeding management is based on an improved and better balanced diet as well as an improved enclosure design, feeding patterns and aestivation management which reflect more closely the conditions in the wild. The ideas behind these changes have been outlined by Kuchling and DeJose (1989).

This project has been successful. In 1988, 12 eggs were obtained from three females and 11 of these hatched between February and April 1989. Because of past difficulties in raising hatchlings husbandry difficulties were expected and did arise; in particular the hatchlings developed an infection of the skin, which extended to the eyes and toes. The infection proved hard to combat. In July 1990, five of these hatchlings were alive and were responding well to treatment. Nursery facilities and diets had been improved and growth rates were approximating those in the wild.

In 1989 13 fertile eggs were obtained from five females, but two eggs had thin shells and cracked when being laid. The remaining 11 were incubated at 24° and 29°C and all hatched during April 1990.

Perth Zoo provided new outdoor nursery facilities and feeding management has been altered. The health difficulties that arose with the 1989 hatchlings have not occurred. Experiments to determine the most effective method of raising hatchlings will be continued by Perth Zoo and the University of Western Australia.

1.6 Causes of Endangered Status

There are a number of compounding reasons for the current status of the Western Swamp Tortoise.

1.6.1 Geographic range and habitat

Because of the rediscovery of the Western Swamp Tortoise within the Perth metropolitan area as late as 1953, little is known of its pre-European geographic range. There are no indications, however, that it had a range in the recent past significantly different from its recent one, i.e. an area of about 100-150 km^2. Within this very small range the species is restricted to winter-wet ephemeral swamps with suitable aestivating refuges nearby. Western Swamp Tortoises do not occur in the many permanent swamps or lakes on the Swan Coastal Plain, so presumably they cannot survive in this habitat.

Most of the original range of the Western Swamp Tortoise has been greatly modified in the past 160 years. What we know now of breeding and hatchling survival in the two nature reserves (see below) suggests that the habitat in them is far from ideal and that they must be considered as containing only marginal habitat.

Additionally, both reserves, particularly Ellen Brook Nature Reserve, are small. It is likely that some animals are lost when they move outside the reserves and are exposed to unsuitable habitat and increased predation.

1.6.2 Biology

Pseudemydura umbrina is the smallest Australian chelid. It is also the only species in which the female is smaller than the male. Egg size is similar to other species in the family and, accordingly, it has very low fecundity: females produce a maximum of one clutch of three to five eggs per annum. This compares unfavourably with the local long-necked tortoise *Chelodina oblonga*, which can produce two-three clutches per year each of 8-16 eggs, and other Australian freshwater tortoises (Burbidge 1967; Clay 1981).

Only live food is eaten; other species eat a greater variety of food including carrion and vegetable matter. Growth is slow, food being available for only a short period each year, and sexual maturity is not usually reached until 10-15 years or older.

Longevity is not known; however, it is known to be greater than 50 years and may be much more. Adult females captured in the early 1960s, which were probably at least 20 years old, are still producing viable eggs.

1.6.3 Effects of drought

Aestivating tortoises desiccate during the summer. Measurements of desiccation rates of radio transmitter-equipped animals at Twin Swamps Nature Reserve have shown that hatchlings must achieve a body weight of about 25 g in their first six months in order to survive the following summer. This is not achievable in years of below-average rainfall because the swamps retain water for only a short time. Furthermore, there is evidence that females are not able to produce eggs in low rainfall years; thus two successive years of average or above-average rainfall are required for effective recruitment to take place.

Since the mid-1960s Perth has had many years of below-average rainfall. This has undoubtedly affected the abundance of the Western Swamp Tortoise.

1.6.4 Effects of predators

There is only a little direct evidence that introduced predators have a significant effect on the tortoises. However, there is now much circumstantial evidence that predators, particularly the fox, kill Western Swamp Tortoises. They may also destroy eggs, as has been documented for other Australian tortoises (Clay 1981, Thompson 1983). Foxes were abundant in both nature reserves and there is no other explanation for the rapid decline in numbers at Twin Swamps Nature Reserve. Tortoises are thought to be more prone to predation at Twin Swamps Nature Reserve, where aestivation refuges are mostly on the surface. At Ellen Brook Nature Reserve, where aestivation occurs underground, the species is better protected, but the very small population size means that even occasional predation can have a significant effect.

1.6.5 Summary

The endangered status of the Western Swamp Tortoise can be explained by a combination of the following factors:

(i) a very small geographic range, most of which has been converted to agricultural, industrial or urban use;

(ii) protection of habitat solely in two small nature reserves that include only marginal habitat;

(iii) a specialised biology that includes dependence on a rare habitat, a wholly carnivorous diet, low fecundity and slow growth rates, mitigated to some extent by great longevity;

(iv) increasing aridity, a factor compounded by the marginal nature of the remaining habitat and which will become worse if current climatic predictions are correct; and

(v) the presence of exotic predators, particularly the European Red Fox.

2. MANAGEMENT

2.1 Aim of management program

To ensure that the Western Swamp Tortoise persists by creating at least two viable populations in the wild.

2.2 Strategies

The long term conservation of the Western Swamp Tortoise is dependent on:

(i). the management of the tortoise population;

(ii) the management of its habitat;

(iii) the identification and acquisition of additional habitat; and

(iv) the support of the public of Western Australia.

This will involve:

- population monitoring;
- management of the nature reserves to maintain and improve the tortoises' habitat, to prevent external factors reducing water availability or water quality, to eliminate or reduce predation and to prevent emigration; this will include the preparation of a management plan for the reserves under the provisions of the Conservation and Land Management Act 1984;
- intervention in the reproductive biology of the species to increase recruitment by a scientifically managed program of captive breeding ensuring optimal representation of founder lineages, with the eventual release of captive-bred animals to the wild;
- identification, purchase and, where necessary, rehabilitation or construction of additional suitable habitat;
- ensuring that the importance of the area within and around the two nature reserves is recognised by all levels of Government and that this is taken into account when assessing proposed developments; and
- a public education program.

2.2.1 Population monitoring

Populations on both nature reserves have been monitored since 1963, initially by the senior author while at The University of Western Australia and, since 1967, by the senior author and staff under his direction from the Department of Fisheries and Wildlife and the Department of Conservation and Land Management. Monitoring requires regular visits to the nature reserves during the winter and spring to attempt to capture animals. Each tortoise is individually marked and data are kept on sex, age (where possible), carapace length and width, and body weight. Each animal handled is photographed regularly. Data are maintained on a card index (which includes a photograph of each animal and is used in the field), copies of which are held in a fire-proof safe at the Wildlife Research Centre and at a private residence, and on a micro-computer data-base, copies of which are also held in a fire-proof safe.

Monitoring will remain the responsibility of the Department of Conservation and Land Management's Research Division. Populations estimates will be calculated annually.

2.2.2 Habitat management and control of deleterious effects from surrounding land

ELLEN BROOK NATURE RESERVE AND ADJOINING AREAS

The management of Ellen Brook Nature Reserve will continue to be the responsibility of the Department of Conservation and Land Management. Because of increasing pressures on the Department's Metropolitan Region Staff to manage more land, steps will be taken to ensure that the management of Ellen Brook Nature Reserve is given the highest priority.

The Conservation and Land Management Act 1984 provides that written plans of management be prepared for various categories of land, including nature reserves. The Department of Conservation and Land Management will prepare a management plan for Ellen Brook Nature Reserve.

The plan will include management of the following: water quantity and quality, predators and fire.

Water quantity and quality

The Department of Conservation and Land Management has maintained water depth records at two depth gauges and has had water samples from Ellen Brook Nature Reserve analysed annually by the W.A. Chemistry Centre since 1972. Data are held on a Departmental file and in a micro-computer data base, copies of which are stored in a fire-proof safe. Monitoring of water depth and quality will continue and will be the responsibility of the Department of Conservation and Land Management's Research Division.

Water quality is excellent and there is no evidence of pollution entering the reserve.

Use of adjacent land and drainage

A drain runs from the Great Northern Highway through the southern part of Ellen Brook Nature Reserve to join a natural drainage line that flows into Ellen Brook. This drain accepts water from Great Northern Highway and from adjacent private property. At some times of the year it is likely to be a physical barrier to the movement of tortoises within the reserve, because of its steep sides or because of the rapid flow of water.

There have been several proposals to mine clay from private land near the reserve and these have been the subject of assessment by the Environmental Protection Authority. In 1988 and 1989 a study of the possible effects of clay mining near the reserve was conducted by Bowman Bishaw Gorham (1989) on behalf of Bristile Clay Tiles, International Brick and Tile Holdings Ltd (now part of the Metro Brick Group), Prestige Brick Company Pty Ltd, Midland Brick Company Pty Ltd and the Main Roads Department. The main conclusions of the study were:

- Clay mining in the vicinity of Ellen Brook Nature Reserve would have no adverse impact on the quantity or quality of water in the tortoise swamps.

- Tortoise habitat in the immediate locality of Ellen Brook Nature Reserve had been reduced in size by at least 70 per cent prior to its declaration in 1962 due to land clearing and drainage. In addition, the surface water catchment for the swamps had been severely restricted due to drainage modifications and the construction of Great Northern Highway on the eastern boundary of the reserve.

- The tortoise swamps now have only a small catchment area, limited to narrow segments on their northern and eastern margins. To the east, runoff from a 150 m section of the Great Northern Highway discharges directly into the swamps; pollution from the Highway is therefore a possible problem.

- The catchment of the drain near the southern boundary of Ellen Brook Nature Reserve comprises land to the south-west, south, south-east and east and includes seven existing or proposed clay quarries and the road train marshalling yard to the south. The drain acts as a throughflow channel to Ellen Brook and does not discharge water into the main tortoise swamps. The water quality in the drain during the study period, while inferior to that in the swamps, was still reasonable.

Recommendations from this study are being reviewed by CALM and other authorities.

Predator control

Fox control has been carried out on Ellen Brook Nature Reserve sporadically since 1979, but the technique available at that time (laying of strychnine baits in meat crackle) proved to be inadequate. Predator control was intensified in 1988 by the Department of Conservation and Land Management's Metropolitan Region staff using new fox control techniques (regular laying of Compound 1080 in fresh meat or fowl egg baits) developed by Dr Jack Kinnear and colleagues from the Department of Conservation and Land Management (Kinnear *et al.* 1988).

However, two significant problems have arisen with respect to control by the use of poison baits. These are:

(i) Much of Ellen Brook Nature Reserve is under water for up to six months of the year. The use of Compound 1080 under such conditions can be ineffective, because it is highly soluble in water. The tortoises are most likely to be eaten by foxes during the wet months when they are not aestivating.

(ii) The reserves are small and re-invasion of them by foxes from surrounding land is rapid.

These problems can be largely solved by the construction of a fox-proof fence. In 1989 the Department of Conservation and Land Management applied for and received $24 000 (50 per cent of the funds required for the construction of a fence) from the Australian National Parks and Wildlife Service under their Endangered Species Program. The other half of the cost was met by the Department of Conservation and Land Management. Construction commenced late in 1989, but was delayed because of

unseasonal heavy rains during the 1989/90 summer. The fence will be completed by December 1990.

Regular patrols of the fence will be maintained by Department of Conservation and Land Management's Metropolitan Region and Northern Forest Region staff. Although the fence is termed 'fox-proof', experience shows that foxes are capable of finding any weak links in a fence, so regular inspection and maintenance are required. In addition poisoning inside the fence will be carried out as necessary to kill any foxes that are able to negotiate it.

The fence will also prevent emigration of Western Swamp Tortoises from the reserve.

Fire

Fire has limited effects on Western Swamp Tortoises at Ellen Brook Nature Reserve because the aestivation sites are underground. The Department of Conservation and Land Management's fire procedures at present are:

(i) to meet its responsibilities under the Bush Fires Act by maintaining a perimeter and internal fire breaks;

(ii) to continue to classify the area as a 'Red Action' area requiring priority response from Departmental fire-fighting forces when a fire is reported;

(iii) to fight any fires on or threatening the nature reserve, including providing assistance to neighbours and the local Bush Fire Brigade where possible; and

(iv) once a fire has entered the main part of the tortoise habitat to allow it to burn to the other side so fire control machinery does not damage the gilgai aestivating tunnels.

These policies will be maintained.

TWIN SWAMPS NATURE RESERVE AND ADJOINING AREAS

The management of Twin Swamps Nature Reserve will continue to be the responsibility of the Department of Conservation and Land Management. Because of increasing pressures on the Department's staff to manage more land, steps will be taken to ensure that the management of Twin Swamps Nature Reserve is given the highest priority after Ellen Brook Nature Reserve.

The Conservation and Land Management Act 1984 provides that written plans of management be prepared for various categories of land, including nature reserves. The Department of Conservation and Land Management will prepare a management plan for Twin Swamps Nature Reserve.

The plan will cover management of the following: water quantity and quality, predators and fire.

Water quantity and quality

The Department of Conservation and Land Management has maintained water depth records at four depth gauges and has had water samples from four swamps in Twin Swamps Nature Reserve analysed by the W.A. Chemistry Centre annually since 1972. Data are held on a Departmental file and in a micro-computer data base, copies of which are stored in a fire-proof safe. Monitoring of water depth and quality will continue and will be the responsibility of the Department of Conservation and Land Management's Research Division.

Swamps at Twin Swamps Nature Reserve are greatly affected by drought. Only in high rainfall years do the swamps contain water for long enough to enable Western Swamp Tortoises to feed sufficiently to survive the summer aestivation period and breed successfully.

Water quality varies between swamps. Some areas receive run-off from surrounding land and have relatively high levels of phosphates and nitrogen; others have excellent quality water. There is no evidence that suggests that Western Swamp Tortoises have been affected by water quality.

Use of adjacent land and drainage

There have been no detailed studies of the hydrology of the Twin Swamps area. Such studies will be carried out and consideration will be given to mechanical deepening of some swamps in order to increase swamp life so that they provide suitable habitat even during drought years.

Fire

Fire is thought to have some detrimental effects on Western Swamp Tortoises at Twin Swamps Nature Reserve because the aestivation site is often in leaf litter or under fallen branches. The Department of Conservation and Land Management's fire procedures at present are:

(i) to meet its responsibilities under the Bush Fires Act by maintaining perimeter and internal fire breaks; and

(ii) to continue to classify the area as a 'Red Action' area requiring priority response from Departmental fire-fighting forces when a fire is reported;

(iii) to fight any fires on or threatening the nature reserve, including providing assistance to neighbours and the local Bush Fire Brigade where possible; and

(iv) to allow fire-fighting machinery off constructed fire-breaks only with the permission of the Regional Ecologist or a senior Research Scientist.

These policies will be maintained. Consideration will be given to reducing the chance of all or a large proportion of the reserve being burnt at one time by carrying out strategic fuel reduction prescribed burning during the winter months when the tortoises are living in the swamps.

2.2.3 Captive Breeding

The extremely small size of the population and its continued decline in the wild means that captive breeding is essential if the species is not to become extinct.

Captive breeding will continue. Responsibility will pass from the Western Swamp Tortoise Captive Breeding Project Management Committee to Perth Zoo on 1 July 1991, but the tortoises will remain the property of the Department of Conservation and Land Management. The Captive Breeding Program will operate to meet, to the greatest extent practicable, the objectives laid down in the IUCN Policy Statement on Captive Breeding (IUCN 1987a). Within the period of this program the captive breeding project will be reviewed to examine the possibility of establishing several captive locations to reduce the vulnerability of the captive population.

Perth Zoo will endeavour to find resources to employ an experienced, professionally-trained zoologist to carry out captive breeding of Western Swamp Tortoises and other endangered species.

The selection of mating pairs will be guided by results of continuing studies on genotypes of the captives.

World Wide Fund for Nature Australia and The Department of Conservation and Land Management have provided funds to enable Dr Kuchling's contract to be extended to 1993 on a part-time basis. As well as working with Perth Zoo on the captive breeding project he will also work with the field population at Ellen Brook Nature Reserve.

2.2.4 Re-introduction to the wild

The following general principles should apply to translocations of endangered species (IUCN 1987b):

(i) The causal factors that lead to the species' rarity in or disappearance from a particular area should no longer be operating or else management should be in place that prevent their operation on the site proposed for translocation.

(ii) The site chosen for translocation must have a sufficient area of suitable habitat to support a viable population of the translocated species and the land tenure must be either a conservation reserve or, if the land is of some other status there must be an agreement in place that protects the area from disturbance in the long term.

(iii) The genetic status of the source population and of the founder population must be considered to prevent loss of genetic variation. The age and sex structure of the founder population should also be considered in the light of knowledge about the species' social structure and behaviour.

(iv) Animals translocated should be free from parasites or disease; this is especially important if they come from a captive population.

(v) The release should be made under the best seasonal conditions.

(vi) Released animals should be permanently marked and their survival and reproductive success monitored.

The following options exist for translocation of captive-bred Western Swamp Tortoises:

(i) restocking of the population on Ellen Brook Nature Reserve;

(ii) re-introduction to Twin Swamps Nature Reserve; and

(iii) re-introduction to areas of former habitat after they have been purchased and rehabilitated.

Ellen Brook Nature Reserve has a small population of Western Swamp Tortoises. It apparently has low productivity resulting in slow growth and recruitment rates, but has the advantage of relatively stable water conditions, even in dry years. Twin Swamps Nature Reserve appears to have offered good habitat during periods of average to above-average rainfall (e.g. the mid-1960s) when the tortoises reproduced successfully and grew much faster than those at Ellen Brook. However, the population did not fare well during periods of drought; possibly partly because nearby drought refuges have been destroyed. Predation by foxes is thought to have been a significant factor in the decline of the Twin Swamps population.

The carrying capacity is not known for either reserve. If Ellen Brook is at or near its carrying capacity, restocking could lead to even lower growth rates than exist at present. On the other hand, if Ellen Brook is below capacity, it is likely that this is because of fox predation, and once this pressure is removed the population should increase naturally.

Thus, option 1 is not favoured.

Option 2 has the advantage of creating two populations of Western Swamp Tortoises in the wild. It will require management of Twin Swamps Nature Reserve to make it suitable for permanent habitation by Western Swamp Tortoises. This will involve the prevention of predation by foxes, by effective control and/or the erection of a fox-proof fence and, possibly, the mechanical deepening of some of the swamps so that they provide suitable habitat even during drought years. These and other management options will be considered when a management plan is written for Twin Swamps Nature Reserve (see Section 2.2.2).

Option 3 is not immediately available. It will be considered if and when additional habitat is purchased (see Section 2.2.5).

The timing of translocations and the number of tortoises released will be dependent on the continued success of captive breeding and will be decided by the Western Swamp Tortoise Recovery Team (see below).

Translocated tortoises will be equipped with radio-transmitters to monitor their survival and reproductive success in the wild.

Translocations will be guided by the Department's Policy No. 29 "Captive breeding and cultivation of endangered species and their re-establishment or translocation in the wild" and by the IUCN Position Statement on Translocation of Living Organisms (IUCN 1987b). Translocations will be the responsibility of the Department of Conservation and Land Management.

2.2.5 Purchase of additional habitat

The habitat in the two nature reserves is both restricted and marginal. Studies to identify areas of suitable habitat will be conducted and purchase of such areas will be considered as part of the Department of Conservation and Land Management's program of land purchases for nature conservation.

Purchase of former Swamp Tortoise habitat adjacent to Ellen Brook Nature Reserve and its inclusion in the reserve would expand the area which is suitable for tortoises and increase the carrying capacity of the reserve, allowing the population to increase to a more secure number. Land purchases to provide more suitable habitat will be very expensive because they are likely to be within or near the Perth metropolitan area.

2.2.6 Public education program

The support of the public is essential if the Western Swamp Tortoise is to be conserved, since the program described here is expensive in terms of both staff and finance.

The Department of Conservation and Land Management and Perth Zoo, in cooperation with other relevant organizations, will coordinate a public education program on the Western Swamp Tortoise and on the measures being undertaken to prevent its extinction.

2.3 Western Swamp Tortoise Recovery Team

Coordination of research and management of the Western Swamp Tortoise and of the education program will be carried out by a Western Swamp Tortoise Recovery Team comprising representatives of the Department of Conservation and Land Management (chair), Perth Zoo, The University of Western Australia and any other organizations that become involved in this program in the future.

2.4 Term of Program

Unless superseded earlier, the term of this program will be ten years.

REFERENCES

Bowman Bishaw Gorham (1989). Ellen Brook Nature Reserve surface water study November 1989. Project No: M19138. Bowman Bishaw Gorham, Subiaco.

Burbidge, A.A. (1967). The biology of south-western Australian tortoises. Ph.D. Thesis, University of Western Australia, Nedlands.

Burbidge, A.A. (1981). The ecology of the Western Swamp Tortoise, *Pseudemydura umbrina* (Testudines, Chelidae). *Australian Wildlife Research* **8**, 203-222.

Burbidge, A.A. (1984). A very rare Australian : the Western Swamp Tortoise. In: Archer, M. and Clayton, G. (eds), *Vertebrate zoogeography and evolution in Australia*. Hesperion Press, Perth.

Burbidge, A.A. (1987b). Endangered! Western Swamp Tortoise. *Landscope* **3**(3), 44.

Burbidge, A. (1987a). The Western Swamp Tortoise. Resource Notes No. 13. Department of Conservation and Land Management, Perth.

Burbidge, A.A., Folley, G.L. and Smith, G.T. (1986). The Noisy Scrub-bird. Western Australian Wildlife Management Plan No. 2. Department of Conservation and Land Management, Perth.

Burbidge, A. and Friend, T. (1988). Back from the edge of extinction. In: Newman, P., Neville, S. and Duxbury, L. (eds), *Case studies in environmental hope*. Environmental Protection Authority, Perth.

Burbidge, A.A. and Jenkins, R.W.G. (1984). Endangered vertebrates of Australia and its island Territories. Australian National Parks and Wildlife Service, Canberra.

Burbidge, A.A., Kirsch, J.A.W. and Main, A.R. (1974). Relationships within the Chelidae (Testudines, Pleurodira) of Australia and New Guinea. *Copeia* **1974**, 392-409.

Bull, J.J., Legler, J.M. and Vogt, R.C. (1985). Non-temperature dependent sex determination in two suborders of turtles. *Copeia* 1985, 784-86.

Clay, B.T. (1981). Observations on the breeding biology and behaviour of the long-necked tortoise *Chelodina oblonga*. *Journal of the Royal Society of Western Australia* **4**, 27-32.

Gaffney, E.S. (1977). The side-necked turtle family Chelidae: a theory of relationships using shared derived characters. *American Museum Novitates* No. 2620.

Gaffney, E.S., Archer, M. and White, A. (1989). Chelid turtles from the Miocene freshwater limestones of Riversleigh Station, northwestern Queensland, Australia. *American Museum Novitates* No. 2959.

Gaffney, E.S and Meylan, P.A. (1988). A phylogeny of turtles. In: Benton, M.A. (ed.), *The phylogeny and classification of tetrapods, Volume 1: Amphibians, Reptiles, Birds.* Systematics Association Special Volume No. 35A, Clarendon Press, Oxford pp. 157-219.

Georges, A. (1988). Sex determination is idependent of incubation temperature in another chelid turtle, *Chelodina longicollis*. *Copeia* 1988, 248-254.

Glauert, L. (1954). Herpetological miscellanea, IV. A new swamp tortoise from the Swan River District. *Western Australian Naturalist* **4**, 125-127.

Groombridge, B. (1982). *The IUCN Amphibia-Reptilia Red Data Book. Part I. Testudines, Crocodylia, Rhynchocephalia.* IUCN, Gland, Switzerland.

Groombridge, B. (1988). *World Checklist of Threatened Amphibians and Reptiles.* Fourth Edition (in press). Nature Conservancy Council, Peterborough.

IUCN (1987a). The IUCN policy on captive breeding. As approved by the 22nd meeting of the IUCN Council. IUCN, Gland, Switzerland.

IUCN (1987b). The IUCN position statement on translocation of living organisms. Introductions, re-introductions and re-stocking. As approved by the 22nd meeting of the IUCN Council. IUCN, Gland, Switzerland.

IUCN (1988). 1988 IUCN Red List of Threatened Animals. IUCN, Gland, Switzerland.

IUCN/SSC Tortoise and Freshwater Turtle Specialist Group (1989). Tortoises and Freshwater Turtles. An Action Plan for their Conservation. IUCN, Gland, Switzerland.

Jolly, G.M. (1965). Explicit estimates from capture-recapture data with both death and dilution - stochastic model. *Biometrika* **52**, 225-47.

Kinnear, J.E., Onus, M.L. and Bromilow R.N. (1988). Fox control and rock wallaby population dynamics. *Australian Wildlife Research* **15**, 435-447.

Krebs, C. (1989). *Ecological Techniques*. Harper & Row Publishers, New York.

Kuchling, G. (1989). Assessment of ovarian follicles and oviducal eggs by ultra-sound scanning in live freshwater turtles, *Chelodina oblonga. Herpetologia* **45**, 89-94.

Kuchling, G. and DeJose, J.P. (1989). A captive breeding operation to rescue the critically endangered Western Swamp turtle *Pseudemydura umbrina* . International Zoo Yearbook **28**, 103-109.

Lucas, J.S. (1963). Ecology and conservation of *Pseudemydura umbrina* Siebenrock 1901. Honours group report, Zoology Department, University of Western Australia Nedlands.

Manley, B.J.F. and Parr, M.J. (1968). A new method of estimating population size, survivorship and birth rate from capture-recapture data. *Transactions of the Society of British Entomologists* **18**, 81-89.

Palmer-Allen, M. and Beynon, F. (1990). Hatchling sex ratios are independent of temperature in field nests of the long-necked turtle *Chelodina longicollis*. Abstract, Australian Society of Herpetologists, 1990 Conference.

Seber, G.A.F. (1982). *The estimation of animal abundance and related parameters.* Griffin, London.

Siebenrock, F. (1901). Beschreibung einer neuen Schild-krotengattung aus der Familie Chelydridae von Australien. *Sitzber. Akademie Wiss. Wein math. nat. Kl., Jahrg.* 1901, 248-258.

Siebenrock, F. (1907). Beschreibung und Abbildung von *Pseudemydura umbrina* Siebenr. und uber ihre systematische Stellung in der Familie Chelydridae. *Sitzber. Akademie Wiss. Wein math. nat. Kl.* 116, 1205-1211.

Spence, T., Fairfax, R. and Loach, I. (1979). The Western Australian swamp tortoise in captivity. *International Zoo Yearbook* **19**, 58-60.

Thompson, M.B. (1988). Influence of incubation temperature and water potential on sex determination in *Emydura maquarii* (Testudines, Pleurodira) *Herpetologia* **44**, 86-90.

Thompson, M.B. (1983). Populations of the Murray River Tortoise, *Emydura* (Chelodina): the Effect of Egg Predation by the Red Fox, *Vulpes vulpes*. *Australian Wildlife Research* **10**, 363-71.

Williams, E.E. (1958). Rediscovery of the Australian chelid genus *Pseudemydura* Siebenrock (Chelidae, Testudines). *Breviora* No. 84.

GLOSSARY

aestivation, dormancy during the summer.

carapace, the upper part of the shell of tortoises and turtles.

Chelidae, the family of pleurodiran Testudines to which the Western Swamp Tortoise belongs.

chelid, a member of the Chelidae.

Cryptodira, the sub-order of Testudines containing the hidden-necked families; families where most species (but not marine turtles) are able to withdraw their necks into the shell by bending the neck in a vertical plane.

fecundity, the capacity to produce young.

gilgai, a clay soil containing natural hollows.

Gondwanan, originating in Gondwana, the southern 'super-continent' that split up to form Australia, Antarctica, South America, Africa, Madagascar, New Zealand and India.

husbandry (of animals), careful management.

Miocene, a geological epoch lasting from about 7 to 26 million years ago.

palpation, examination by the sense of touch.

plastron, the under part of the shell of tortoises and turtles.

Pleurodira, the sub-order of Testudines containing the side-necked families; families where species are unable to withdraw their necks into the shell but are able to gain some protection for the head by bending the neck in a horizontal plane (side-ways) between the carapace and plastron.

pygal, a bone forming part of the carapace of a testudinid.

radiography, the production of images on a photographic plate using X-rays or other rays.

re-introduction, intentional movement of an organism into part of its native range from which it has disappeared.

re-stocking, movement of animals with the intention of building up the number of individuals in an original habitat.

taxonomy, study of the classification of organisms according to their similarities and differences.

Testudines, the order of Reptiles to which tortoises and turtles belong.

testudinid, a tortoise or turtle.

translocation, moving an animal from one place to another.

vernacular, the common name for a plant or animal.