RED DATA BOOK SPECIES IN THE CAPE FLORISTIC REGION: THREATS, PRIORITIES AND TARGET SPECIES

By

A G Rebelo*

Percy Fitzpatrick Institute of African Ornithology, University of Cape Town, Rondebosch 7700, South Africa

SUMMARY

The Cape Floristic Region (CFR) contains a disproportionate number of southern Africa's Red Data Book plants (70%), freshwater fish (57%), amphibians (43%), butterflies (38%), and reptiles (35%), relative to the small area (4%) of the subcontinent which it occupies. With the exception of reptiles, the vast majority of these species are endemic to the CFR, occurring mainly in mountain and lowland fynbos vegetation. Among the threats to the continued survival of these species, agriculture and alien invasive plants rank highest overall, although many scavenging birds and large mammals have been hunted and poisoned to extinction within the CFR. An active reintroduction of these large mammals from outside the CFR has been the dominant strategy of local conservation agencies. *The focus on large mammals as target species for conservation strategies has been to the detriment of floral preservation.* The geographical distribution of threatened species is not related to the extent to which vegetation types have been transformed. Thus renoster shrubland, which has been reduced to 6 per cent of its original lowland extent, contains few Red Data Book taxa relative to fynbos. By far the largest concentration of Red Data Book species of plants, butterflies, reptiles and amphibians occurs in the greater Cape Town metropolitan area. With 15.1 Red Data Book plant species per km², this area ranks as one of the most urgent conservation priorities in the world.

INTRODUCTION

The Cape Floristic Region (CFR, Fig. 1) occupies some 90 000 km² at the southern tip of Africa. With 8 600 plant species, of which 68 per cent are endemic (Bond and Goldblatt 1984), it ranks as one of the world's six floristic kingdoms (Taktajan 1986). In terms of local plant species richness, some centres of endemism in the CFR rank with the richest centres in tropical rain forests (Cowling *et al.* in press). However, unlike most rain forest centres of plant endemism, the CFR does not have a fauna of comparative richness in species or endemics. Furthermore, the large mammals and scavenging raptors were largely eliminated from the CFR during the 18th century. Consequently, conservation strategies in the CFR have lacked the 'large and hairy' and 'cute and cuddly' emphasis characteristic of conservation programmes elsewhere in Africa (Ferrar 1989).

The CFR has been, and is being, extensively transformed by pastoral, agricultural and urban development and alien plant encroachment (Jarman 1986, Macdonald and Richardson 1986, Rebelo 1992). In the lowlands of the western Cape only six per cent of renoster shrubland and 14 per cent of fynbos are currently untransformed by these agents (Boucher 1981).

* Present address: Conservation Biology Research Unit, National Botanical Institute, Kirstenbosch, Claremont 7735, South Africa.

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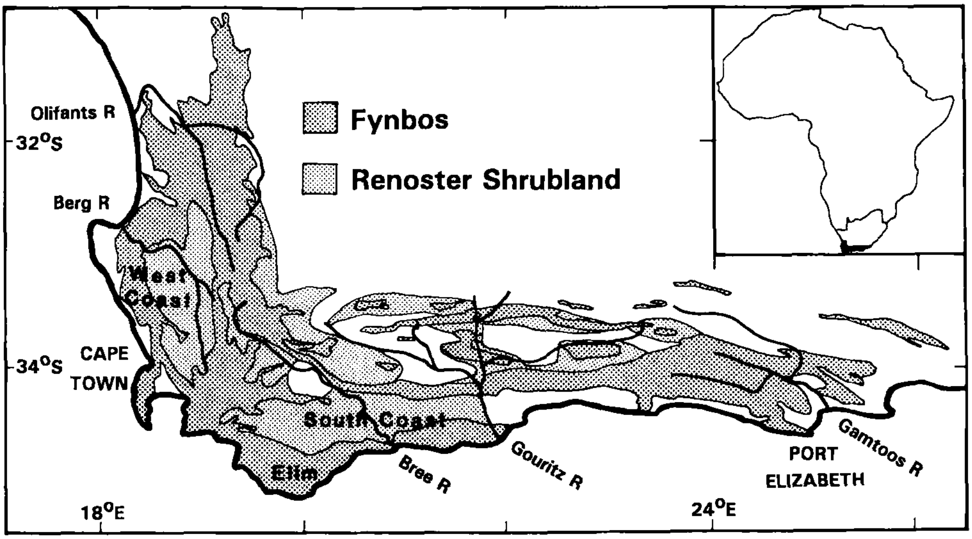

Fig. 1. The location of the Cape Floristic Region showing the distribution of fynbos (shaded) and renoster shrubland (West Coast, South Coast) vegetation and the location of the major river systems.

A holistic view, integrating patterns of threats to different species with areas containing high numbers of threatened species and the identification of suitable 'target' species would greatly enhance conservation strategies in the CFR. Specifically I ask:

- Which taxa are threatened in the CFR and are they representative of those of the subcontinent?;
- In which geographical regions of the CFR are Red Data Book species concentrated and how does this pattern vary among taxa?;
- How do these patterns vary among the vegetation types within the CFR, given that vegetation types form the focus of conservation assessments and the determination of priorities within the region?;
- What threats are responsible for the decline and extinction of species in the CFR, and how do these differ among taxa?; and,
- How have the above patterns influenced the conservation strategies adopted within the region?

METHODS

Taxa threatened

Red Data Book species of plants (Hall *et al.* 1980, Hall and Veldhuis 1985), butterflies (Henning and Henning 1989), fish (Skelton 1987), reptiles and amphibians (Branch 1988a), breeding birds (Brooke 1984) and mammals (Smithers 1983) were categorized as occurring either in the CFR (Fig. 1), the remainder of South Africa, or both. Peripheral species (those relatively common elsewhere in Africa) were excluded from Red Data Book lists for the remainder of South Africa. Species were categorized as threatened (by human activities: extinct, endangered or vulnerable), naturally rare (rare, critically rare, Hall and Veldhuis 1985, and restricted, Branch 1988a), and those for which there is insufficient data (indeterminate or uncertain). Total species lists for southern Africa and the CFR were also compiled (see Tables 1–7 for references). These data were used to test the null hypothesis that the frequency of Red Data Book species in taxonomic categories should mirror both the total species and endemic species richness for the CFR and South Africa, respectively. Taxa especially susceptible to decreasing populations through human activities should be over-represented in Red Data Book lists.

Areas with concentrations of rare species

The historical distribution ranges of Red Data Book species of plants, butterflies, reptiles, amphibians, and fish were mapped on a quarter-degree grid system and species richness per degree-square was determined. It was not feasible to map the distribution ranges of species by quarter-degrees for Red Data Book mammals and birds as their historical distribution ranges are not known with sufficient precision.

Habitat ranges

Species in each group were categorized by which habitat they occurred in, using vegetation type categories defined by Moll and Bossi (1984) and plant biogeographic region (Weimarck 1941). Although habitat requirements are usually given in the Red Data Book species accounts, these proved inadequate. Furthermore, even though a preliminary analysis by vegetation type had been undertaken for plant data (Hall and Veldhuis 1985), this was apparently determined from distribution data at a quarter-degree scale. Consequently, these data may have a high degree of error. I made no attempt to modify any obvious errors as my knowledge of vegetation type requirements is largely confined to the Proteaceae. For butterflies (Henning and Henning 1989), habitat descriptions often refer to vegetation and some food plants, but these were usually inadequate: confusion between vegetation types (fynbos, karoo, thicket and renoster shrubland) and plants (references to 'grasses' in fynbos vegetation, when probably Restionaceae are implied) were apparent. In addition, it is possible that butterfly male territories, adult- and larval-feeding sites may occur in different vegetation types: this could not be ascertained from the accounts. Thus habitat distributions for butterflies (and amphibians and reptiles) were based largely on dominant vegetation types present (Moll and Bossi 1984) at recorded localities. Where ambiguities were present, all probable vegetation types present at all current and historical sites were recorded. In the case of fish, the vegetation types through which the occupied portion of the river flows were used, ignoring any sediment translocation downstream which might modify the substratum.

Some data on historical distributions of mammals are available (Skead 1980), but seldom allow frequented vegetation types to be determined. I have therefore assumed that all large mammals which were historically absent from the Cape Peninsula (Skead 1980) tended to avoid mountain fynbos, and that all large herbivores were largely confined to renoster shrubland, thicket and karoo, and perhaps to a lesser extent West

Coast lowland fynbos during spring, as argued by Skead (1980). Although very good distributional data exist for birds, habitat requirements for CFR birds are poorly recorded: only feeding range was categorized as habitat.

For mammals the distribution by vegetation types for each species was combined with mass data (from Smithers 1986) to determine the dispersion of mass classes within extinct, threatened and non-threatened species. Where mass data were not available, mass was extrapolated from related species based on body measurements. Geographic variation in mass was ignored, and the geographically closest population was selected where regional variation in mass was provided in Smithers (1986).

Types of rarity

Although Red Data Book species are often considered as 'rare', this typification masks the variables associated with rarity. Based on their historical distribution ranges, species were categorized as:

— localized (confined to an area of less than five quarter-degree grid squares (ca. 3 000 km^2) = Restricted sensu Branch 1988a);
— sparse (occurring in many disjunct, small populations, or at low densities, over a wide area, with the distribution pattern unlikely to be the result of low collecting intensity); or,
— common (greater than ca. 3 000 km^2 in areal extent, populations probably large and widespread).

This classification ignores total population sizes, but such data are not available, except for larger mammal and bird species. Furthermore, such available data do not reflect historical population sizes (Macdonald 1989).

Threats

Threats were totalled for all species for which threats were listed in the Red Data Books as causing, or possibly causing, a decrease in numbers: only in the case of plants were data consistently lacking. All mammal species over 50 kg which were extinct in the CFR prior to 1800 were considered to have been hunted to extinction (Skead 1980), rather than influenced primarily by stockfarming, agriculture or vegetation transformations (see discussion). For each taxon, the threats were scaled by dividing the totals per threat by the total for the largest threat and multiplying by 10. These scores were then totalled to provide an overall rank of threat. Some inconsistencies were noted: 'hybridization' was not recorded as a threat to plants, 'collecting' was dismissed as a threat to butterflies and 'genetic decline' was applied to most plant species with small adult populations.

RESULTS

Taxa threatened

The representation of plant families between the CFR and the rest of South Africa was region-specific ($\chi^2 > 1\ 000$, $P < 0.001$, $df = 15$) (Table 1). Ten of the sixteen families included in the analysis exceeded the overall significance value for the Chi-squared test (i.e. $P=0.05$: $\chi^2=26.3$)—the exceptions being the Asteraceae, Cyperaceae, Fabaceae, Orchidaceae, Oxalidaceae, and Scrophulariaceae. The Ericaceae, Campanulaceae, Iridaceae, Proteaceae, Restionaceae, and Rutaceae were over-represented in the CFR and the Asclepiadaceae, Euphorbiaceae, Mesembryanthemaceae and Poaceae under-represented in the CFR (Table 1). These results agree with the family composition of the fynbos Biome (Gibbs Russell 1987).

Table 1

Status of Red Data Book species and subspecies among families of Angiosperms in South Africa (RSA) and the Cape Floristic Region (CFR). *Listed are the richest ten families in each of southern Africa (sAf: Botswana, Lesotho, Namibia, South Africa incl. the independent states and Swaziland: Gibbs Russell 1985) and the CFR (Bond and Goldblatt 1984)*, and the ten families with the most rare species in the CFR (Hall and Veldhuis 1985). Endemic species (End) to the CFR are from Bond and Goldblatt (1984), and Red Data Book species and subspecies for RSA excluding the CFR are from Hall *et al.* (1980). X = extinct; T = threatened (endangered or vulnerable); R = naturally rare; I = indeterminate or unknown.

	All species			Red Data Book taxa										
	sAf	CFR	CFR	Non-CFR					CFR					Shared
Family	Total	Total	End	X	T	R	I	Tot	X	T	R	I	Tot	
Asteraceae	2116	986	608	1	1	6	33	41	2	11	40	113	166	14
Ericaceae	984	688	666				1	1	5	26	48	59	138	0
Mesembry.	2408	660	507		5	4	31	40	1	11	10	34	56	7
Fabaceae	1540	644	525		1	21	5	27	1	9	21	79	110	1
Iridaceae	858	612	485		1	41	30	72	5	46	90	101	242	12
Proteaceae	366	320	306			6	2	8	3	62	58	8	131	1
Restionaceae	282	310	290			2	0	2	1	21	20	12	55	0
Scrophulariceae	543	310	160		2	1	10	13		2	3	30	35	3
Rutaceae	291	259	242			3	0	3	2	20	52	29	103	1
Campanulaceae	256	222	157			1	9	10		1	3	70	74	1
Orchidaceae	439	206	124		5	11	56	72		15	24	19	58	3
Cyperaceae	464	203	124					0			1	14	15	0
Poaceae	783	181	76		1	0	6	7		1	0	8	9	0
Oxalidaceae	195	129	90			3	8	11		3	5	42	50	2
Asclepiadaceae	769	125	35	1	10	14	31	56	1	9	12	29	51	10
Euphorbiaceae	461	97	38		6	11	10	27		5	2	9	16	2
Subtotal	12755	5952	4433	2	32	124	232	390	21	242	389	656	1309	57
TOTAL [1,2]	20370	8600	5865	4	71	257	339	667	29	282	420	704	1435	69
Total CFR [3]									26	255	389	656	1326	

Notes:

[1] Other extinct species in the CFR belong to the Bruniaceae (3 spp), Crassulaceae (2), and one each in the Amaryllidaceae, Hyacinthaceae and Malvaceae.
Other CFR families with more than two threatened species include: Amaryllidaceae (13), Hyacinthaceae (7), Penaeaceae* (4), Bruniaceae* (3), and Polygalaceae (3). * = Families endemic (>95% species) to the CFR.

[2] All data based on Appendix 1 in Hall and Veldhuis (1985), where this differs from their Appendix 3, but with *Elegia fastigiata* (see Appendix 2—Hall and Veldhuis (*loc. cit.*)) included as extinct.

[3] Total figures for Red Data Book species listed for the CFR in Appendix 3 of Hall and Veldhuis (1985): these exclude the Worcester and Little Karoo. The concordance between rare and indeterminate categories between the subtotal and total is incidental.

Likewise, in the CFR, the frequency of endemic species among families differs significantly from that expected from total species richness ($\chi^2 > 145$, $P < 0.001$, $df = 15$). Values exceeding 20% of the significance value ($P = 0.05$, $\chi^2 = 26.3$) occurred in five families with fewer than expected endemics (Asclepiadaceae, Asteraceae, Euphorbiaceae, Poaceae, and Scrophulariaceae) and one with more than expected (Ericaceae, Table 1). Analysis of the 10 most species-rich families in the CFR yielded similar patterns ($P < 0.05$, $\chi^2 = 16.9$, $df = 9$).

For the 10 richest CFR families, Red Data Book plant species richness differs significantly from that expected from total species richness ($\chi^2 > 200$, $P < 0.001$, $df = 9$): five families each almost exceeded the significance for the entire test ($P = 0.05$, $\chi^2 = 16.9$): Red Data Book species were under-represented in the Mesembryanthemaceae and Scrophulariaceae and over-represented in the Iridaceae, Proteaceae and Rutaceae (Table 1). Red Data Book plant species richness is significantly different from endemic species richness for the top 10 families in the CFR ($\chi^2 > 170$, $P < 0.001$, $df = 9$)—three families exceeded the significance for the entire test ($P = 0.05$, $\chi^2 = 16.9$): Red Data Book species were under-represented in the Mesembryanthemaceae and over-represented in the Iridaceae and Proteaceae; the Campanulaceae and Rutaceae were also strongly over-represented (with values greater than 12.0, Table 1).

Threatened (including extinct) plant species in the CFR (Table 1) are over-represented (value exceeding significance limits for test: $P = 0.05$, $\chi^2 = 16.9$, $df = 9$) in the Proteaceae relative to total Red Data Book species, and in the Iridaceae and Proteaceae relative to both endemic and total species. Similarly, the Asteraceae are under-represented relative to total species. Species marginally over-represented (value greater than 10.0 in the χ^2) are the Campanulaceae relative to Red Data Book species and the Fabaceae relative to total species in the CFR.

The representation of butterfly families was strongly dependent on region ($\chi^2 = 38$, $df = 8$, $P < 0.001$), with the Lycaenidae over-represented and the Acreidae, Hesperiidae and Nymphalidae under-represented in the CFR (Table 2). Endemism in butterfly families was independent of the richness of endemic species in the CFR ($\chi^2 = 15$, $df = 5$, $P < 0.05$), with the Lycaenidae containing a higher, and the Nymphalidae and Pieridae a lower, than expected level of endemism. Similarly, the Lycaenidae contribute overwhelmingly (96%) to the incidence of Red Data Book species in the CFR. This dominance of the CFR by Lycaenidae is similar to the rest of South Africa, but other families (Hesperiidae and families not well represented in the CFR) comprise one-third of the Red Data Book species in South Africa outside the CFR. Within the CFR all six threatened species belong to the Lycaenidae and no butterfly species is listed as extinct (Table 2), although Dickson's Monkey Blue *Lepidochrysops methymna dicksoni* has not been seen for 30 years, Cottrell's Blue *Chrysoritis cottrelli* for 12 years, and the Lion's Head Copper *Argyrocupha malagrida malagrida* for 'a few' years.

The representation of families and orders of mammals, birds, reptiles, amphibians, and fishes was independent of region, i.e. not significantly different (χ^2, $P > 0.05$) between southern Africa excluding the CFR and the CFR.

Table 2

Status of Red Data Book species and subspecies among families of Butterflies (Lepidoptera: Rhopalocera) in South Africa and the Cape Floristic Region (Henning and Henning 1989). The old concept of Nymphalidae has been retained. Species totals for southern Africa (south of Angola and Zambezi River) and the CFR and CFR endemics are from Dickson and Kroon (1978). Headings as in Table 1.

	All species			Red Data Book taxa										
	sAf	CFR	CFR	Non-CFR					CFR					Shared
Family	Total	Total	End	X	T	R	I	Tot	X	T	R	I	Tot	
Danaidae	7	2	0					0					0	—
Satyridae	78	23	7			6	3	9			1		1	0
Acraeidae	46	3	0				3	3					0	—
Charaxidae	37	5	1					0					0	—
Nymphalidae	68	10	0			4	2	6					0	—
Libytheidae	1	0	—					0					—	—
Lycaenidae	352	143	59	2	3	38	14	57		6	37	9	52	3
Pieridae	53	20	0			2		2					0	—
Papilionidae	17	3	0				1	1					0	—
Hesperiidae	123	25	5			6	7	13			1		1	0
TOTAL	782	234	72	2	3	56	30	91	0	6	39	9	54	3

Apart from the endemic Bontebok *Damaliscus dorcas dorcas*, Bluebuck *Hippotragus leucophaeus*, and Grysbok *Raphicerus melanotis* (Artiodactyla), three species of the Insectivora and four of the Rodentia comprise the total complement of mammal species endemic to the CFR. The two larger endemic ungulates (Bontebok and Bluebuck) were confined to renoster shrubland and the smallest to fynbos. An endemic gerbil and fossorial molerat were confined to lowland fynbos and thicket vegetation, the other two endemic rodents being generalists. One endemic shrew species occurs on the fynbos/Forest ecotone, whereas the two endemic moles occur in lowland fynbos and thicket vegetation. Rodentia, Insectivora and Chiroptera are under-represented among Red Data Book species relative to their abundance in the CFR: Red Data Book mammal species are dominated by species larger than 50 kg (73%: Table 3).

Mammals contain the highest proportion of extinct species (11%) of all the taxa in the CFR. Of the 16 mammal species recorded historically that exceeded 50 kg in mass, 10 (63%) were hunted to extinction: two of these (Bluebuck and Quagga *Equus quagga*) are extinct globally. Four of these have been reintroduced into reserves in the CFR from elsewhere on the subcontinent (Table 3). A further three species over 50 kg in mass are in the threatened category, and the Bontebok is no longer threatened (since mid-20th century), so that 88 per cent of mammal species larger than 50 kg in mass have been impacted by human activities in the CFR. Only the bushpig *Potamochoerus porcus* and Kudu *Tragelaphus strepsiceros*, among mammals larger than 50 kg in mass, have not been adversely impacted by human activities in the CFR, the latter persisting even under heavy hunting pressure within its historical distribution range (Little Karoo) (Smithers 1983). Only four of the 14 mammal species (29%) exterminated from within the CFR were less than 50 kg in mass: two were carnivores

Table 3

Status of Red Data Book species among orders of Mammalia (excluding marine Cetaceae and Pinnipedia) in South Africa and the Cape Floristic Region (Skead 1980, Smithers 1986, Rookmaaker 1989). Species totals for southern Africa (south of Angola and Zambezi River) and the CFR and CFR endemics are from Smithers 1983. Headings as in Table 1.

	All species			Red Data Book taxa										
	sAf	CFR	CFR	Non-CFR					CFR					Shared
Order	Total	Total	End	X	T	R	I	Tot	X[1]	T[2]	R	I	Tot	
Insectivora	39	15	3		2	4	9	15			1	4	5	2
Chiroptera[3]	74	20	0				26	26				3	3	2
Primates	7	2	0			1		1					0	—
Philodota	1	0	—		1			1					—	—
Lagomorpha	7	3	0		1			1					0	—
Rodentia	78	33	4		2	4	6	12		1	1		2	2
Carnivora	37	26	0		3	9		12	4	3	4		11	11
Proboscidea	1	1	0					0		1			1	1
Hyracoidea	4	2	0			1		1				1	1	1
Tubulidentata	1	1	0		1			1		1			1	1
Perissodactyla	5	3	0	1	2			3	2	1			3	3
Artiodactyla	41	21	3	1	4	5		10	8	0	2		10	8
TOTAL	295	127	10	2	16	24	41	83	14	7	8	8	37	32

Notes: (* Reintroduced to the CFR; $ endemic; # globally extinct)

[1] Extinct:

Carnivora: Spotted Hyaena *Crocuta crocuta* (60 kg), Brown Hyaena *Hyaena brunnae* (45), Wild Dog *Lycaon pictus* (27), Lion *Panthera leo* (200);

Perissodactyla: Hook-lipped Rhinoceros *Diceros bicornos* (860), Quagga *Equus quagga* (240)#;

Artiodactyla: Red Hartebeest *Alcelaphus buselaphus* (130)*, Hippopotamus *Hippopotamus amphibius* (1 400)*, Blue Antelope *Hippotragus leucophaeus* (200)$#, Gemsbok *Oryx gazella* (230)*, *Redunca arundicum* (45), Oribi *Ourebia ourebi* (14), Buffalo *Syncerus cafer* (780)*, Eland *Taurotragus oryx* (600)*.

[2] Threatened:

Rodentia: White-tailed Mouse *Mystromys albicaudatis* (0.09);

Carnivora: African Wild Cat *Felis lybica* (5), Serval *F. serval* (10), Honey Badger *Mellivora capensis* (12);

Misc.: African Elephant *Loxodonta africana* (5 000); Antbear *Oryteropus afer* (52); Cape Mountain Zebra *Equus zebra* (240).

[3] Only one species of bat is a non-breeding migrant to the subcontinent: it has been included in the totals.

and two were grazing ungulates (Table 3). Carnivora feature strongly among the threatened and naturally rare (sparse, not localized) species in the CFR, because of low densities and several hundred years of persecution by stock farmers (Table 3).

All mammals greater than 300 kg are threatened or extinct in the CFR (Figure 2). Other than the elephant *Loxodonta africana*, which survives in the CFR as three individuals (Smithers 1986), all mammals over one metric ton are extinct. Only a single species, the Reedbuck *Redunca arundinum*, has gone extinct in fynbos but this species was probably more common in renoster shrubland (Smithers 1986). Extinctions are most marked in karoo, renoster shrubland and thicket vegetation, which supported the largest mammals (Figure 2). The only mammal less than 5 kg that has had its distribution range reduced is the White-tailed Mouse *Mystromys albicaudatus*, which occurred in fynbos and renoster shrubland (Smithers 1983).

Birds have the lowest levels of endemism (2.1%) of all taxa in the CFR (Table 4). Six Passerine species—two nectar-feeders, two granivores and two insectivores (all largely confined to fynbos vegetation)—are endemic to the CFR, reflecting the preponderance of passerine species in the region. Two near-endemic species, the Cape Francolin *Francolinus capensis* (Galliformes, an omnivore in thicket) and Cape Bulbul *Pycnonotus capensis* (Passeriformes: a frugivore in thicket) were excluded as they extend along the west coast well north of the CFR.

Red Data Book bird species are strongly biased to birds of prey (Falconiformes) and cranes/bustards (Gruiformes)—passerines are under-represented (Table 4). Four bird species are extinct in the CFR: two vultures, a crane and a bittern. A further seven species, mainly Falconiformes and Gruiformes, are threatened—the majority of these are threatened throughout South Africa.

The status of the Ostrich *Struthio camelus australis*, the only bird exceeding 50 kg in the CFR, presents a problem of categorization. Despite some farmers having maintained tame ostriches as early as 1775, the species was apparently regularly hunted to the extent that a special proclamation was issued in 1822 to check its destruction (Smit 1963). Sufficient birds obviously remained during the 1850s, when domestication for the feather industry commenced. These birds were hybridized with a few imported males of *Struthio camelus camelus* from North Africa and *Struthio camelus syriacus* from Syria during the latter half of the nineteenth century in order to improve feather quality. Considerable selection for superior strains was undertaken at the turn of the century, when a studbook was maintained and hybrid stock was keenly sought. During the slump of 1914 to 1930 the ostrich population decreased dramatically from almost 800 000 birds to 32 000; this period was characterized by intense culling of 'inferior' strains (Smit 1963). Today free-range birds are frequent on farms in the CFR (Hockey *et al.* 1989), although it is uncertain whether these are remnants of the local race or were obtained from domesticated stock: certainly a few show features indicative of hybridization (R. K. Brooke pers. comm.). Therefore the status of the Ostrich in the CFR might be variously considered, depending on interpretation of definitions, as extinct in the wild, threatened owing to hybridization with hybrid domestic stock, or, because of the probable high proportion of local genes (despite selection) as no longer threatened (since 1850).

Although 17 per cent of reptiles are endemic to the CFR, there are no endemic snake (Serpentes) species out of the 38 species which occur in the CFR (Table 5). Skinks (Scincidae), girdled lizards (Cordylidae) and chameleons (Chamaeleonidae) comprise two-thirds of the 19 endemic species to the CFR—only one endemic species (geometric tortoise *Psammobates geometrica*: Chelonia) is not a saurid. No differences in taxonomic composition are evident between Red Data Book species within and outside the CFR (Table 5): both regions are dominated by girdled lizards, geckoes (Gekkonidae), typical snakes (Colubridae), and skinks. The Nile crocodile *Crocodylus niloticus* has never occurred within the CFR.

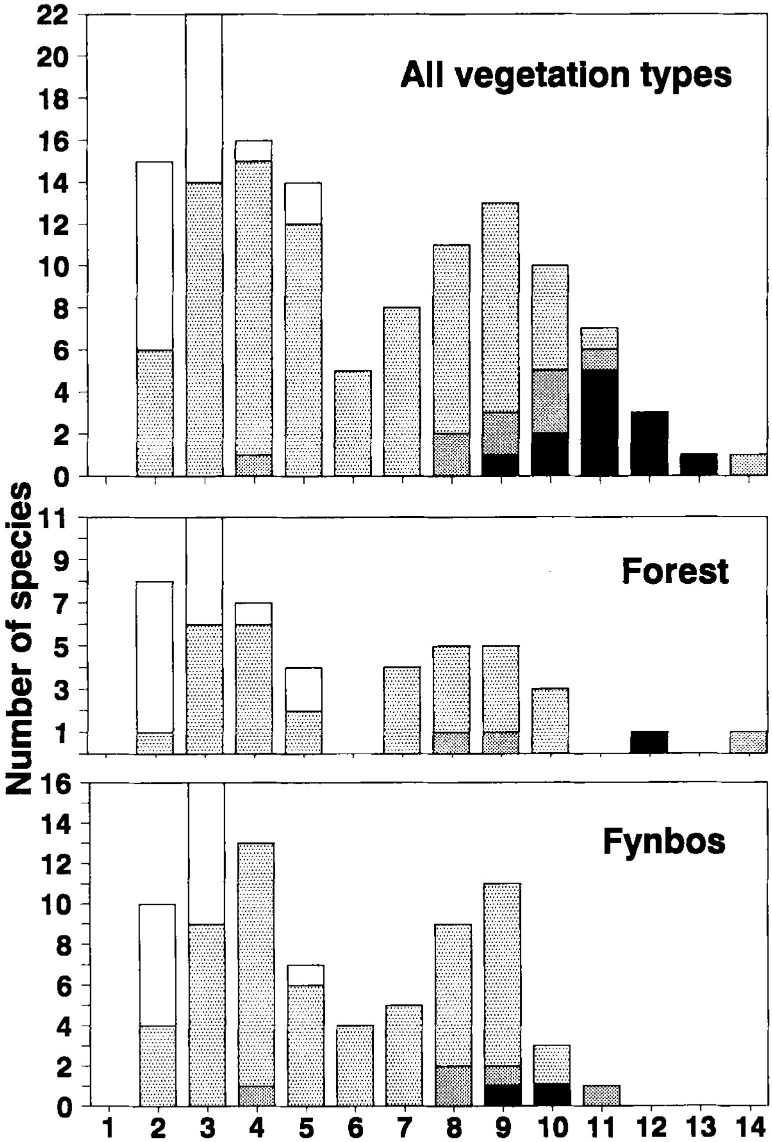

Fig. 2. The frequency composition of extinct (solid), threatened (dark shading), stable non-flying (light shading) and stable flying (= Chiroptera, unshaded) mammals by mass class* in the major vegetation types of the Cape Floristic Region. *The mass classes are: **(1)** <3g, 3–10g, 11–30g, 31–100g, **(5)** 101–309g, 310g–1kg,. 1–3kg, 3–10kg, 11–30kg, **(10)** 31–100kg, 101–309kg, 310–1000kg, 1001–3099kg, **(14)** >3100kg. See next page.

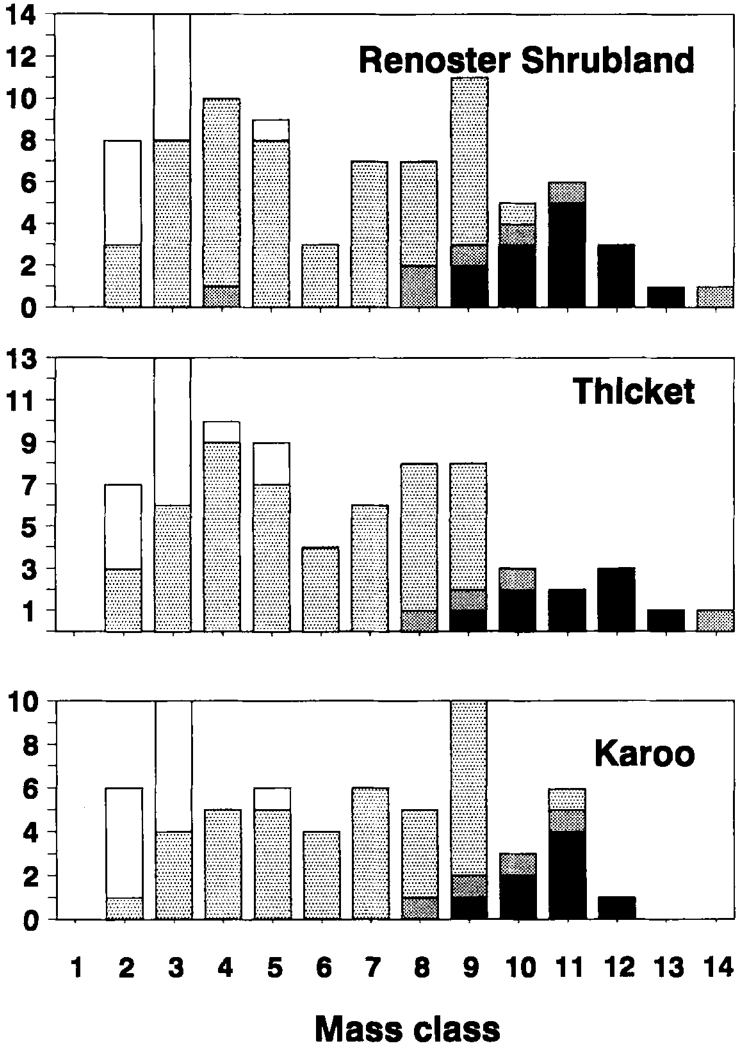

Fig. 2 (continued)

In contrast to the reptiles, almost half (47%) of the amphibian species in the CFR are endemic (Table 6). Although all four Heleophrynidae are endemic to the CFR, and only one other species occurs in the rest of southern Africa, there are no significant family differences in species composition or endemism (Table 6). However, nearly half (44%) of southern African Red Data Book species and all five threatened species are endemic to the CFR. Only the Hyperoliidae do not contain Red Data Book taxa in the CFR.

Over half (52%) of the freshwater fish species in the CFR are endemic (Table 7). Half the species present and three-quarters of the endemic species in the CFR are

Table 4

Status of Red Data Book species among orders of Birds (Aves: excluding non-breeding birds and marine Sphenisciformes and Procellariformes) in South Africa and the Cape Floristic Region (Brooke 1984). Species totals for southern Africa (south of Angola and Zambezi River) and the CFR and CFR endemics are from Maclean (1989). Headings as in Table 1.

	All species			Red Data Book taxa										
	sAf	CFR	CFR	Non-CFR					CFR					Shared
Family	Total	Total	End	X	T	R	I	Tot	X[1]	T[2]	R	I	Tot	
Struthionif.[3]	1	1	0					0				1	1	1
Pelecaniformes	5	4	0			2		2			1		1	1
Ciconiiformes	32	16	0		1	1		2	1		1		2	2
Phoenicopterif.	2	2	0				2	2				2	2	2
Falconiformes	53	22	0		5	3	2	10	2	3	1		6	6
Gruiformes	31	15	0		4	2	1	7	1	3	1	2	7	7
Charadriiformes	26	13	0	1				1					0	—
Psittaciformes	8	0	—		1			1					—	—
Strigiformes	12	5	0		1	1	1	3		1			1	1
Coraciiformes	17	2	0		1		1	2					0	—
Piciformes	26	11	0			1		1					0	—
Passeriformes	360	137	6	1	6	3	8	18				1	1	1
Misc.	121	60	0					0					0	—
TOTAL	694	288	6	2	19	13	15	49	4	7	4	6	21	21

Notes:

[1] Extinct: Bittern *Botaurus stellaris*, Lammergeier *Gypaetus barbatus*, Egyptian Vulture *Neophron percnopterus*, Wattled Crane *Grus carunculata*.

[2] Threatened: Lappetfaced Vulture *Torgos tracheliotus*, Martial Eagle *Polemaetus bellicosus*, Cape Vulture *Gyps coprotheres*, *Black-rumped Button Quail Turnix hottentotta*, Stanley's Bustard *Neotis denhami*, Ludwig's Bustard *N. ludwigii*, Grass Owl *Tyto capensis*.

[3] See text for problems with the status of the Ostrich *Struthio camelus australis*.

barbels (Cyprinidae), which also comprise 83 and 44 per cent of the Red Data Book species in the CFR and the rest of South Africa, respectively. The CFR contributes about two-thirds of both the Red Data Book species (71%) and threatened species (58%) in South Africa, despite having only 13 per cent of the subcontinent's fish species (Table 7).

By way of comparison, mammals, birds, amphibians and plants have a similar proportion of species (40%) in the CFR relative to the subcontinent (Table 8). Butterflies and reptiles have a much smaller proportion (29%) and fish are by far the least well represented (13%) in the CFR relative to the subcontinent. Patterns of endemism within the CFR are quite different among taxonomic groups: plants, fish and amphibians have high ratios (>45%) of endemism, whereas birds, mammals and reptiles have very low ratios (<20%) (Table 8). There is a very close correspondence between the ratio of endemism to total species richness in the CFR and the ratio of Red Data Book species richness in the CFR relative to that of southern Africa (including the CFR), the exceptions being those taxa with very low ratios of endemism, which share a high proportion of Red Data Book species between the regions (Table 8).

Table 5

Status of Red Data Book species and subspecies among families of Reptiles (excluding marine and freshwater Chelonii) in South Africa and the Cape Floristic Region (Branch 1988a). Species totals for southern Africa (south of Angola and Zambezi River) and the CFR and CFR endemics are from Branch (1988b). Headings as in Table 1.

	All species			Red Data Book taxa										
	RSA	CFR	CFR	Non-CFR						CFR				Shared
Family	Total	Total	End	X	T	R	I	Tot	X	T	R	I	Tot	
Chelonia	11	6	1			1		1		1	1		2	0
Serpentes Misc	17	4	0		1			1					0	—
Colubridae	85	25	0			6		6		1	2		3	2
Elapidae	13	4	0			1		1			1		1	1
Viperidae	12	5	0		2	2		4			1		1	1
Amphisbaena	12	0	—			1		1					—	—
Sauria Scincidae	59	14	5		1	5		6			2		2	0
Lacertidae	30	10	2			1		1			1		1	0
Cordylidae	49	14	4	1	2	6		9		1	2		3	2
Chamaeleonidae	16	5	4			3		3		1			1	0
Gekkonidae	64	18	3		1	3	1	5			2	1	3	1
Misc	11	4	0					0					0	—
Crocodylia	1	0	—		1			1					—	—
TOTAL	380	109	19	1	8	29	1	39	0	4	12	1	17	7

Table 6

Status of Red Data Book species and subspecies among families of Amphibians in South Africa and the Cape Floristic Region (Branch 1988a). Species totals South Africa (incl. Lesotho and Swaziland) and the CFR and CFR endemics are from Passmore and Carruthers (1979) and Branch (1988a). Headings as in Table 1.

	All species			Red Data Book taxa										
	RSA	CFR	CFR	Non-CFR						CFR				Shared
Family	Total	Total	End	X	T	R	I	Tot	X	T	R	I	Tot	
Pipidae	3	1	1					0		1			1	0
Heleophrynidae	5	4	4					0		2			2	0
Bufonidae	12	6	3			1		1			1		1	0
Microhylidae	13	8	5			1		1		1			1	0
Ranidae	36	13	4			3	1	4		1	1		2	0
Hyperoliidae	21	6	1			3		3					0	—
Misc.[1]	5	0	—					0					—	—
TOTAL	95	38	18	0	0	8	1	9	0	5	2	0	7	0

Notes:

[1] Arthroleptidae, Hemisotidae and Rhacophoridae.

Table 7

Status of Red Data Book species among families of freshwater Fish (Pisces) in South Africa and the Cape Floristic Region (Skelton 1987). Species totals for southern Africa (south of Angola and Zambezi River) and the CFR and CFR endemics are from Jackson (1975) and Scott and Hamman (1984), respectively. Only families with Red Data Book species are listed. Headings as in Table 1.

	All species			Red Data Book taxa										
	sAf	CFR	CFR	Non-CFR					CFR					Shared
Family	Total	Total	End	X	T	R	I	Tot	X	T	R	I	Tot	
Cyprinidae	76	14	11		3	1		4		5	5		10	0
Bagridae	5	2	2			1		1		1	1		2	0
Mochokidae	13	0	—		1			1					—	—
Anabantidae	4	1	0		1			1					0	—
Cichlidae	26	1	0			2		2					0	—
Subtotal	124	18	13											
TOTAL	212	27	14	0	5	4	0	9	0	6	6	0	12	0

The proportion of Red Data Book species relative to total species richness are, except for mammals and birds, much higher within the CFR than in the rest of South Africa (Table 8): the largest differences are for fish and plants (with CFR values 10.5 and 3.3 times that of southern African values, respectively). The ratio for the remaining taxa varies from 1.5 to 2.0 times that of the rest of South Africa (Table 8).

Known extinctions in the CFR have been confined to mammals, birds and plants. Although twice as many plants as mammals have gone extinct, the proportion of extinctions to the total number of species in the CFR is 30 times higher for mammals (Table 8). A small proportion of reptile and butterfly species are threatened by man's activities: both these groups have a high proportion of naturally rare species. Species

Table 8

Summary statistics for vertebrate classes, butterflies and plants for the Cape Floristic Region (CFR) relative to southern Africa (sAf—including the CFR) and South Africa (RSA—excluding the CFR), extracted from Tables 1–7.

Subscripts are: $_{end}$ = endemic; $_{rdb}$ = Red Data Book species; and, $_{tot}$ = total species.

	Species richness (%)		Red Data Book species (%)				Red Data Book status in CFR (% of CFR_{tot})			
	CFR_{tot} ÷ sAf_{tot}	CFR_{end} ÷ CFR_{tot}	CFR_{rdb} ÷ CFR_{tot}	RSA_{rdb} ÷ RSA_{tot}	CFR_{rdb} ÷ $(CFR + RSA)_{rdb}$	Shared between CFR + RSA ÷ CFR	Extct	Threat	Rare	Indet.
Mammal.	43.0	7.9	29.1	28.1	42.0	86.5	11.0	5.5	6.3	6.3
Aves	41.5	2.1	7.3	7.1	42.9	100.0	1.4	2.4	1.4	2.1
Reptilia	28.7	17.4	15.6	10.3	34.7	41.2	0.0	3.7	11.0	0.9
Amphibia	40.0	47.4	18.4	9.5	43.8	0.0	0.0	13.2	5.3	0.0
Pisces	12.7	51.9	44.4	4.2	57.1	0.0	0.0	22.2	22.2	0.0
Lepidopt.	29.9	30.8	23.1	12.8	38.0	5.6	0.0	2.6	16.7	3.8
Plantae	42.2	68.2	16.7	4.6	70.6	4.8	0.3	3.3	4.9	8.2

with an indeterminate status occur predominantly among nocturnal mammals, plants and butterflies: the status of taxonomic groups with relatively few species is generally better known than that of larger groups (Table 8). As with Western Australia (Burbidge and McKenzie 1989), the number of extinct birds and reptiles is significantly fewer than that for mammals ($\chi^2 = 16.5$ and 8.5, $P < 0.005$, based on expected total species richness, respectively).

Areas with concentrations of rare species

The richness of Red Data Book butterfly, amphibian, reptile and plant species is highest in the south-west, centred on the Cape Peninsula and adjacent lowlands (Figure 3). This pattern is mirrored by the distribution of threatened species in the CFR (Figure 3). Reptiles, amphibians and butterflies also all show a minor concordance of threatened and higher species richness in the mountains of the Uitenhage area.

Butterfly Red Data Book species show several satellite areas with high richness (Figure 3). These probably reflect collecting intensity and are centred on prominent mountain passes. The south coastal areas of species richness and threatened species reflect the prominence of thicket species and the development of holiday resorts along the coast.

Amphibian Red Data Book species are largely concentrated on the black-(acid-) water lakes of the southwestern Cape lowlands and the high mountains of the western CFR (Figure 3).

Reptile Red Data Book species show a strong arid northwest dispersion, with threatened (endangered) species largely concentrated in the fynbos and renoster shrubland lowlands (Fig. 3). A 'vulnerable' species of girdled lizard *Cordylus cataphractus*, threatened by the pet trade, occurs in the mountains of the northwest and extends beyond the region to the north.

Plant Red Data Book species occur throughout the region: only 20 (9%) of the 212 quarter-degree grid squares did not contain a Red Data Book species. Some 90 and 94 Red Data Book plant species occupy the two quarter-degree grid squares on the Cape Peninsula, with high concentrations of threatened species on the Peninsula and adjacent lowlands and in the Elim area. High numbers of rare and indeterminate species occur in the mountain ranges in the southwest, with lesser peaks to the north and east (Fig. 3).

The Olifants River system contains 11 indigenous species of fish, of which eight have Red Data Book status, with five being threatened (Skelton 1987). Seven of the Red Data Book species occur in the southern Cedarberg (Fig. 3). One species, the Chubbyhead Barb *Barbus anoplus* (Cypriniformes: Cyprinidae), is apparently extinct from the system, but is widespread in the east beyond the CFR (Scott and Hamman 1984). Thus the Olifants River contains 83 per cent of threatened and two-thirds of the Red Data Book fish species. The Berg River system shares four of its five species with the Bree River system, which contains an additional three species (Scott and Hamman 1984). Three species in the combined system have Red Data Book status, with two threatened (one shared and one confined to the Berg and two adjacent

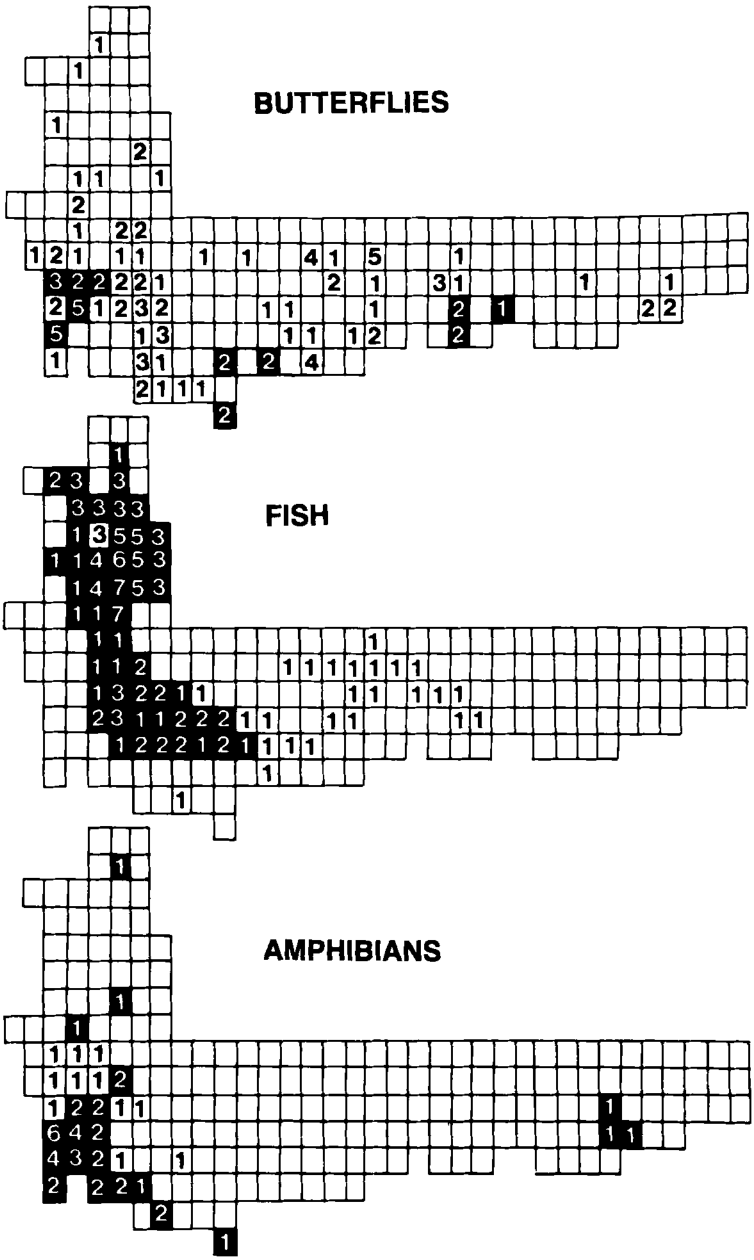

Fig. 3. Species richness of Red Data Book species in the Cape Floristic Kingdom per quarter-degree grid square. Black grid squares (with white numerals) contain threatened species (i.e. extinct, endangered, or vulnerable), light stippling (reptiles) = a vulnerable species threatened by pet trade, plants [0 = 1–9, 1 = 10–19, etc.; shading = more than 15 threatened species]. See next page.

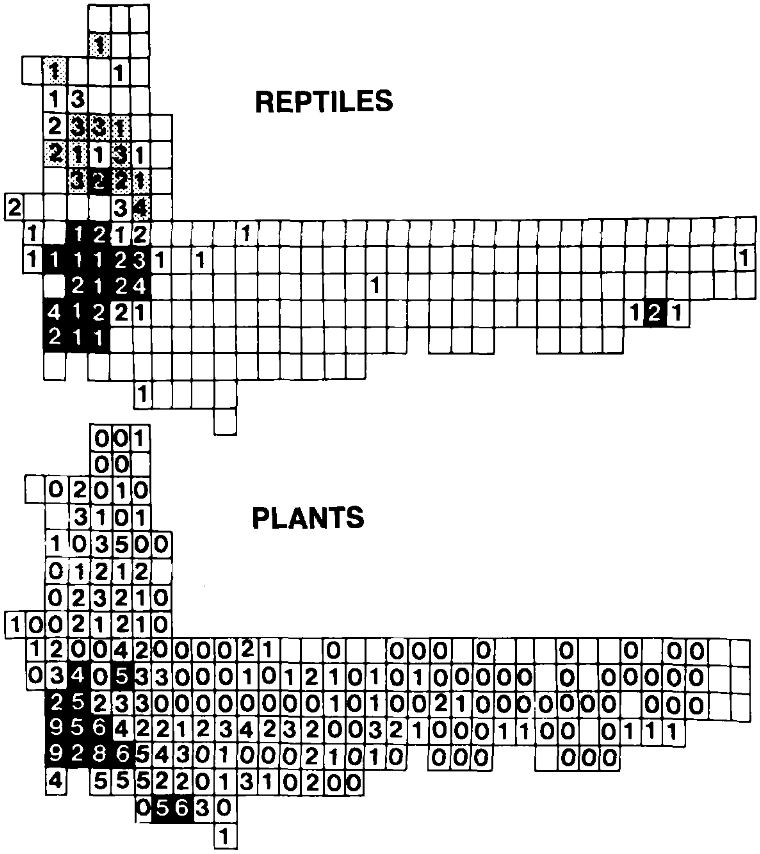

Fig. 3 (*continued*)

rivers) and one rare (confined to the Bree and three adjacent rivers). The Gouritz River system contains eight species of fish, two of which are naturally rare: only one species is confined to the Gouritz and adjacent rivers (Scott and Hamman 1984). The Gamtoos River system contains 11 species of fish, none of which are confined to the river or adjacent rivers or have Red Data Book status: one out of the five species common to the combined Gouritz-Gamtoos Rivers is endemic to the combined system (Scott and Hamman 1984). Although not a Red Data Book species, nor a CFR endemic, the Cape Kurper *Sandelia capensis* (Perciformes: Anabantidae) has become extinct in three rivers in the CFR—the largest reduction in distribution range amongst CFR fish species (Scott and Hamman 1984).

The majority of large mammals and predatory and scavenging birds were probably fairly widespread within the CFR, with the notable exceptions of: the Quagga, which may not have occurred historically on the west coast lowlands; the Gemsbok *Oryx gazella*, which historically occurred only as far south as Piketberg; the endemic Bluebuck, which was apparently confined to the Swellendam area of the South Coast renoster shrubland when Europeans first explored the area (prehistorically the species also occurred in West Coast and East Coast renoster shrubland); and the endemic Bontebok, which occurred throughout South Coast renoster shrubland (Skead 1980, Smithers 1983, Rookmaaker 1989). However, insufficient data exist for clear patterns to be deduced. All the endemic bird species are mountain fynbos species, and consequently have not been notably impacted by humans.

Habitat ranges

Despite the large scale transformation of the lowlands of the CFR, relatively few Red Data Book plant species occur within regions dominated by lowland vegetation types (thicket, renoster shrubland and lowland fynbos, Table 9). By contrast, Red Data Book mammal and bird species were predominant in these vegetation types. Furthermore, the majority of large mammal species occurred in these vegetation types, with smaller species in fynbos vegetation types (mainly Insectivora and Rodentia). Whereas Red Data Book mammal species were fairly widespread between renoster shrubland, thicket and karoo, Red Data Book bird species appear to have

Table 9

Distribution of Red Data Book species within major vegetation types in the Cape Floristic Region. Figures in parenthesis are species numbers per km². Vegetation types are based on Moll and Bossi (1984), as modified by Hall and Veldhuis (1985) based on Weimarck's (1941) centres of endemism.

	Area (km^2)	No of Red Data Book species						
		Plants	Butterflies	Amphibians	Reptiles	Fish	Birds	Mammals
Thicket:								
West coast	3 555	97 (2.7)	3 (0.1)	0	2 (0.1)	0	4 (0.1)	19 (0.5)
South coast	1 410	122 (8.7)	6 (0.4)	0	1 (0.1)	0	7 (0.5)	19 (1.3)
Renoster shrubland:								
West coast	7 280	187 (2.6)	6 (0.1)	1 (+)	2 (+)	2 (+)	12 (0.2)	17 (0.2)
Central	3 570	55 (1.5)	2 (0.1)	1 (+)	1 (+)	2 (0.1)	9 (0.3)	21 (0.6)
South coast	6 940	171 (2.5)	1 (+)	0	0	1 (+)	12 (+)	19 (0.3)
Eastern	500	47 (9.4)	0	0	0	0	11 (2.2)	20 (4.0)
Karoo:								
Clanwilliam	583	44 (7.5)	1 (0.1)	0	1 (0.1)	3 (0.5)	7 (1.2)	19 (3.3)
Little	14 530	100 (0.7)	3 (+)	0	0	0	11 (+)	20 (0.1)
Afromontane:								
Forest	1 700	24 (1.4)	1 (0.1)	0	0	0	1 (0.1)	6 (0.4)
Fynbos (Mountain)								
Northern	12 020	365 (3.0)	6 (+)	1 (+)	8 (0.1)	10 (0.1)	1 (+)	7 (0.1)
Peninsula	300	127 (42.3)	5 (1.7)	4 (1.3)	1 (0.3)	0	2 (0.7)	7 (2.3)
Southern	4 660	479 (10.3)	12 (2.6)	4 (0.1)	6 (0.1)	1 (+)	1 (+)	7 (0.1)
Langeberg	1 970	151 (7.7)	3 (0.1)	0	0	2 (0.1)	2 (0.1)	7 (0.4)
Outeniqua	5 690	66 (1.2)	1 (+)	0	0	0	1 (+)	7 (0.1)
Eastern	7 660	31 (0.4)	4 (0.1)	1 (+)	2 (+)	1 (+)	1 (+)	8 (0.1)
Inland	4 980	103 (2.1)	10 (0.2)	0	3 (0.1)	1 (+)	1 (+)	6 (0.1)
(Lowlands):								
South coast	3 110	90 (2.9)	5 (0.2)	0	0	0	1 (+)	9 (0.3)
West coast	3 505	167 (4.8)	3 (0.1)	2 (0.1)	1 (+)	0	1 (+)	10 (0.3)

been richer in coastal renoster shrubland and Little Karoo than in thicket, Mountain renoster shrubland or Clanwilliam Karoo.

By far the highest numbers of Red Data Book plant, amphibian and butterfly species occur in southern mountain fynbos. The ratio of species to area is far higher for the mountain fynbos on the Cape Peninsula for plants, amphibians and reptiles. Butterflies and plants are also well represented (on an areal basis) in South Coast thicket.

Although these data are crude they suggest that similar overall patterns occur in species habitat preferences among plants, butterflies and amphibians, with a preponderance of rare and threatened species in the southwest in fynbos vegetation. By contrast, reptile species were richest in the more arid fynbos vegetation in the northwest.

Types of rarity

The majority of Red Data Book plant, amphibian, reptile and butterfly species in the CFR are localized endemics (Table 10). Mammals and fish tend to have a low proportion (< 30 %) of localized species: there are no localized bird species in the CFR. Species with low densities per unit area and wide distribution ranges dominate rarity types in birds, comprising predominantly predatory and wetland species, and the Orchidaceae in plants (Table 10). The largest proportion of mammals and fish historically occurred over large areas (even though most fish species were limited to a

Table 10

Types of rarity (sparse and restricted) or non-rarity (common) exhibited in the historical distribution ranges of Red Data Book species in the Cape Floristic Region. Analysis is confined to categories X, E, V and R. Only those plant families with more than 35 species in these categories are included.

Taxon	Total spp with data	Localized (%)	Sparse (%)	Common[1] (%)
PLANTS				
Ericaceae	(79)	82	18	0
Asteraceae	(53)	72	28	0
Proteaceae	(123)	75	18	7
Rutaceae	(74)	74	19	7
Iridaceae	(141)	67	28	5
Restionaceae	(41)	60	33	7
Orchidaceae	(39)	28	67	5
ANIMALS				
Amphibia	(7)	86	14	0
Reptilia	(16)	69	25	6
Lepidoptera	(45)	64	36	0
Mammalia	(29)	29	24	48
Pisces	(12)	17	25	58
Aves	(21)	0	86	14

Notes:

[1] Includes peripheral species historically common elsewhere.

single river system) and were relatively common within their distribution range (Table 10). A fair proportion of Red Data Book plant and reptile species were also formerly common over wide distribution ranges.

Threats

The most important threats to Red Data Book taxa in the CFR are agriculture and alien invasive plants (Table 11). However, each taxon is influenced by different factors. Thus, Red Data Book bird and mammal species are most threatened by hunting and poisoning, plant and fish species by alien introductions, amphibian and reptile species by agriculture and butterfly species by urbanization (especially the development of coastal holiday resorts). Factors affecting most taxa include: agricul-

Table 11

Threats to taxa in the Cape Floristic Region, in terms of numbers of species affected. Numbers of species have been scaled so that the threat category with the most species equals 10.

Threat	Score								Rank
	Plant Elim[1]	Total[2]	Butter-fly	Fish	Amphi-bian	Reptile	Bird	Mam-mal	of threat
# spp in largest category	49	84	9	10	4	5	8	20	
Agriculture	4.4	5.3	8.9	9.0	10.0	10.0	1.3	1.5	46.0
Alien invasive plants	10.0	10.0	4.4	6.0	0	4.0	0	0	24.4
Hunting/poisoning	—	—	0	0	0	0	10.0	10.0	20.0
Fire (frequency & timing)	2.3	3.7	5.6	0	2.5	2.0	2.5	0	16.3
Urbanization/industrialization	5.6	3.8	10.0	1.0	0	0	0	0	14.8
Commercial collecting[3]	1.6	1.3	0	0	0	10.0	0	0	11.3
Dams/wiers/roads	1.7	0.9	2.2	4.0	2.5	0	1.3	0	10.9
Alien predators	—	—	0	10.0	0	0	0	0	10.0
Pollution[4]	0.2	0.4	0	4.0	5.0	0	0	0	9.4
Afforestation	1.0	0.9	2.2	0	2.5	2.0	1.3	0	8.9
Mining/quarrying	0.8	1.2	0	1.0	0	4.0	0	0.5	6.7
Grazing/browsing	0.8	2.9	0	0	0	0	3.8	0	6.7
Hybridization[5]	0	0	0	0	2.5	0	0	0.5	3.0
Intolerance of human presence	—	—	—	—	—	—	2.5	0	2.5
Casual flower picking	1.5	0.2	—	—	—	—	—	—	0.2
Presumed genetic decline[6]	4.5	1.1	0	0	0	0	0	0	1.1
Mowing/trampling	0.8	1.0	—	—	—	—	—	—	1.0

Notes:

[1] Data for the plant species of the Agulhas region (Hall and Veldhuis 1985). Typical of fynbos, little agricultural transformation has occurred, consequently this threat is under-represented relative to the entire Cape Floristic Region. Values in this column do not contribute to the rank of threat.

[2] Data for 232 species for which threats are listed in Hall and Veldhuis (1985).

[3] Collecting was dismissed as a possible threat to butterflies by Henning and Henning (1989).

[4] Including: Fertilizers, pesticides, salinization, eutrophication, and acid rain.

[5] Hybridization was apparently not considered for plants.

[6] Caused by inbreeding depression and stochastic processes inherent to small populations—categorization invariably speculative: no genetic studies of plants have been undertaken.

ture, alien invasive plants, aseasonal and too frequent fires, dams and roads, and afforestation.

Only fish species are influenced by alien predators (mainly other fish species). Although the alien Argentinian Ant *Iridomyrmex humilis* may disrupt plant seed dispersal by excluding species of indigenous ant (Bond and Slingsby 1983), no plant species appears to have been influenced sufficiently to record this as a threat. The impact of *I. humilis* on butterfly larvae-ant associations has not been ascertained: this threat may be important for species with limited distribution ranges in peri-urban areas, where alien ant populations may be large (Brooke *et al.* 1986).

Only bird species are intolerant of continued human presence, reflecting the vulnerability of large animals which nest in accessible habitats (e.g. wetlands). Only reptiles are seriously affected by commercial collecting, although the effect of commercial plant exploitation is insidious as seed banks are notoriously difficult to estimate. Collecting of butterflies as a source of species reduction was dismissed by Henning and Henning (1989) in their introduction, based on results obtained from extermination trials in America (Pyle *et al.* 1984), and consequently was not included as a threat to any species. Nevertheless, Claassens and Dickson (1980) state that '. . . the particularly contemptible instance of the destruction of a very rare and beautiful butterfly through gross over-collecting . . .' was responsible for the Department of Nature and Environmental Conservation of the Cape promulgating a 'protected list' of butterflies in 1976. They also note that Dickson's Copper *Oxychaeta dicksoni* probably went extinct at several localities from commercial over-collecting. Commercial collecting may still be a problem, despite the legislation (Greig 1981). Although the Red Data Book account (Henning and Henning 1989) lists this vulnerable species' low densities and small population sizes as factors contributing to its rarity, there is no mention of possible over-collecting. The conservation significance of amateur and commercial collecting of rare butterflies urgently requires a balanced reappraisal.

DISCUSSION

History and location of threats

Human impact on species richness in the CFR appears to reflect largely the relative carrying capacity of soils and the distribution of animal and plant species in these habitats. Thus, nutrient-rich soils supporting renoster shrubland and thicket vegetation were the first to be affected by man and have been affected most extensively.

RENOSTER SHRUBLAND

Initial exploitation of renoster shrubland by European settlers was primarily by way of shooting large mammals for provisions (Skead 1980). Large mammals provided the early stockfarmers with meat and clothes (Boucher 1986). Although a permanent European settlement commenced only in 1652, by 1657 the first proclamation limiting the hunting of wildlife was issued. By the late 1680s large mammals had virtually disappeared within 200 km of Cape Town (Gunn and Codd 1981), and by 1800 large mammals were scarce in the CFR (Pringle 1982). The grasslands of the renoster shrubland were initially used for grazing, although hay was reaped for use in Cape Town (Skead 1980). Expansion of the early colony occurred with the increase in cattle herds and the exhaustion of pastures (Boucher 1986). By the 1750s the first reports of shrub encroachment were recorded for West Coast renoster shrubland, and similarly for South Coast renoster shrubland in 1775 (Skead 1980). By 1800 the transformation from grassland to shrubland was complete (Muir 1929, Cowling *et al.* 1986), and hay was no longer available (Skead 1980).

We can therefore conclude that the extermination of large mammals from the lowlands of the CFR was caused by hunting rather than by competition for grazing. The transformation of renoster shrubland appears to have been later than the decline in large mammals by half a century. Recorded introductions of epizootic diseases (e.g. rinderpest in the 1890s) and game-proof fencing (this century) played little role in the CFR, in contrast to much of the rest of Africa (Macdonald 1989). Furthermore, the extinction of the large mammals occurred more or less concurrently with the transformation of renoster shrubland from a grassland to a shrubland. Although the extinctions probably preceded the transformations, very few grazing species would have been likely to survive in the transformed vegetation. The reedbuck and oribi *Ourebia ourebi* are candidate mammal species possibly small enough to have survived hunting, but reduced by the transformation from grassland to shrubland.

Moister areas of renoster shrubland have been converted to vineyards and much of the remainder to winter wheat and pasture (Boucher 1981, Cowling *et al.* 1986), mainly since the First World War (Macdonald 1989). Currently, some 71% of renoster shrubland has been transformed, although 85 per cent of both West and South Coast renoster shrubland are transformed (Rebelo 1992). Remaining patches are on steep slopes and hill tops, which, although currently unsuitable for farming, are being converted to cropland with the aid of technological advances. Land subsidies also favour conversion to cropland, despite legislation prohibiting the destruction of virgin lands (McDowell 1986). Consequently, renoster shrubland is now largely unsuitable for restocking with large mammals, and land is too expensive to acquire for reserves. It is important to note that the extermination of such a large number of African mammalian species, generally regarded as resilient to hunting owing to a long association with mankind (Owen-Smith 1989), probably reflects the long history (350 years) of European exploitation in the CFR, more specifically the long period before the establishment of wildlife protection movements (Pringle 1982). The high cost of land and the absence of large mammals together account for the small proportion of renoster shrubland currently preserved—0.5 per cent of the original area of the vegetation type (Rebelo 1992).

Although we can estimate loss of large mammal species from renoster shrubland, it is difficult to determine what plant losses have been incurred, since the transformation took place before any scientific observations of the region (Macdonald 1989). It appears that renoster shrubland, even during its grassland stage, consisted of widespread plant species (Cowling *et al.* 1986), with rare species being sparse rather than localized and endemic species being widespread throughout the vegetation type. Many of the shrub species which now dominate renoster shrubland are pioneers (tolerant of short fire cycles) in fynbos on granitic substrata, and the geophytes and annuals are shared with thicket vegetation (Boucher 1981). However, it is unclear whether any localized species went extinct. Any extinctions must have occurred during the transformation from grassland to shrubland at around 1750, before the extensive botanical exploration of the CFR, which commenced in earnest during the 1770s (Gunn and Codd 1981)—certainly few species have become extinct with the conversion of renoster shrubland to commercial crops during the past century. Nevertheless, if renoster shrubland contained many endemics or localized species, then it is curious that there are no species recorded by collectors between 1600 and 1750 that have never been recorded since. Similarly, there is not a single species of extinct amphibian, reptile or fish in renoster shrubland. It appears more probable, therefore, that renoster shrubland contained very few localized endemic animal or plant species. However, little is known about the invertebrates, other than that the CFR is a region of high diversity in flies (Bowden 1978), beetles (Scholtz and Holm 1985) and bees (Michener 1979).

FYNBOS OF THE MOUNTAINS

The situation in fynbos vegetation in the mountains contrasts dramatically with renoster shrubland. Almost half of mountain fynbos is protected, mainly in State Forests and Mountain Catchment Areas (Grove 1987, Rebelo 1992). This is primarily because of South Africa's acute water shortage and the need to protect mountainous catchment areas, rather than any attempt to protect the flora itself, although some areas (with spectacular scenery) have subsequently been assigned a conservation status based on elements of their flora (Rebelo 1992). Furthermore, the discovery that alien invasive plant species may reduce streamflow by 50% (Versveld and Van Wilgen 1986) and their potential for uncontrollable fires, resulted in the implementation of an efficient alien removal campaign in mountain fynbos (Macdonald 1989). The coincidence of low agricultural potential, regional lack of water, and invasion by alien species which are relatively easy to control, with the large number of locally endemic plant, butterfly, reptile and amphibian species has prevented a catastrophic extinction of species in the CFR. Similarly, the six CFR endemic bird species are well protected, and under no threat at present.

Local endemism in fynbos (both in the mountains and lowlands) is high for plants, butterflies, and amphibians. This may stem from these taxa comprising relatively 'sessile' groups. Thus many localized amphibian species are confined to acid or black-water wetlands on mountain slopes or in the lowlands. The low nutrient status in fynbos soils has resulted in convergence between plant's seed dispersal and larval development in butterflies. Since many fynbos plant species load their seeds with nutrients, an efficient anti-seed-predation system is essential (Bond and Breytenbach 1985). One such mechanism is to utilize ants to bury seeds (myrmecochory) where rodents and birds cannot consume them. However, this is at the expense of efficient dispersal, with dispersal distances typically in the order of a few metres (Bond and Slingsby 1983). Similarly, the low nutrient status of foliage (specifically the high carbon to nitrogen ratio) prevents grazing or browsing by, amongst other animals, butterflies (Cottrell 1985). The over-represented Lycaenidae utilize ants as a proteinrich food source in later larval stages (Cottrell 1985). Thus, butterfly species may be restricted to areas where the correct ant species and both adult and larval feeding plant species co-exist.

The pattern of Red Data Book plant distribution is strongly correlated with that of total plant species richness, with the southern and northern fynbos centres of endemism by far the richest in species (Rebelo and Tansley in press). Whether the distribution of Red Data Book species in other taxa also reflects the pattern of species richness within fynbos vegetation is not known, as distribution data on a suitably fine scale are not readily available.

FYNBOS OF THE LOWLANDS

The conservation status of fynbos in the lowlands is quite different from that of the mountains. Of the original extent half has been transformed to agriculture and only three per cent is preserved in nature reserves (Rebelo 1992). Based on the Proteaceae, two centres of plant endemism can be recognized in both South Coast and West Coast lowland fynbos (Rebelo and Siegfried 1990). One of these centres coincides roughly with the Greater Cape Town Metropolitan area. Based on the distribution of Red Data Book Proteaceae species, the Greater Cape Town Metropolitan area contains significantly more Red Data Book species than predicted by species richness, even though the Proteaceae are under-representative of species richness in these grid squares (Rebelo and Tansley in press). A total of 74 Red Data Book plant species occur within lowland fynbos in the Greater Cape Town Metropolitan area on 485 ha of remaining untransformed land (McDowell *et al.* 1991). In addition, two endangered amphibian species occur in acid-water lakes (confined to fynbos vegetation) within the metropolitan area. Only eight Red Data Book plant species occur within the more extensive thicket vegetation in the area. The location of Cape Town is unfortunate: had it been situated any distance more than 70 km to the north, the number of Red Data Book plant species threatened by urbanization would probably be an order of magnitude lower.

Fortunately, the fynbos centre of endemism extends 60 km northwards beyond the metropolitan area. This area to the north of the present zone of urbanization has been identified as the top priority site within the CFR for conservation action (Jarman 1986). However, this area is designated for future urban expansion (McDowell *et al.* 1991). As with the other lowland centres of endemism, the non-urban portions of the Greater Cape Town Metropolitan area are extensively transformed by alien invasive plant species (Boucher 1981, Macdonald and Richardson 1986), placing an additional cost (that of clearing aliens), over and above that created by speculators awaiting urban development, on land to be acquired for reserves.

This pattern of high numbers of local fynbos endemics within the Greater Cape Town Metropolitan area does not occur in reptiles or butterflies. Reptiles predominate in the thicket sands. There is a preponderance of localized endemic butterfly species on the Tygerberg and Darling ranges of hills and in thicket vegetation. This pattern of distribution of butterflies should be investigated to determine whether the species are ecotonal, perhaps having larval and adult foods in different vegetation types. Thicket vegetation, being close to the sea, is under heavy pressure for the development of coastal resorts (Cowling and Pierce 1985).

In contrast to the distribution patterns of all other taxa, that of fish species does not reflect a particular threat operative in a localized area. Rather it reflects the historical origin of the endemic species, having resulted from past connections of the Olifants River System to the Orange River in the north (Skelton 1986). Thus threats to fish do not include afforestation and fires, which would probably have played a role had localized fish species been more evenly distributed within rivers in fynbos. The majority of the species are now confined to the upper river valleys, mainly within fynbos vegetation, where introduced alien predatory fishes have been unable to colonize and where there is minimal agricultural degradation of the catchment (Gaigher *et al.* 1980, Skelton 1987).

FOREST

The paucity of Red Data Book plant (and animal) species in Afrotropical Forest may simply reflect the decrease in species richness of these subtropical vegetation types with increasing latitude and the lack of endemic species. Alpha species richness in Forest in the west of the CFR is one-third that of Natal for plants and birds and 44 per cent for mammals (Geldenhuys and MacDevette 1989). Despite extensive exploitation of these forests for wood which has eliminated many stands (Skead 1980), very few forest species have Red Data Book status. The redeyed dove *Streptopelia semitorquata australis* decreased locally in abundance following logging of the forests, but, after the introduction of the Beira subspecies *S. s. semitorquata* into the western Cape during the 1930s, the resulting hybrid swarm has expanded into woodlots and urban areas (Brooke *et al.* 1986)

Threats, extinctions and size in mammals

In the CFR, extinction in mammals is related to body size. Virtually all species larger than 300 kg were hunted to extinction and all except one mammal species larger than 100 kg are threatened. Conservation action has been geared towards reintroducing large mammals (including species not recorded historically, but excluding large predators) in the CFR (Table 3). The smallest extinct species is 14 kg, and the smallest threatened species, with the exception of one 90 g rodent, is 5 kg. These patterns contrast strongly with those from mainland Australia (Burbidge and McKenzie 1989), where larger mammals were not much reduced by hunting and poisoning and where extinct and threatened species range from 35 kg to 5.5 kg in size. Man-induced aridification, and the introduction of alien predators and large alien herbivores, which have had the greatest impact on mammals in Australia, appear not to have operated in the CFR. The proportion of species which have gone extinct, declined, or neither, is nearly identical ($\chi^2 = 0.26$ $P > 0.05$) between the CFR and Australia.

However, the patterns related to soil nutrient status and aridity appear similar between the CFR and Australia (areas listed in inverted commas below). Thus arid vegetation (karoo and 'Deserts and Pastoral', with little land transformed to agriculture but extensively grazed) and nutrient-rich soils (renoster shrubland, thicket and 'wheatbelt'), which have been most extensively transformed to agriculture, have the most extinct and threatened species. Similarly, the Darling region in Australia is analogous to fynbos and forest, and parallels it in having far fewer mammal species that are extinct or threatened (Burbidge and McKenzie 1989).

The CFR differs from Australia in that its natural vegetation is relatively resistant to the introduction of alien mammals (Breytenbach 1986). Thus the three rodents are largely commensal with man, and introduced fallow deer *Cervus dama* and Himalayan tahrs *Hemitragus jemlahicus* are extremely localized in occurrence. The success of the tahr can perhaps be explained by the extinction of leopards on Table Mountain. This can again perhaps be explained by the low fertility of fynbos which is unsuitable for large mammals, and competition with sheep, goats and cattle in renoster shrubland and thicket vegetation which would have prevented its establishment. By contrast, fynbos is highly susceptible to invasion by certain guilds of plants (large woody shrubs or trees with canopy-stored seeds released only after fire, Richardson *et al.* 1990), and renoster shrubland and lowland fynbos appear susceptible to invasion by annual grasses which replace the geophytes (Vlok 1989).

The results for the CFR suggest that despite the possibility of a Pleistocene overkill and the marked fluctuation of large mammal populations between the Pleistocene glacials and interglacials (Klein 1983), and the probable decline of the bluebuck due to competition with sheep and cattle kept by Khoisan tribesmen (Smithers 1983), large mammals were further reduced by the arrival of Europeans in the region. That this pattern of elimination has not occurred throughout Africa is thus probably not the result of inherent adaptations of large mammals to survive with *Homo sapiens*, but a reflection of the short period between European colonization and the development of conservation awareness in the rest of Africa. Thus southern Africa, where European colonization is older than in the rest of sub-Saharan Africa, has been damaged the most. Consequently, it is fallacious to presume that large African mammals are adapted to man's hunting techniques: as early as the 18th century, technology was adequate to eliminate most mammals larger than 50 kg.

Conservation strategies: problems with target (flagship) species

The juxtaposition of renoster shrubland and fynbos, with their dichotomy in soil fertility, plant and animal species composition, land values and conservation status, has resulted in some unfortunate misconceptions amongst conservation agencies. As a consequence of lower land costs, fynbos has been favoured for reserve acquisition for restocking the large mammals extinct in the CFR. As a consequence of the extremely poor grazing (Tainton *et al.* 1989), these reserves have been bushcut, ploughed, replanted with pastures of alien invasive grasses, fertilized, enriched with copper and other deficient minerals (both in element form and as salt licks), and burned as frequently as is possible (Millar 1970, Greyling and Huntley 1984, Zumpt and Heine 1977, Novelli 1986, Scott 1986). These 'veld improvement' (Scott 1986) exercises have invariably proved futile, with large mammal species not establishing primarily due to mineral deficiency diseases and concomitant high parasite loads (Barnard and Van der Walt 1961, Van Rensburg 1975, De Graaf *et al.* 1976, Van der Walt *et al.* 1976a, b).

This can be construed as supporting evidence that large mammals were not a permanent component of fynbos vegetation. The impact of these practices on plant species richness was seldom considered. As one example, the Bontebok National Park was relocated during 1961 from a limestone fynbos site, where deficiency diseases were limiting population growth, to a site with fynbos on Enon conglomerates. The latter site was incorrectly stated to support renoster shrubland (Jarman 1986), even though a survey (Grobler and Marais 1967) showed some 64 per cent of the reserve vegetation to comprise fynbos. This reflects a tendency to over-emphasize relatively unconserved vegetation types, especially in ecotonal areas, possibly as a result of motivation requirements for acquiring reserves being linked to the conservation status of vegetation types.

There is no doubt that linking conservation to the preservation of attractive and charismatic species engenders public interest and participation (Ferrar 1989). Provided that the limitations of this approach are appreciated by reserve managers, it offers rapid gains. Far too often, however, preservation of target large mammals has gone hand in hand with 'habitat improvement', to the benefit of the target species and the detriment of other species and ecological processes (Rice 1990, Rebelo 1992).

By contrast with fynbos, the acquisition of provincial nature reserves in renoster shrubland has largely centred on the preservation of the geometric tortoise (Rebelo 1992). Thus out of six provincial nature reserves containing renoster shrubland (Jarman 1986), four were established solely for protecting this tortoise. This possibly arose through a combination of the geometric tortoise being the largest endangered species extant in renoster shrubland and the exceedingly high expenses that would be incurred by any attempt to reintroduce viable populations of large mammals into a renoster shrubland reserve. In contrast to large mammals, the life cycle of the geometric tortoise is such that its efficient preservation also guarantees the preservation of coexisting plant species (Greig 1984). Coupled with its considerable public appeal, it is thus an ideal 'flagship' or 'target' species (Ferrar 1989).

The use of even such apparently suitable 'flagship' species has its drawbacks, however. Two of the reserves have recently been deproclaimed, as viable tortoise populations have not persisted within them. The associated vegetation or its species composition was not considered in the decision to deproclaim, and consequently the only existing viable population of Worcester sunshine-conebush *Leucadendron flexuosum* (Proteaceae; Hall and Veldhuis 1985) has been exterminated (Wood 1991).

The inability of fynbos to support high densities of herbivores and grazers may explain the paucity of species of plants, amphibians, reptiles and birds threatened by alien introduced mammal species (chiefly predators), as appears to have occurred in other areas throughout the world (Atkinson 1989). With the exception of fish, only the Himalayan tahr, the Argentine ant, and the domestic cat *Felis catus* appear to have had a noticeable impact on indigenous vegetation or animals (Macdonald and Richardson 1986). The majority of other alien animal species have had their impacts confined to man-modified areas, usually within urban and cultivated areas (Brooke *et al.* 1986). With the exception of *F. catus* hybridizing with the African Wild Cat *F. lybica* (Smithers 1983, but see Brooke *et al.* 1986, who maintain that the threat is exaggerated), naturalized alien animals (excluding commensals, such as cattle and feral dogs) do not feature as a threat to any Red Data Book species of terrestrial animal or plant in the CFR (Breytenbach 1986).

CONCLUSIONS

The Cape Floristic Region must rank globally as one of the foremost conservation priorities. The high endemicity of plant, butterfly, fish and amphibian species makes the region distinct from that of the rest of the subcontinent. Fortunately, by far the majority of endemic species within the most speciose plant and animal families in the CFR occur in fynbos, which is the best conserved vegetation type owing to the low agricultural potential of fynbos soils and the need to conserve water in a predominantly arid region. Large scale extinction would probably have occurred had there been a concentration of species in the agriculturally important renoster shrubland and thicket vegetation: those few endemic mammals, birds and reptiles confined to these vegetation types are either extinct, threatened or have been rescued at the brink of extinction. Available evidence does not indicate that many renoster shrubland plant species have gone extinct in historical times, but rather that renoster shrubland was dominated by grasses prior to a transformation to shrubland caused by overgrazing during the 18th century. Nevertheless, large mammals have formed the focus of conservation efforts in the CFR, to the detriment of fynbos plant and animal species. Fortunately, increasing emphasis is being placed locally on the plant species.

Consequently, even though renoster shrubland is the most heavily transformed of the vegetation types within the CFR, its preservation is not as urgent as that of lowland fynbos in terms of threatened species. Although agriculture and alien plant invasion currently rank as the most important threats to species in the CFR, and hunting and poisoning as the historical reason for the extinction of many large mammals, it is urbanization that is the greatest threat to floral diversity at present. Thus although 85 per cent (7 300 km^2) of the original extent of West Coast renoster shrubland has been converted to agriculture, the impact of the 765 km^2 transformed by urbanization has been equivalent in terms of species threatened. This is not because urbanization produces more drastic transformation, as extremely few fynbos and renoster shrubland plant species are able to tolerate agricultural perturbations such as ploughing. Rather it is the location of the largest urban area within a lowland fynbos centre of endemism that is responsible for the high ranking of urbanization as a threat in the CFR. Thus it is the area within and adjacent to the Greater Cape Town Metropolitan region which contains the highest concentration of threatened plants and animals. Urgent, expensive and novel action is required to prevent one of the centres of endemism within the CFR from being eliminated.

At this stage in the conservation of the CFR we have little knowledge of functionally important, indicator, or keystone species. Pattern of movement of pollinators, seed dispersers, herbivore/grazers and predators among vegetation types and specifically seasonal movements between lowland and mountain fynbos are not understood. Research must be urgently targeted at identifying keystone taxa which will serve the function of both indicator and flagship (target) species. The status of conserved areas within the CFR should be upgraded to reflect the region's international importance in conserving biotic diversity. A minimum requirement is that the entire CFR should be declared a Biosphere Reserve, as proposed by Burgers *et al.* (1990), and should be the target of international conservation action, on a par with that being given to the tropical rain forests.

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