

Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies

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Abstract

The rich biodiversity of the Cape Floristic Region makes a substantial contribution to the regional (particularly the Western Cape) and national economy. Harvesting of marine resources, such as linefish, rock lobster, abalone and bait species, is worth over R1300 million year⁻¹, or R1.12 million km⁻¹ year⁻¹. Harvests of fynbos products such as wildflowers and thatching reed, and forest products, timber and ferns, are worth R27 and R26 ha⁻¹ year⁻¹ on average, respectively, and a total of R78 million year⁻¹. Natural resource-based tourism is one of the greatest income generators in the region, which is renowned for its beauty and floral diversity as well as other nature pursuits such as whale watching and angling. The natural resources of the CFR also contribute indirectly to the region's economic output: fynbos bees contribute to commercial fruit production, and fynbos mountain catchments provide the region's main water supply. Less tangible values include the option, or future use, value of the region's rich biodiversity, and existence value, for which estimates have been made on the basis of contingent valuation studies. The total economic value of the CFR is estimated to be at least R10,000 million per year (US\$1 = R7 in 2000), equivalent to over 10% of the regional Gross Geographic Product. However, invasion of aliens, transformation of natural vegetation and overexploitation of resources threaten the sustainability of this value. Invasive alien plants, which are the greatest proximate threat to floral diversity, already intercept significant water supplies. However, clearing is costly, and while government has an incentive to clear publicly owned mountain catchment areas, private land-owners do not. Similarly, private benefits of conserving fynbos areas do not provide sufficient incentive to protect against transformation to more lucrative farming activities, including monoculture of indigenous species. Current values of marine resources are unlikely to be upheld due to the overexploited status of most stocks, a problem which is compounded by poorly defined property rights, open access and inadequate law enforcement. It will be necessary to provide incentives to private landowners and resource users if optimal levels of protection are to be achieved to maximise benefits to society.

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1. Introduction

The Cape Floristic Region (CFR), which falls mainly within the Western Cape, South Africa (Fig. 1), is one of the 'hottest' biodiversity hotspots in the world (Myers, 1990). It is the smallest and richest of the world's six floral kingdoms, with over 8700 plant species (Low and Rebelo, 1996), of which 68% are endemic to the area (Bond and Goldblatt, 1984). The diversity of

the CFR is mostly associated with the fynbos biome, a fire-prone shrubland that grows on infertile, sandy soils of the region (Cowling, 1992), although a number of other vegetation types of the forest, thicket, succulent karoo, and Nama karoo biomes also contribute to the plant biodiversity of the area (Low and Rebelo, 1996; Cowling, 1992). The surrounding coastal areas, which fall within two major biogeographic provinces (Turpie et al., 2000), also add significant biodiversity to the region.

Three main factors threaten the biodiversity of the CFR and its adjacent coastline:

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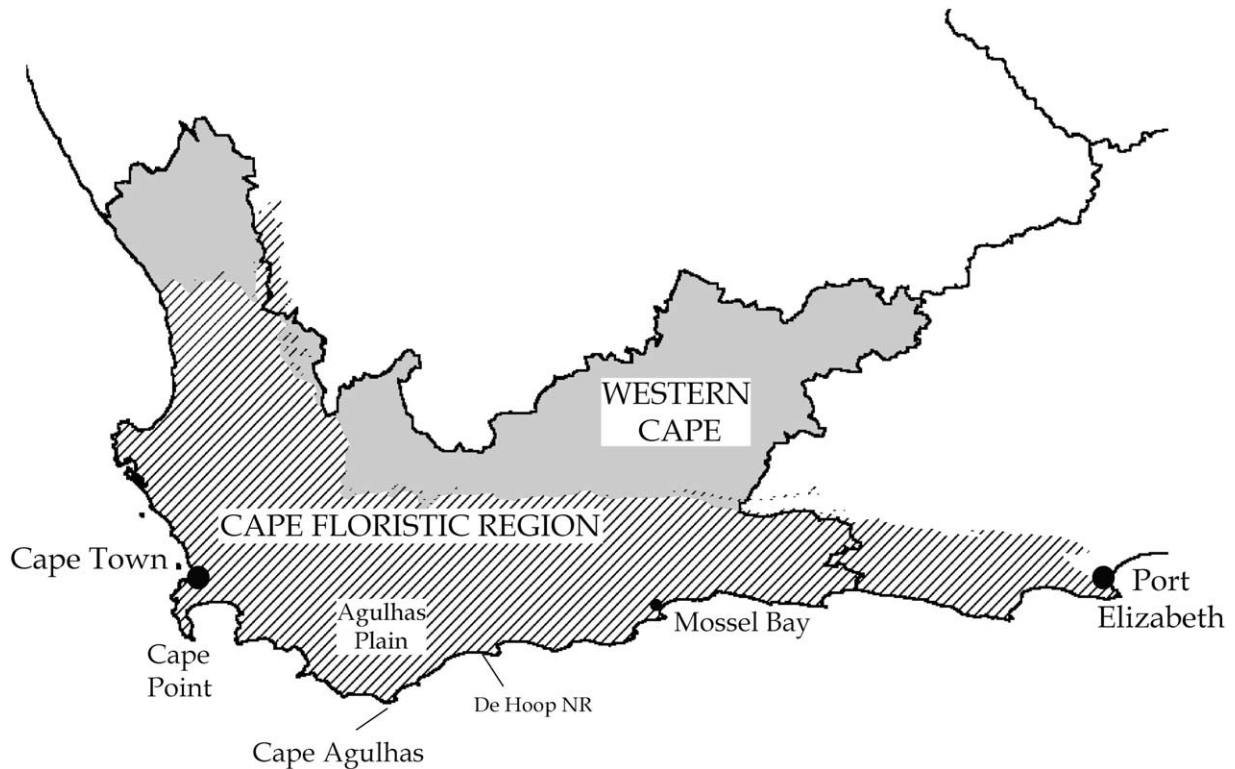


Fig. 1. Map showing the Cape Floristic Region in relation to the Western Cape Province, South Africa.

1. Exploitation of terrestrial and marine resources has already led to the degradation and depletion of many resource stocks, and further degradation is likely unless effective measures are set in place (Gelderblom et al., 2003).
2. Invasive alien organisms form one of the greatest threats to the region's terrestrial biodiversity (Richardson et al., 1997; Rouget et al., 2003a), and enormous expense is required to reverse this trend (Frazee et al., 2003; Pence et al., 2003).
3. Urban development and conversion to agriculture (Rouget et al., 2003a), including for the monoculture of indigenous species (Heydenrych et al., 1999), steadily erodes the remaining area of natural vegetation.

While a substantial area is within publicly owned protected areas (Rouget et al., 2003b), a far greater area needs to be protected from existing threats if successful conservation of biodiversity patterns and processes are to be achieved (Cowling et al., 2003). Priority conservation areas have been identified (Cowling et al., 2003), but the factors determining the amount of area identified for protection have been defined purely on biophysical grounds, with the aim of maximising conservation goals such as representativeness and connectivity. No matter how sophisticated, conservation planning cannot afford to ignore economic forces at play, and should also serve the goal of maximising

benefits to society. Even if the direct costs of conservation are minimised by efficient design measures (see Frazee et al., 2003), the full benefits and opportunity costs of conservation need to be considered if a regional conservation plan is to be socially optimal, and the incentives and disincentives for conservation need to be understood if the plan is to be effective. Indeed, it is recognised that the areas identified as requiring protection are so large that it will probably only be possible if some of this protection is afforded by means of off-reserve conservation measures. In a society where economic development is seen as critical to the nation's future wellbeing and where individuals act to maximise their own welfare, conservation action will only be successful if the incentive exists both from a public and private perspective (Wells, 1998). Yet, the value of the region's biodiversity has never been articulated, or has it been compared with the opportunity costs of conservation at any level.

There are a number of different values associated with biodiversity (Fig. 2). Values range from more tangible consumptive and non-consumptive use values, through to less tangible values such as option and existence value. The estimation of biodiversity values in monetary terms helps to promote and justify conservation actions at the public policy and decision-making level, and is essential to define the optimal level of conservation. Values perceived by decision-makers influence their choices with regard to the management of biological

resources, and socially optimal decisions require the full valuation of costs and benefits of the options under consideration (Munasinghe and McNeely, 1994). Values perceived by private land-owners and resource users are often quite different from social values, and will determine whether they are aligned with public policy. If not, they can be manipulated through the use of incentive measures.

The main aim of this study is to provide a broad-brush estimate of the economic value of the biodiversity of the CFR, and how the main agents of biodiversity loss impact on these values. We investigate the incentives for conservation at a regional level and at the level of the individual.

2. Study area

This study concentrates on the CFR area contained within the Western Cape Province, although parts of the CFR also extend into the Northern and Eastern Cape (Fig. 1). The terrestrial component of this study focuses on the fynbos, thicket and forest biomes within that part of the CFR included in the Western Cape Province (Table 1). Enclaves of the succulent karoo biome within the CFR (Low and Rebelo, 1996) were excluded from the study. Although the fynbos biome comprises both fynbos and renosterveld vegetation, the latter has been almost completely transformed for agriculture (McDowell and Moll, 1992; Kemper et al., 1999; Rouget et al., 2003a), and the remaining fragments are considered irreplaceable in terms of their conservation value (Cowling et al., 2003). The vegetation types that were considered for this study make up 2.9 million ha of extant (untransformed) vegetation, which represents approximately one third the total terrestrial area of the CFR (Table 1).

The marine component considers biological resources of the entire, approximately 1200 km-long coastline of

the CFR. This coastline falls within part of two coastal biogeographical provinces: the Cool Temperate Province on the west coast and Warm Temperate Province on the south coast (Turpie et al., 2000).

3. Methods

3.1. Consumptive use values

Consumptive use values for fynbos vegetation were derived on the basis of existing published and unpublished data, a questionnaire survey of landowners and key informant interviews. A questionnaire survey was administered to 60 landowners on the Agulhas Plain area within the CFR to elicit quantitative information on the harvest of fynbos products, grazing practices and beekeeping activities. Landowners were asked to list the flower species (including ‘greens’) harvested for the flower trade from natural habitats on their lands and to give the quantities of each harvested over the preceding year. As the interview survey was conducted randomly on lands of a range of post-fire ages, we assume that the figures reflect average yields within this dynamic system. Harvests reported in the survey were quantified in relation to vegetation type (stems or kg per ha per vegetation type) using geographic information system (GIS) data of farm boundaries and vegetation types (Lombard et al., 1997). Additional data, particularly on the harvesting of other fynbos products, were obtained from published and unpublished data and key informant interviews. Prices of fynbos resources were obtained from a representative selection of landowners and buyers, as well from the literature. Fynbos values were disaggregated to different types of vegetation as far as possible because the threats facing these areas differ in nature and intensity.

Table 1
Biomes, vegetation types, and remaining (untransformed) areas within the Western Cape section of the Cape Floristic Region, which were used for the calculation of values in this study

Biome	Vegetation type ^a	Area (ha) ^b
Fynbos	Mountain Fynbos	2,272,732
	Grassy Fynbos	19,776
	Laterite (Elim) Fynbos	27,729
	Limestone Fynbos	204,061
	Sand Plain Fynbos	156,240
Thicket Forest	Dune Thicket–Fynbos Mosaic ^c	196,235
	Afromontane forest	35,757
Total		2,912,530

^a Derived from Low and Rebelo (1996).

^b GIS coverages provided by Environmentek, CSIR; and the Department of Water Affairs and Forestry.

^c Although part of the thicket biome, this vegetation comprises fynbos elements and was considered to be fynbos (Dune asteraceous fynbos), rather than thicket for the purposes of this study.

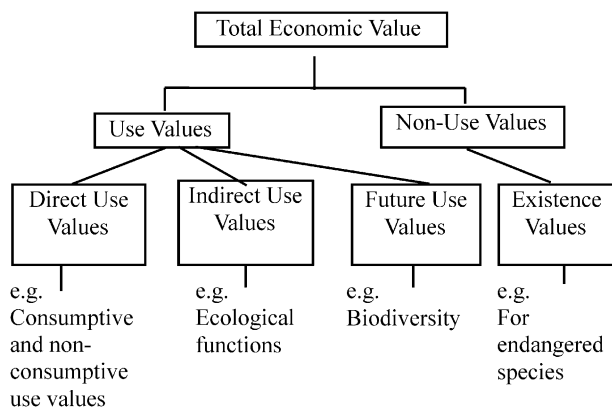


Fig. 2. Categories of economic value associated with natural systems (after Munasinghe, 1994).

Harvests and values of forest resources were obtained from the Department of Water Affairs and Forestry.

Information on the harvests and value of marine resources was obtained primarily from published data (Boonstra, 1996; Avis et al., 1999a,b; Boonzaier et al., 1999, *Fishing Industry Handbook*, 2001).

For all harvested resources, the gross value of final outputs was used to estimate the value added to national income (Gross Domestic Product). Value added is the gross value of final outputs, less expenditure on intermediate goods and services, or inputs consumed in the production process (Gittinger, 1982). Enterprise boundaries were defined such that multiplier effects were not included. For harvested fynbos products, intermediate costs were expected to be somewhat less than the average for agriculture (52%—DoA, 2002), and were assumed to be 25–35% of gross value. Intermediate costs were taken to be 60% of gross value in the case of wood products (R. Hassan, Department of Agricultural Economics, University of Pretoria, personal communication). Corresponding values used for fisheries were 20% for net fisheries and other small-scale fisheries (based on Hutchings and Lamberth, 2002), and 40% for rocklobster and abalone. All values are converted to 2000 rands (ca. R7=\$1) using the Consumer Price Index, and are given in 2000 rands irrespective of date to which they refer, unless otherwise stated.

3.2. Non-consumptive use (tourism) value

Data on tourist numbers and expenditure were obtained from published statistics. Expenditure due to nature-based tourism was estimated on the basis of a questionnaire survey was carried out in the Agulhas Plain region between September 1996 and January 1998. A total of 262 questionnaires were completed, representing 904 visitors. Of these, 74% were domestic tourists and the remainder were international. In addition to questions on group size and origins, respondents were asked to indicate their main interests in the area (village aspects, rural landscapes, friends/family, festivals, culture, business, the southern tip of Africa, the natural environment or other), and to estimate how much of the reason for visiting the area was attributable to its natural environment (percentages given with descriptive guides, e.g. 100%—only reason, 20%—small part of the reason).

The value of ecotourism, as a specialist type of nature-based tourism, was estimated on the basis of published information.

While input costs might be in the order of 30% of gross turnover, the value added to the national economy was estimated to be equivalent to total expenditure, due to the fact that this figure did not include the substantial multiplier effects of the industry.

3.3. Indirect use value

Indirect use values considered were the production of honey and fruit in the CFR which is facilitated by the use of bees captured from fynbos vegetation. Data were obtained from the Agricultural Research Council and from the literature. Value added in honey production and by the fruit industry was assumed to be 40% of total turnover.

Production of water was not considered as an indirect use value per se, but valuation of its loss due to alien infestation was estimated (see later). Other indirect use values, such as carbon sequestration, were beyond the scope of this study.

3.4. Option and existence value

Option values are discussed on the basis of available literature, and existence values were drawn from recent contingent valuation studies.

3.5. The economic impacts of alien invasion of fynbos

Values obtained for fynbos were average values incorporating all states of fynbos vegetation from uninvaded to heavily invaded. In order to estimate the value of remaining uninvaded habitats relative to invaded areas, the following analysis was performed. Areas of each type of fynbos under four different levels of invasion were calculated from GIS data, and the values of fynbos areas of different states was estimated by solving for X in the following equation:

$$X_{\text{avg}} \cdot A_{\text{tot}} = X \cdot A_{\text{light}} + 0.875X \cdot A_{\text{scattered}} + 0.5X \cdot A_{\text{medium}} + 0.125X \cdot A_{\text{dense}}, \quad (1)$$

where X_{avg} is the overall average value per ha, X is value per ha for pristine or lightly infested vegetation, and A is the total area (ha) of the vegetation type. The equation assumes that values are inversely proportional to alien vegetation cover. In the case of tourism values, only ecotourism values were assumed to be affected by alien invasion.

The values derived for different states of fynbos were used to estimate the productive losses that have been caused by alien vegetation. Constant prices are assumed, in that losses are valued at the same price as current outputs, although in reality, prices may have been lower at higher output levels.

The costs of aliens were also considered in terms of lost water run-off from fynbos catchments. Estimates were based on experimental and monitoring studies (van Wilgen et al., 1998) which have modelled the effects of catchment invasion (Le Maitre et al., 1996). Using the relationship between mean annual precipitation

(MAP, taken as 1200 mm on average) and mean annual runoff (MAR) as:

$$\text{MAR} = -367.6 + 0.74 \text{ MAP}, \quad (2)$$

(Le Maitre et al., 1996), the MAR for the fynbos biome, under minimal biomass cover, was estimated to be 520 mm for an average rainfall year. The loss of runoff with increased biomass in catchment areas due to invasive alien vegetation, was estimated using the following equation for a 10,000 ha catchment:

$$Q = 0.0238 \times B,$$

where Q is the reduction in annual streamflow (mm) and B is the above-ground biomass (g m^{-2} ; van Wilgen et al., 1997). A reduction in streamflow of 100 mm is equivalent to reduction in water yield of 10 Mm³ (million cubic metres) of water per year. Water losses were valued at the average cost of water production through future supply schemes. The average capital and operating costs of the 20 remaining sites for water supply schemes in the Western Cape is estimated to be R0.75 m⁻³ (DWA, 1994; Burgers et al., 1995).

3.6. The consumptive use value of terrestrial resources

3.6.1. Fynbos products

Although there is evidence that some medicines and foods have been harvested from fynbos in the past by Khoisan people, fynbos has never been rich in these products, and few food or medicinal plants are harvested from the fynbos today (Cowling and Richardson, 1995). The most important foods harvested are sour figs (*Carpobrotus* spp.) and honeybush tea (*Cyclopia* spp.). Buchu (*Agathosma* spp.) is exploited for essential oils used in flavouring, perfumery, medicine and brandy (Cowling and Richardson, 1995). Thatching reed (*Thamnochortus* spp.) is harvested in substantial quantities from the wild, even today. Currently the most important species harvested in the wild are flowers and greens for the ornamental industry.

Sour figs, *Carpobrotus acinaciformis*, *C. deliciosus* and *C. edulis*, are commonly harvested from Strandveld vegetation, especially along the south coast (Cowling and Richardson, 1995), where harvests of over 3 kg ha⁻¹ have been reported. Known harvests from two areas, valued at R7.90 kg⁻¹, have a gross value of R169,000. Assuming similar harvest levels from other strandveld areas, the total value of the sour fig harvest is estimated to be in the region of R5 million. Assuming 35% input costs, this translates to a value added of R3.325 million, or roughly R17 ha⁻¹ of Strandveld, although being an informal activity, this value is not currently reflected in national accounting statistics.

Honeybush tea is made from at least nine of the 20 species of *Cyclopia*, but mainly *C. intermedia*, *C. subternata*, and *C. sessiliflora*. Most of this is harvested from a Mountain Fynbos area of about 20,000 ha in the eastern CFR. It is estimated that 25 t of dried and processed honeybush is produced by farmers per year, with a market value of R375,000. Assuming 75% of total turnover is value added to the economy, the total value added is R281,000, giving an average of R14 ha⁻¹ for the harvest area and R0.12 ha⁻¹ for Mountain Fynbos.

Buchu, mainly from *Agathosma crenulata* and *A. betulina*, is collected from Mountain Fynbos, mainly from a region of roughly 600,000 ha in the western part of the CFR. In addition to a small local market for medicinal use and buchu brandy, the buchu industry has a large export component where the essential oils are used in the flavour and fragrance industries. The export industry is estimated to be worth R13.5 million per annum, of which approximately 50% is attributed to harvests from natural veld. Assuming 65% of total turnover is value added to the economy, Mountain Fynbos yields a value added of R1.93 ha⁻¹ on average.

The most important thatching reed, *Thamnochortus insignis*, making up about 98% of the total thatch harvest, is harvested from the Limestone Fynbos, where it occurs at high densities of up to 11,700 plants per ha. In addition, *T. erectus* and *T. spicigerus*, are harvested along the south and west coast, respectively (Cowling and Richardson, 1995), and *Chondropetalum tectorum* is harvested in small quantities throughout the fynbos region. A total of about 5.6 million bundles, worth about R6.3 million, were estimated to be harvested annually in the region in the early 1990s. The entire thatching industry is reported to be worth about R15.5 million (Cowling and Richardson, 1995). Assuming 35% input costs for the industry, it has a total added value of about R10 million, which translates to an average of R49.46 ha⁻¹ for Limestone Fynbos.

The wildflower industry involves flowers (Proteaceae) and 'greens' (e.g. foliage, ericas) harvested for the fresh industry, and flowers, including *Leucadendron* cones and other products, harvested for the dried flower industry. At least 100 wild species are used in the wildflower industry (Cowling and Richardson, 1995), and 70 species were named by Agulhas Plain farmers in this study. The choice of species changes from year to year, subject to fluctuating market demands created by local and overseas fashions.

In 1999, the fynbos flower industry as a whole generated a gross income of R149.3 million per year, of which R91.5 million and R37.8 million are from the export of fresh and dried flowers, respectively, and R20 million is from local sales (1999 Rands; SAPPEX News, July 1999). The industry is partly based on cultivation, and natural vegetation is estimated to be responsible for 57.6% of this turnover, equivalent to R90.5 million in

2000 Rands. Assuming that 65% of the industry turnover is value added to regional and national income, this gives a total value added by natural vegetation of R58.8 million. Nearly all of this is thought to be from the Agulhas Plain (Heydenrych et al., 1999).

This value is not evenly spread across different fynbos vegetation types. Based on quantitative survey data, the average net income at the farm level for privately owned natural fynbos in the Agulhas Plain ranges from R13 to R159 ha⁻¹ (Table 2). Total value added by the industry at a national level is 5.35 times the total net value of flower harvesting at the farm level. Thus total value added thus ranges from R68 to R847 ha⁻¹ for different vegetation types on the Agulhas Plain, with the highest value for Mountain Fynbos, or from R7 to R177 ha⁻¹ for the study area as a whole, with the highest value attributed to Laterite fynbos (Table 2).

Estimates of the consumptive use values of different fynbos products for different vegetation types are summarised in Table 3. These estimates are based on limited data: there is very little quantitative information on

current levels of use of fynbos products, and most of this work has been carried out on the Agulhas Plain. It is not known whether the current yields estimated earlier are sustainable, as basic information regarding stocks or sustainable yields is lacking.

3.6.2. Forest products

The southern Cape forests are the largest forest complex in southern Africa, forming the southern end of a chain of Afromontane forests along the eastern escarpment and the coastal forests of South Africa (Midgley et al., 1997; Vermeulen, 1999). These forests cover about 60,500 ha. About 35,700 ha are controlled by the Department of Water Affairs and Forestry (DWAF), of which 9276 ha are managed as production forests (Vermeulen, 1999). Forests on private land are protected under the Forest Act (Act 84 of 1984). The indigenous forest area has been heavily invaded by exotic plants, particularly *Acacia melanoxylon* (blackwood), which now forms an important component of the timber harvest. Timber is sold in block form on auction, and is

Table 2

Average annual net income per ha and total net income to landowners (on harvested and unharvested land) from Proteaceae flowers and cones (f/c) and from other fynbos flowers and greens in the four different types of fynbos on the Agulhas Plain

Vegetation type	Area (ha)	Type of product	No. species used	Average current net income/ha	Total net income (R/y)	Estimated total average VAD/ha (national level)
Mountain Fynbos	48,646	Proteaceae f/c	13	105.48	7,712,337	18.14
		Other	42	53.06		
Laterite Fynbos	12,953	Proteaceae f/c	3	9.04	916,684	176.71
		Other	7	61.73		
Limestone Fynbos	13,593	Proteaceae f/c	5	125.27	2,122,955	55.61
		Other	17	30.41		
Strandveld	19,398	Other	5	12.81	248,488	6.77
Total	94,590		70		11,000,464	

Values are based on mean yields per ha, and value added at farmgate level (VAD), for each species in the area. Average VAD/ha for the industry as a whole is taken as total VAD attributed to vegetation types in the same ratios as relative farmgate values. Values are 2000 Rands.

Table 3

Summary table of the estimated average value added at farmgate level (VAD) (R/ha) of fynbos ecosystem products available for consumption (R/ha/year) by vegetation type

Product	Mountain Fynbos	Laterite Fynbos	Limestone Fynbos	Sand plain Fynbos	Strandveld
Flowers & Greens	18.14	176.71	55.61	–	6.77
Buchu	1.93	–	–	–	–
Sour Figs	–	–	–	–	0.64
Honeybush Tea	0.12	–	–	–	–
Thatch	–	–	49.46	–	–
Total VAD	20.14	176.71	105.07	0	7.41

mostly used in the well-established local furniture industry, with a small amount finding its way further afield.

In 1998, a total of 3589 m³ of timber (including 1600 m³ of blackwood) was auctioned, realising a total income of R3.26 million (R2.9 million in 1998 Rands), and an estimated R1.3 million value added to the economy. Although prices vary from auction to auction, the average price for blackwood is about 15% higher than the average price for all indigenous timber. However, three indigenous species, *Ocotea bullata* (stinkwood), *Olinia ventosa* (hard pear) and *Podocarpus* spp. (yellowwood), yield the highest prices (R1763, R1334 and R1301 m⁻³, respectively, cf. R942.40 for blackwood in September 1999). The furniture industry now depends on the cheaper blackwood as a substitute for stinkwood.

The main non-timber forest product harvested from these forests is the seven-weeks fern (*Rumohra adiantiformis*), whose long-lasting fronds are used in flower arrangements (van Dijk, 1987). *Rumohra* is harvested by private contractors over a total area of 14,500 ha, under the control of DWAF. Following overharvesting in the past (Milton and Moll, 1988), the harvest is now considered sustainable, with a cycle of 15 months, and limited to 50% of suitable fronds per plant. About 1.5–1.7 million fern fronds are harvested per year (Kok, 1999; Vermeulen, 1999), realising an average annual income of R393,000, yielding an estimated value added of R275,000.

3.7. The consumptive use value of coastal marine resources

The coast of the CFR is characterised by highly productive, though relatively species-poor west coast region, and a species-rich, but less productive south coast, with increasing levels of diversity and endemism towards the east (Awad et al., 2002). Fisheries are a major economic sector in the CFR region, particularly on the west coast, which is the hub of the South African fishing industry. Much of the fishery sector is based on the offshore pelagic and demersal fisheries, which are beyond the scope of this study. However, the diverse commercial and recreational fisheries associated with the coastal shelf, described later, are also substantial.

3.7.1. Seaweed

The commercial seaweed industry in the Western Cape is based mainly on kelp (*Ecklonia*, *Laminaria*) and *Gracilaria*, harvested from concession areas (Boonzaier et al., 1999). Kelp harvests reached a maximum of about 5000 t in 1977 (Anderson et al., 1989), and about 1800 t are now harvested annually (Fishing Industry Handbook, 2001). Dried kelp is mainly exported for the extraction of alginic acid, but the cultured abalone industry is now fuelling demand for live kelp (some 300

t by 1999). In 1998, the industry generated some R9.2 million (Fishing Industry Handbook, 2001), suggesting an added value of about R7.6 million.

3.7.2. Fish

The main inshore fisheries in the CFR region can be divided into net and line fisheries. The net fishery, targeting mainly harders (Mugilidae) and St Joseph sharks (*Callorhynchus capensis*), has an annual reported catch of approximately 1406 t in the region (Lamberth et al., 1997), yielding a total value of about R2.8 million. However, the reported catch has been found to be a fraction of the actual catch, and it is estimated that the actual total catch for the CFR region is 6000 t (Hutchings and Lamberth, 2002), with a value of at least R12 million per annum. This excludes illegally caught line-fish which are often worth considerably more (e.g. R25 kg⁻¹ for galjoen *Dichistius capensis*) than legally caught species such as harder (R2 kg⁻¹; Hutchings and Lamberth, 2002), and are thought to make up a significant proportion of the catch.

Linefisheries comprise mainly the commercial boat-based fisheries and recreational angling. The commercial fishery, for snoek (*Thyrstites atun*) and hottentot (*Pachymetopon grande*) on the west coast, and more importantly, for sparids and other species on the south coast, employs about 20,650 people, and is estimated to contribute R323 million in value added to the economy (based on McGrath et al., 1997). There are an estimated 412,000 recreational shore-anglers in South Africa (McGrath et al., 1997). Recreational shore angling is very intense along the south coast as far as the Agulhas Plain, with 2.29 anglers km⁻¹ on average, compared with 0.36 km⁻¹ further east, and 0.12 km⁻¹ along the west coast (Brouwer et al., 1997). Angling effort between Cape Point and the Agulhas Plain is estimated to be about 660,000 angler days per year, resulting in an annual catch of over 1.1 million fish, weighing nearly 1500 t (Lamberth, 1996), or 4.5 t per km of coast. Recreational shore angling is important to the economy, supporting other industries, such as bait and tackle outlets, that result in job creation (Avis et al., 1999a). Indeed, shore angling is estimated to generate over 40,000 jobs in the region (McGrath et al., 1997). Recreational shore and ski-boat anglers within the CFR are estimated to contribute R671 million and R15 million, respectively, to the economy (McGrath et al., 1997).

In addition, the linefishery includes a spearfishing component, which is entirely recreational. This is the smallest sector of the linefishery, with an estimated national total of 7000 participants of whom approximately 3000 are estimated to operate regularly within the CFR (Mann et al., 1997). The landed catch value for the fishery as a whole is approximately R1.5 million, and the total value of the spearfishery is estimated to be

in the order of R42 million (S. Lamberth, unpublished data). Thus, an estimated catch value of R643,000 and total spearfishery value of R19 million can be attributed to the CFR.

The total value added by linefisheries (R1028 million) accounts for 1.3% of the GGP of the three coastal provinces (McGrath et al., 1997), although not all of this would be reflected in the primary sector accounts.

3.7.3. Rocklobster

The national catch of West Coast Rock Lobster *Jasus lalandii* is harvested predominantly from within the CFR. Having maintained a steady catch of about 10,000 t a year in the 1950s and 1960s, by 2000 the depleted stock only allowed a total allowable catch of some 2000 t, of which 174 t is allocated to the recreational sector. Whereas populations of the west coast rock lobster *Jasus lalandii* have declined on the west coast, they have increased in recent years on the south coast, possibly due to natural long-term dynamic change. Approximately 90% of the catch is exported, and in 1998, the total value of the fishery was in the region of R164 million (Fishing Industry Handbook, 2001), generating an estimated value added of about R98 million.

3.7.4. Abalone

South Africa's valuable abalone *Haliotis midae* stocks occur entirely within the CFR. The west coast and Cape Peninsula stocks are only exploited by recreational fishers, apart from a small commercial quota on Robben Island. The Agulhas coast is the centre of the commercial, illegal and recreational abalone fishery. Further east, abalone stocks are restricted to recreational use, although poachers also target these stocks. The 580-km long commercial fishing area is divided into seven fishing zones, each of which is allocated a total allowable catch.

The commercial fishery remained relatively stable over about 25 years, having a total allowable catch of 600 t. In 1998/1999, the total allowable catch was expanded to incorporate subsistence and recreational quotas, with a total of 820 t, of which 515 was allocated to the commercial sector. However, a massive poaching led to the reduction in the commercial quota to 371 t in 2000/2001 (Tarr, 2000). The legal commercial catch in 1998 was worth some R91 million (Fishing Industry Handbook, 2001). In addition, however, it is estimated that some 1600–1750 t of illegally caught abalone are exported annually to the Far East (Pulfrich, 2001). Including the illegal sector, the export value of the industry, is estimated to be approximately R240 million (Hauck, 1997). The recreational sector of the fishery, which has been reduced by changes in regulations, took 107 t in 2001, for which 17,000 permit-holders paid R255,000. The landed catch value of this fishery is approximately R23 million.

3.7.5. Other marine organisms

Several invertebrate species and small fish are exploited for consumption or for bait, particularly towards the east of the study area.

Mussels are exploited to a limited extent, with a commercial harvest of 14 t (Boonstra, 1996), worth about R45,000. There is some small scale commercial harvesting of wild oysters (*Striostrea* spp.) on the Cape south coast. Here, 134 harvesters collected about 560,000 oysters (75 t) in 1994, worth R0.95 million (Boonstra, 1996). The fishery has now expanded to 179 registered harvesters. The 1998 harvest of wild oysters was valued at R2 million (Fishing Industry Handbook, 2001).

The quantity and value of the harvest of bait organisms by anglers has recently been estimated on the basis of survey data (Table 4). Based on the local selling prices of these organisms, the results suggest that this harvest is worth over R35 million annually, although note that this is for an area which extends some 300 km beyond the CFR. This value is not recorded in the national accounts, except inasmuch as angling expenditure is concerned (already accounted for earlier), but it vastly outweighs the value of commercial catches of mussels and oysters.

3.8. Tourism value of the cfr's natural resources

The Western Cape has a 28% share of the national tourist market, and more than 50% of international visitors include this province in their itinerary. A total of R9304 million is spent annually by holiday visitors to the Western Cape of which overseas tourists are responsible for 48% (Wesgro and KPMG, 1998). Tourism accounts for about 9% of the Western Cape's Gross Geographic Product (Wesgro and KPMG, 1998).

One way of estimating the contribution of natural resources to tourism receipts is to establish their contribution to tourist decisions to visit the area. In this study, international visitors rated the natural environment more highly than domestic visitors in terms of its percentage contribution to the reason for their visiting the Agulhas Plain area ($74.3 \pm 20.8\%$, $n=67$ versus $63.8 \pm 31.1\%$, $n=137$), the difference being significant ($t=1.97$, $P<0.05$). If these figures can be extrapolated to the CFR, then R6406 million of the value of tourism can be ascribed to the natural environment.

Alternatively, one can use the proportion of tourists for whom an aspect of the natural environment was the main motivation for their visit. The 1991 White Paper on tourism states that more than 90% of foreign tourists come to South Africa primarily to enjoy the country's scenery, flora and fauna, but this is considered to be an overestimate (Grossman and Koch, 1995). In this study, 80% of tourists surveyed in the CFR cited natural or semi-natural (rural) attractions as the primary

Table 4
Estimated mass or number of different invertebrates harvested annually by shore-anglers and their total value

Type	Total harvest by anglers (tons or numbers)			Estimated total value R/year
	West coast	South coast	East coast (Breede to Kei)	
Redbait	47 t	290 t	176 t	5,130,000
Polychaete worms	1.35 m	635,000	365,000	2,350,000
Chiton			21,000	2100
Abalone, siffie		5 600	25,000	45,900
Alikreukel			5800	5800
Periwinkle			5800	58
Bivalves	5.484 m	8.243 m	562,000	14,289,000
Squid	0.5 t	10 t		168,000
Octopus		23,000	580	353,700
Talorchestia	47,000			470
Rock lobster	1000			25,000
Mud and sand prawns	4.4 m	9.6 m	2.5 m	12,375,000
Crabs		19,000	12,000	38,750
Bait fish	6.25 t	13.64 t	164.3 t	368,380
Total				35,152,158

Data are based on comprehensive species list and informal market values (S. Lamberth, unpublished data).

reason for their visit. Thus, it is estimated that the overall contribution of broad nature-based tourism is R7443 million, or 7.2% of GGP. This figure is higher than the above estimate because tourists attracted primarily for nature-based activities also spend money on other activities.

Nature-based tourism may be divided into passive or active forms, the latter being further subdivided into ecotourism and adventure tourism (Fig. 3). In the Agulhas Plain tourism study, 24% of respondents visiting primarily to enjoy natural features cited ecotourism

or adventure tourism activities as the main reason for their visit, while the remainder cited reasons such as seeing the southern tip of Africa (17%), rural landscapes (15%), and other reasons (e.g. relaxing). In the absence of further data, this could be extrapolated to provide a regional estimate of R1786 million in active nature-based tourism expenditure, accounting for 1.7% of GGP.

Ecotourism is defined here as tourism involving direct use or appreciation of elements of biodiversity. The value of certain ecotourism activities is estimated on the basis of existing data, as follows.

The tourism value of angling can be estimated on the basis that 34% of the approximately 1,315,000 angling days spent in the area (Brouwer et al., 1997) are by visitors (McGrath et al., 1997). With a daily expenditure by visiting anglers of R175 (McGrath et al., 1997), this suggests that angling tourism contributes at least R78 million to ecotourism value. Note that this value is also captured as a consumptive use value of coastal resources but is excluded from the latter in the overall summation of values for the CFR.

In South Africa, annual expenditure by an estimated population of over 20,000 active domestic birders on their hobby is estimated to be as high as R145 million (Turpie and Ryan, 1998). Birders visiting from overseas add another R28 million. Approximately 6.5% of all birding time in the country is spent in the fynbos, and 13.7% is spent in marine, coastal and estuarine habitats (Turpie and Ryan, 1998). Thus, assuming that one-fifth of the latter is within the CFR, it is estimated that 9.3% of all birding activity takes place within the region. This region is not endowed with a high diversity of birds, but contains several endemic species, a factor which is important for biodiversity 'listers'. Thus, it is estimated that birdwatching contributes at least R16 million towards tourism expenditure in the region. Including expenditure on viewing bird colonies (Turpie and Ryan,

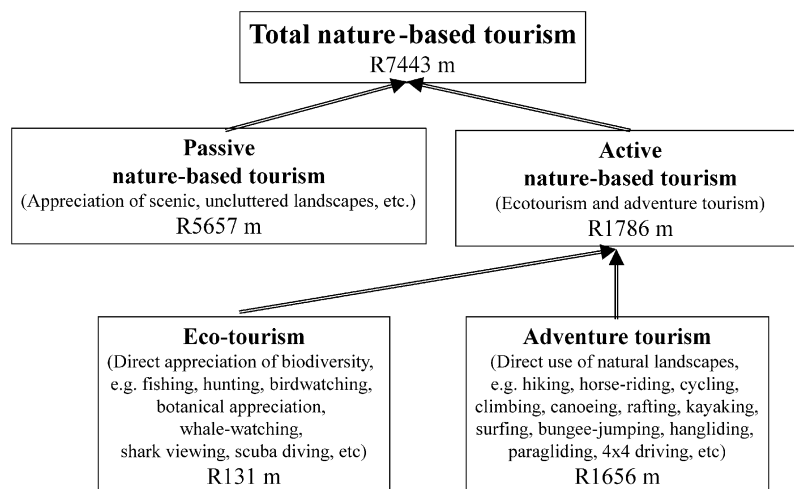


Fig. 3. The estimated contribution of different types of activities to the total value of nature-based tourism in the Western Cape.

1998), generally by non-birders, the total expenditure on birds within the region approximates about R19 million per annum.

Whale-watching has undergone tremendous expansion over the past 10 years, coinciding with the recovery of the Southern Right Whale population. This activity is almost entirely within the CFR, with major whale-watching points in Cape Town, Hermanus and at De Hoop Nature Reserve. It was estimated that about 22,000 international and 56,000 domestic tourists went whale-watching in Hermanus over the 1995 spring season, incurring a combined expenditure of R7.3 million (Findlay, 1997).

Assuming that scuba diving and shark-watching incur similar expenses to birdwatching and whale-watching, respectively, a rough first estimation of total ecotourism expenditure is about R130 million, which accounts for 7% of active nature tourism value, and 2% of broad-based nature tourism value. This is an underestimate, however, as it excludes other ecotourism activities such as plant identification.

3.9. Indirect use value of natural systems

3.9.1. Beekeeping

The Cape Honeybee *Apis mellifera capensis* is endemic to the CFR, where it is naturally limited in population size by available nesting sites (Rebelo, 1987). Hives are kept throughout most of the fynbos region and are used both for the production of honey and for providing a pollination service to fruit farmers. There are an estimated 73,000 hives in the Western Cape, of which about 58,000 hives (roughly 80%) utilise indigenous vegetation of the CFR (M. Allsopp, Agricultural Research Council, personal communication). The latter colonies typically rely on a combination of fynbos and alien gum trees (*Eucalyptus* spp.), the gums being responsible for most of honey production, while the fynbos ensures that honeybees can forage throughout the year (Heydenrych, 1999). On average, hives yield 20 kg of honey per year, which retails at approximately R30 kg⁻¹. Total production from fynbos hives is estimated to be 1160 t, and the total value added by fynbos-related honey production in the CFR is estimated to be in the order R13.9 million per annum.

Approximately 15,000 hives are used annually for pollination of fruit orchards, and an additional 5000 hives pollinate other crops such as onions (M. Allsopp, personal communication), with only strong enough hives being selected for the purpose. Hives are used for an average of 2.4 pollination cycles per year, for which beekeepers are paid about R180 per hive per cycle by fruit farmers, yielding a total revenue of R8.64 million. The entire fruit-producing region depends to a large degree on this service (van der Merwe and Eloff, 1995; Plant Protection Research Institute, 1992; Johannsmeier

and Mostert 2001; Table 5), and it thus indirectly reliant on the existence of fynbos vegetation. Different crops are reliant to different degrees on pollination by commercial bee hives (Table 5). Using this 'bee-factor', R1820 million of Western Cape crop production is attributable to bees (Table 5). Since 80% of colonies are reliant on fynbos for their survival, a gross production value of R1456, with an estimated corresponding value added of about R580 million, could be attributed to the fynbos.

The actual contribution of fynbos, via commercial beekeeping, to honey and fruit production is difficult to pinpoint, however. Many fruit crops would be unviable without the use of bee pollinators. Without this input, production is variable and may fail altogether, especially in areas which have become too developed to support adequate populations of natural pollinators. For this reason, the value of production, corrected for dependence on bee pollinators, can be ascribed entirely to bees (e.g. Morse and Calderone, 2000). This is true to the degree that the crop may not be viable without this service, but nor would it be viable without other inputs such as labour! While the entire value may thus be ascribed to bees in one sense, it would be more informative to investigate how crop production would be affected by a change in supply of pollinators.

Similarly, 80% of beekeeping operations are dependent on a combination of fynbos and exotic gums. Irrespective of their relative contributions to production or hive strength, the demise of either would likely render such operations unviable. Thus while it is valid to ascribe the value of fynbos-related honey and fruit production entirely to fynbos, it is equally valid, in this sense, to place the value on exotic Eucalypts. Taken a step further, all beekeeping operations in the province are totally dependent on fynbos for the supply of wild

Table 5

The value of bees as pollinators of agricultural crops in the fynbos region, using the bee factor as the percentage dependence of the crops' pollination on bee hives

Crop	Annual production 1999 (t)	Gross value of production (R million)	Bee factor (%)	Gross value attributed to bees (R million)
Deciduous fruit	2,240,139	3714.3	35	1 295.7
Berries	3517	17.2	37	6.4
Nuts	3288	23.1	26	6.1
Tropical Fruit	208,621	331.8	32	106.1
Grain crops	80,493	125.1	14	18.1
Oilseed crops	283,477	255.1	54	137.8
Vegetables	357,102	493.2	25	123.7
Seed production	?	60.5	80	48.4
Other	?	375.5	21	77.4
Total	4,159,387	5395.9		1 819.8

Values in 2000 Rands (Adapted from Johannsmeier and Mostert, 2001; M. Allsopp, personal communication).

bees, with colonies being replaced approximately every 3 years. Nevertheless, the value actually belongs to the combination, which if severely perturbed would result in a reduction of output. Indeed, the steady decline in the number of commercial hives is attributed to a decline in suitable fynbos, but the removal of exotic gums for conservation reasons will also negatively affect this industry.

3.10. Option and existence value

3.10.1. Option value

Only a fraction of fynbos species are actually used at present, but the maintenance of genetic diversity is important for many industries. For example, wild genetic resources are very important to the wildflower industry in order to maintain South Africa's competitive edge in international markets, because the industry is subject to fashion trends which dictate which species are marketed. Within-species genetic variation is also important. The rooibos tea industry is based exclusively on the cultivation of on a single strain of *Aspalathus linearis* (van Wyk and van der Bank, 1996). The reliance on a single genetic strain places some risk on the industry (e.g. vulnerability to disease), but there is a large amount of variation within *A. linearis*, which offers a large gene pool from which favourable cultivars can be selected if necessary (van Wyk and van der Bank, 1996). Wild genetic diversity is equally important in the development of new cultivated crops such as honeybush tea.

The European horticultural industry has benefited greatly from fynbos species. For example, the Dutch have developed 136 forms of *Freesia*—a CFR-centred bulb—with a value of R300 million at Dutch flower auctions in 1991 (Cowling and Richardson, 1995). The same trend is applicable to cultivars of other bulbous species as well as certain *Erica* species, succulents and members of the Proteaceae. New genetic material is constantly being sought and there is most likely a large amount of “bio-prospecting” taking place in the CFR, both legally and illegally. In addition, there has been some marine bio-prospecting in the south coast region, particularly for sponges, in the Tsitsikamma National Park, but the potential value of these resources is unknown at this stage (Avis et al., 1999a).

It is extremely difficult, however, to predict what uses may be found for the remaining species in future, or what their value might be. Although the value of fynbos plants for medicinal purposes has not been very well researched (Fourie et al., 1992), Scott (1993) suggests that there is potential in certain plant families that are well represented in CFR, for extraction of medicinally important compounds. It has been predicted that the projected loss of 50,000 species in the world by the turn of the century would mean the loss to the pharmaceutical industry of some 25 prescription drugs with a market value of US\$25,000 million (Scott, 1993). The

CFR has more than 1400 species of plants with Red Data Book status (Cowling and Richardson, 1995). If these plants were to go extinct, the proportional loss to the future pharmaceutical industry based on the above assumption could be as much as US \$700 million!

Option values also include future growth in tourism. At present, however, it is impossible to guess the future benefits that might arise from the preservation of the CFR's biodiversity. The best measure that one can derive is simply the society's willingness to pay to retain the option for future use. Because of this, option and existence value are frequently considered together. The expenditure by the international community on ensuring the conservation of this region's biome is an important component of this value.

3.11. Existence value

The existence value of the area's biodiversity has recently been investigated in a contingent valuation survey of 800 households throughout the Western Cape (Turpie, in press). Using both open and closed ended questions, the study found a total provincial willingness to pay for the protection of biodiversity in South Africa of R393 million per year. Of this R153 million was allocated to the fynbos biome (approximately R21.50 ha⁻¹year⁻¹), and R75 million to the entire South African coastal zone (R24,000 km⁻¹). Of the latter, R28.8 million can be proportionately ascribed to the CFR, although this is a conservative assumption, since people tend to put more value in local resources than those further afield. Note that these measures of existence value do not include values held by the rest of the country or internationally.

3.12. Total economic value of the CFR's natural resources

Using the earlier findings, it is estimated that the total economic value of the CFR's biodiversity is in the region of R10,000 million per year (Table 6). This represents over 10% of the region's Gross Geographic Product (provincial contribution to GDP). Tourism accounts for the greatest proportion of this, and natural resource harvesting also generates a substantial proportion of the value. The consumptive use value of marine resources far outweighs that of terrestrial resources (Table 6). Marine resource use is worth some R1.12 million km⁻¹year⁻¹, or about R2250 ha⁻¹ if the area is extended 5 km out to sea, while resource use values from fynbos and forests yield overall average values of R27 and R26 ha⁻¹, respectively (including non-harvested areas). While the fynbos biome has a far higher existence value than the coastal zone (Table 6), the reverse is true when considered on a per unit area basis (R21.50 ha⁻¹ versus R476 ha⁻¹).

Several additional values have not been included in the earlier estimates. These include the consumptive use values of game and game-bird hunting, harvesting of aquatic resources such as arum lilies (*Zantedeschia aethiopica*) and 'waterblommetjies' (*Aponogeton* spp.). According to official statistics, game breeding and hunting generates about R1.8 million (1995 prices) in the Western Cape (Hosking, 1996). Some gamebird hunting takes place in the CFR, a major potential gamebird hunting 'hotspot' in southern Africa (Griffiths, 1998), although the extent and value of this industry in the region is unknown. In addition, terrestrial habitats also have many indirect use values in addition to those cited earlier, such as grazing, aquaculture, carbon sequestration, nutrient cycling and the production of water. Fynbos does not offer very good grazing, however: Mountain Fynbos has a livestock grazing capacity of about one small stock unit per 8 ha (Le Roux, 1988), but it is used in some areas to supplement the diet of cattle and sheep. Grazing may be fairly important in Grassy Fynbos. Mariculture, particularly of mussels, oysters and abalone, is important in Saldanha, the Agulhas coast, and in Knysna and Port Elizabeth. Although these industries do not use local biological resources, they are reliant on the healthy coastal and estuarine ecosystems in which they operate. Similarly, aquaculture is reliant on well-functioning freshwater systems. There is considerable cultivation of exotic fish in rivers within the CFR region.

Table 6
Summary of the value of biodiversity within the Cape Floristic Region. Values in 2000 Rands

Type of value	Total annual value (R)
<i>Consumptive use value (harvests)</i>	
Fynbos	76,793,500
Forests	1,575,000
Coastal marine resources	1,323,195,000
Total	1,401,563,500
<i>Non-consumptive use value (tourism)</i>	
Ecotourism	130,000,000
Adventure tourism	1,656,000,000
Passive nature-based tourism	5,657,000,000
Total	7,443,000,000
<i>Indirect use value (beekeeping)</i>	
Honey	13,990,000
Orchard pollination services	580,000,000
Total	593,990,000
Option value	?
<i>Existence value</i>	
Terrestrial fynbos area	153,000,000
Coastal area	28,800,000
Total	181,800,000
Grand total	9,620,263,500

Although water runoff from CFR, fynbos-clad mountain catchments is known, it is difficult to attribute a value to fynbos. Technically, water supply does not depend on fynbos, and would be even greater if the mountains were covered in concrete! Thus we have not attempted to attribute this value to fynbos, but instead we consider the costs of water losses caused by alien invasion in the following section.

Higgins et al. (1997) estimated that the net present value (discounted at 3% over 50 years) of a pristine fynbos ecosystem, including water production, was between R1000 and R10,700 ha⁻¹, depending on the estimates of unit values used. This is equivalent to a range of R39–R416 ha⁻¹year⁻¹. Direct use values, predominantly wildflower harvesting, accounted for R1.3–R29.1 ha⁻¹year⁻¹, and water production made up R35–R75 ha⁻¹year⁻¹. The estimated value of genetic storage ranged from R3 to R300 ha⁻¹year⁻¹. While most of the values in Higgins et al. (1997) were estimated rather than taken from actual data, their upper-bound estimate of the direct use value of fynbos (R29 ha⁻¹year⁻¹) was similar to the R27 ha⁻¹year⁻¹ found in this study. If Higgins et al.'s (1997) estimates of genetic storage value, based on costs of maintaining rare species ex situ, were a reasonable estimate of option value, then up to R870 million might be added to the estimated total annual value of the CFR given in Table 6.

Costanza et al. (1997) did not value genetic resources for rangelands (including fynbos) nor for coastal shelf ecosystems in their global valuation of ecosystem services. For rangelands, pollination services were valued at \$25 (R175) ha⁻¹year⁻¹, compared with the approximately R20 ha⁻¹year⁻¹ obtained in this study, and total services were estimated to be worth \$232 (R1624) ha⁻¹year⁻¹. Much of Costanza et al.'s estimated value of \$1610 ha⁻¹year⁻¹ for coastal shelf ecosystems was due to nutrient cycling, with food production making up \$68 (R476) ha⁻¹year⁻¹, less than the estimate obtained in this study.

4. Economic causes and consequences of the main threats to CFR biodiversity

4.1. Invasion of fynbos by aliens

Two-thirds of the remaining fynbos vegetation has been infested with alien plants to some degree, with 13% having an alien cover of greater than 25% (Table 7) (cf. Rouget et al., 2003a). Invasive plants displace natural vegetation, thereby directly undermining its economic values. In this analysis we assume that the loss of goods and services described earlier is proportional to the area covered by aliens. This may be conservative in terms of direct use values, as the presence of aliens may disproportionately increase harvesting costs or

decrease yields in relation to area cover, but the opposite may be true for other types of value, such as tourism, which may not be as sensitive to alien invasion.

In addition to displacing indigenous vegetation, alien invasive plants are major consumers of water in the fynbos region. The biomass of a typical stand of fynbos (7.5 years post-fire, comprising 70% short ericoid-restioid fynbos and 30% tall moist fynbos), and of a 7.5 year-old stand of alien trees, would be roughly 2810 and 10,459 g m⁻², respectively (van Wilgen et al., 1996). A heavily invaded area therefore has an additional biomass of 7649 g m⁻² compared with an uninvaded area. The additional biomass created by aliens in heavily infested areas results in a reduction of streamflow by 182 mm, reducing overall catchment yield by 18.2 Mm³ from 52 to 33.8 Mm³ per year. The impact of different degrees of invasion on water yields is shown in Table 8.

Alien plants do provide some benefits, however. Fynbos provides very little suitable firewood, and certain alien species within the CFR have become a valuable source of firewood. The most important species used for firewood is rooikrans (*Acacia cyclops*) medium to dense infestations of which are viable for commercial exploitation. Different types of fynbos are invaded by this species to different degrees. For all intents and purposes, *A. cyclops* does not occur in Mountain, Laterite or Sand Plain Fynbos. In Limestone Fynbos, dense infestations are 90% *A. cyclops*. In Strandveld, any dense infestations are likely to be 100% *A. cyclops*. The average net income from firewood harvesting that can be yielded from areas of fynbos that are densely infested with *A. cyclops* is R148 ha⁻¹year⁻¹. This value is mainly realised by the informal sector and is not accounted for in national accounting statistics (e.g. GDP).

Based on our estimates of the fynbos values under different levels of invasive vegetation, water losses, and firewood gains, we estimate that alien invasives result in a net loss of value amounting to some R684 million per year (Table 9). Without action, these losses would be

expected to increase as alien plants continue to spread at exponential rates (Higgins et al., 1997).

Given these significant implications, why has the spread of aliens not been brought under better control? The reason lies in a straightforward analysis of the costs and benefits of clearing for different types of land-owners. There is a clear incentive to fund alien clearing on publicly owned mountain catchment areas, where returns in terms of water savings generally justify costs (Marais, 1998). This has resulted in the implementation of government-funded clearing programmes in catchment areas throughout the country. However, private land-owners do not have any such incentive to clear alien vegetation. Farmers do not reap the downstream benefits of increased water production, and in lowland areas such benefits may be negligible. Furthermore, the private benefits of restoring the productive potential of indigenous vegetation do not outweigh the costs of clearing, which range from about R320–R6700 ha⁻¹ for lightly to densely infested areas of lowland acacias (Turpie and Heydenrych, 2000).

Based on Table 2, a typical farmer on the Agulhas Plain, with an average mix of vegetation types and average degree of alien infestation, would make R149 ha⁻¹ from his approximately 500 ha of natural vegetation. Using Eq. (1) to estimate yields from alien-free vegetation, it is estimated that he would be making at least R188 ha⁻¹ if his farm was totally free of alien vegetation, suggesting a current loss of income due to aliens of about 21%. With a conservatively estimated intrinsic spread rate of 10% per annum, the area could be expected to lose 50% of its productivity within 15 years, and could be 90% invaded within 35 years. The net present value of the land (discounted at 8% over 20 years) is thus estimated to be about R1176 ha⁻¹, as opposed to R1846 ha⁻¹ if aliens had never invaded. The cost of clearing this land, which typically might have 10% area under dense infestation, 10% medium and 30% light infestation, would be approximately R490,000

Table 7

The original area of fynbos in the Western Cape divided into areas (ha) of decreasing quality, from uninvaded fynbos to densely infested fynbos and finally, the area that has been lost by habitat transformation

Fynbos type	Extant					Transformed	
	No infestation	Occasional infestation	Scattered infestation	Medium infestation	Dense infestation	Total	
Mountain	890,738 (36.8)	1,052,519 (43.5)	177,724 (7.4)	76,799 (3.2)	74,952 (3.1)	2,272,732	145,068 (6)
Grassy	2094 (10.2)	0 (0)	0 (0)	0 (0)	17,682 (85.8)	19,776	824 (4)
Laterite	144 (0.2)	1423 (2.3)	319 (0.5)	21,634 (35.1)	4209 (6.8)	27,729	33,891 (55)
Limestone	32,839 (15.3)	3880 (1.8)	77,925 (36.3)	44,991 (20.9)	44,426 (20.7)	204,061	10,740 (5)
Sand Plain	28,868 (5.5)	229,300 (4.3)	70,276 (13.5)	33,822 (6.5)	974 (0.2)	156,240	364,560 (70)
Strandveld	40,438 (13.4)	64,967 (21.5)	26,809 (8.9)	44,460 (14.7)	19,561 (6.5)	196,235	105,665 (35)
Total	995,121	1,145,089	353,052	221,706	161,804	2,876,773	660,748

The degree of infestation by alien vegetation is described as occasional (<5% alien cover), scattered (5–25% cover), medium (25–75% cover) and dense (>75% cover). Percentages of the total original area in the Western Cape are given in parentheses. From Turpie et al. (2000), based on GIS information supplied by Environmentek: CSIR, Pretoria.

or R980 ha⁻¹ on average. Even with these costs spread over 10 years, the resultant net present value of the land would amount to R798 ha⁻¹, substantially less than the current situation. Clearing costs would have to be reduced by 60% in order to make clearing worthwhile. Thus at present, unless farmers gain other values, for example, aesthetic or tourism values, from clearing their lands, they are unlikely to do it for financial reasons unless they are extremely far-sighted (and sufficiently wealthy) or appropriate incentives are put in place.

4.2. Transformation of natural vegetation

Land transformation is a major threat to the terrestrial biodiversity of the CFR (Rouget et al., 2003a), usually greatly outweighing any threat of over-exploitation. Almost all of the original area of renosterveld vegetation on the coastal forelands has been lost to cultivation (Rouget et al., 2003a), owing to its association with arable soils (Kemper et al., 1999), and thus its relatively high opportunity cost of conservation. The remainder of this area is under threat due to expansion of the wine industry. Fynbos, due to its relatively poor soils, was spared from this process until relatively recently, when expansion of the wildflower and other industries led to an increasing trend towards cultivation rather than harvesting of indigenous fynbos species. Substantial growth in demand in the past 20 years has led to increased cultivation of fynbos flowers, mostly for the export trade. In 1989 it was estimated that the ratio of veld-derived to cultivated material was 90:10 for the dried-flower industry and 65:35 for the fresh flower trade (Middleman et al., 1989). Today the trend has shifted more in the direction of cultivated products with the ratio of veld-derived to cultivated, probably in the region of 80:20 for the dried flower industry (R. Middelman, personal communication). There has also been a large increase in the cultivation of flowers for the fresh flower industry. Cultivation is far more lucrative than harvesting from the veld. One hectare of cultivated proteas generates the equivalent income of about 50–100 ha of natural veld. It has been estimated that an average turnover of over R20,000 ha⁻¹year⁻¹ can be obtained from intense cultivation of

members of the Protea family (e.g. *Leucospermum cordifolium*) for the fresh flower export market (Leiman, 1996). There is also a trend towards cultivating buchu, which yields approximately R1800–R2500 ha⁻¹ (Cowling and Richardson, 1995), and experiments with cultivation of honeybush tea and thatching reed have been initiated. Thus fynbos products are increasingly being grown in plantations, and future wild harvests may decrease, following the trend of rooibos tea (*Aspalathus linearis*), which is no longer harvested in the wild (Cunningham and Davis, 1997). Thus the consumptive use value of natural fynbos may decrease over time.

As long as the returns from cultivation are far higher than those from natural veld, fynbos vegetation will continue to go under the plough. At present, the opportunity costs of fynbos removal in this process are relatively low to the private landowner (=the decision-maker). The opportunity costs to society as a whole are much greater, although some potential costs, such as loss of bee habitat and water supply, might be offset by the use of indigenous species in cultivation.

4.3. Overexploitation of renewable natural resources

The main threat facing the coastal resources of the CFR is overexploitation. Substantial declines have been reported in the stocks of numerous marine species, with several stocks having collapsed (Griffiths, 2000). The case with terrestrial resources is far less clear, mainly due to a paucity of research into this area. If there has been overexploitation of terrestrial resources, it is often likely to be due to lack of scientific understanding to guide sustainable use practices, as much of the resource base is in private ownership. Overexploitation is suspected in some cases where farmers lease lands to others for harvesting flowers.

Several factors contribute to the overexploitation of marine resources, mainly lack of scientific understanding, life-history characteristics, and most importantly, property rights issues. Commercial line-fisheries target many resident, endemic Sparids, which are typically slow growing and unsuited to intense fishing pressure. Many stocks are already severely depleted, and catch rates are declining (Griffiths, 2000). Although all

Table 8

Impacts of different levels of alien plant infestation on water yield and associated value from a hypothetical 10,000 ha fynbos-clad mountain catchment in the Cape Floristic Region

Infestation level	Extent of alien plant cover (%)	Water yield (m ³ ha ⁻¹ year ⁻¹)	Water loss (m ³) (% of original 2310 m ³)	Value of loss (R ha ⁻¹ year ⁻¹)
Zero/Light	2.5	2260	50 (2.2%)	37.50
Scattered	15	2040	270 (11.7%)	202.50
Medium	50	1400	910 (39.4%)	682.50
Dense	87.5	721	1590 (68.8%)	1192.50

The annual water yield from an uninvaded catchment is estimated as 2310m³. Values in 2000 Rands.

fisheries require licensing and are subject to various restrictions, in many cases this is effectively unlimited or unchecked. The most extreme example of a failed regulatory approach is the abalone fishery, which is in a critical state due to armed poaching activity (Boonzaier et al., 1999). Here, the penalties cannot compete with the gains from illegal activity, a situation which is also often true of less valuable fisheries simply due to the low probability of facing penalties. The combination of weak limits to numbers of permits and lack of enforcement effectively provides open access to resources. As long as access is open, commercial fishers will exploit stocks to the level of economic extinction, where stocks are at risk of biological extinction. Because they gain utility from the activity rather than the catch rate, recreational fishers tend to mine stocks even further than commercial fisheries. Catches by anglers in False Bay have declined from 250 g h⁻¹ to less than 100 g h⁻¹ over the past 40 years (Bennett, 1991), yet angler numbers continue to grow.

The values reported in this paper have all been given in terms of current annual flows. While this is a common way of reporting ecosystem values, it makes the implicit assumption that such values can be sustained

indefinitely. Where resources are being overexploited, it can be expected that future annual values may be lower than current values, especially if substitute resources are available elsewhere. Differences in the potential time path of value flows can be expressed by comparing the present value of future value streams. Values accruing in the future are usually discounted to give greater weight to present values. Under the assumption that current levels of resource use are sustainable and that the current cover of alien vegetation remains stable, the net present value of the CFR's harvested terrestrial resources would be R882 million and harvested marine resources would be about R15,000 million (using a projection of 30 years at 8% discount rate). However, values of natural resource harvests cannot be maintained if their stocks are being diminished. At an 8% discount rate (the private discount rate), an annual decline of 1% in the value of natural resources harvested would lead to a 9% loss of the net present value (NPV) of the resource, and a 5% annual loss leads to a 33% loss of overall value. If future values are not discounted as much, for example with a lower 'social' discount rate of 3%, then the percentage loss of NPV is even greater, a 5% decline leading to a 42% loss of

Table 9

Estimated changes in value per ha of different types of fynbos under different degrees of infestation by aliens, giving current total values and estimated current losses due to aliens

	Average	Light	Scattered	Medium	Dense	Current total	Current loss
<i>Consumptive use</i>							
Mountain Fynbos	20.19	21.38	18.70	10.69	2.67		
Laterite Fynbos	176.71	371.51	325.07	185.75	46.44		
Limestone Fynbos	105.07	161.27	141.11	80.63	20.16		
Sand Plain Fynbos	0.00	212.88	186.27	106.44	26.61		
Strandveld	7.41	9.47	8.29	4.73	1.18	73,678,675	-19,970,889
<i>Nonconsumptive use: ecotourism</i>							
All vegetation types	18.65	20.69	18.10	10.34	2.59	53,286,296	-5,814,778
<i>Nonconsumptive use: other nature-based tourism</i>							
All vegetation types	1145.47	1145.47	1145.47	1145.47	1145.47	3,272,598,344	0
<i>Indirect use: beekeeping</i>							
Mountain	75.19	79.61	69.66	39.80	9.95		
Laterite	386.67	812.93	711.31	406.46	101.62		
Limestone	1052.60	1615.57	1413.63	807.79	201.95		
Sand Plain	687.41	828.12	724.61	414.06	103.52		
Strandveld	655.19	837.39	732.71	418.69	104.67	632,363,759	-194,486,094
<i>Existence value</i>							
All vegetation types	14.32	17.34	8.67	3.47	0.00	40,900,000	-8,634,542
<i>Additional consumptive use: firewood</i>							
Limestone				86.4	172.71		19,596,446
Strandveld				96.15	192.30		
<i>Additional losses: water</i>							
All vegetation types		-37.50	-202.50	-682.50	-1192.50		-474,852,413
Overall net loss							-684,162,269

Estimated overall losses also take gains of alien firewood and water losses into account. Values in 2000 Rands.

NPV. Thus the overexploitation of natural resources can have a substantial negative impact on the NPV of natural ecosystems, or in other words, on the value of these ecosystems to society.

5. Implications for conservation strategy within the CFR

Conservation of the biodiversity of the CFR is an international priority and a major obligation for South Africa as a signatory to the Convention on Biological Diversity. A successful conservation plan will have to address the three main threats of alien invasion, land transformation and overexploitation. Sophisticated analyses have identified which terrestrial areas should be protected in order to maximise the representation and viability of biodiversity in the most space-efficient way (Cowling et al., 2003). Further consideration has been given to the way in which such areas should be configured in order to minimise the direct costs of conservation within protected areas (Frazee et al., 2003), and through using off-reserve conservation agreements on some of the targeted conservation areas (Pence et al., 2003). Little attention has been paid to maximising benefits to society, however. This study provides the first step in developing a more holistic conservation plan that works in the context of existing costs and benefits of conservation action and maximises societal wellbeing.

The optimal area under protection will differ depending on what is being maximised, which, in turn, depends on the goals of the exercise. Whilst obliged to meet international conservation obligations, the main goal of government is to maximise benefits to society as a whole. An appreciation of the full economic value of natural systems helps to increase the perceived optimal area to be protected. This study demonstrates that the value of the CFR's natural systems is significant, even when compared with national income statistics. The benefits clearly outweigh the opportunity costs of protection at a national level. The actual optimal area under protection is more difficult to estimate, however, as it requires a detailed understanding as to how the marginal costs and benefits change with each increment in the area protected. These costs and benefits change because protected areas may expand from isolated mountain areas where opportunity costs are low, into fragmented lowland areas which are potentially productive from an agricultural point of view. Thus, the cumulative benefits of conservation usually increase at a decreasing rate, while the cumulative costs can be expected to increase at an increasing rate. Beyond some point, the net benefit of an extra hectare under protection will become negative. Detailed spatial analysis of costs and benefits is required to estimate such optima, but was beyond the scope of this study.

Determining the optimal area under protection from a societal point of view is not necessarily the final solution, however. The optimal solution for society as a whole is likely to be quite different from that perceived at a local level, and if ignored, this difference has the potential to undermine conservation initiatives. Ideally, a conservation plan should also take cognisance of local-level values in order to achieve a pareto-efficient solution, whereby overall benefits to society are improved without uncompensated losses to any individual. The use of off-reserve conservation measures would probably be necessary to meet conservation obligations without compromising local society, as well as being necessary to ease the government's financial burden.

Off-reserve conservation measures, or conservation on private lands, also carry opportunity costs, and private landowners are less likely to be concerned with indirect use values and non-use values in their decision making. In addition, their shorter time horizon, compared with the long-term horizon of society as a whole, means that the private returns to costly conservation measures are lower. This study has shown that the potential consumptive use value of uninvaded fynbos vegetation is not high enough to provide private landowners with an incentive to enter into costly alien clearing activities, but that subsidies would be able to make clearing worthwhile. Since the income to landowners is higher from pristine than invaded vegetation, it also stands to reason that a conditional subsidies can be used to encourage landowners to contract into a conservation agreement (see Pence et al., 2003). Indeed, since society as a whole stands to benefit from increased water production and biodiversity protection, there is sufficient justification for the state to subsidise clearing in general, without invoking such agreements, especially given the continued tendency for invasion from unprotected areas. However, and in spite of strong sentiments in recent policies towards the use of incentives rather than regulatory mechanisms, the state has instead recently introduced a regulatory mechanism that compels private landowners to clear alien vegetation from their lands (Pence et al., *in press*). Given the fact that this could bankrupt many landowners, this new law is instead likely to provide a perverse incentive to farmers to put alien-invaded lands under the plough.

It must be realised, however, that alien clearing subsidies alone are unlikely to persuade farmers to conserve natural vegetation, or to enter into agreements to do so, whenever land transformation is a more attractive option. The only sure protection against the plough is inclusion in strict protected areas, or finding ways to make natural vegetation more valuable to landowners, such as through ecotourism ventures, the demand for which can be increased with the help of government-

funded marketing. Incentives that work in the absence of agreements will have much more far reaching conservation benefits.

Relatively little attention has been paid to developing a conservation plan for the coastal zone, partly due to its not being part of the biodiversity ‘hotspot’ associated with the terrestrial vegetation of the CFR. This study has shown that the direct use value of the CFR’s coastal marine resources are significantly more valuable, both at a per unit area level and at an aggregate level, than its terrestrial resources. The decline in this value, associated with productivity, rather than the diversity, of resources, will have a much greater effect on local society, not only because of the magnitude of the values involved, but also due to the fact that these losses are not being replaced by more lucrative alternatives as is often the case in terrestrial systems. Although the existence value of coastal resources is also high relative to terrestrial resources, the perceived societal value of coastal marine conservation lies mainly in securing local incomes. Indeed, tourism values, which generate a major source of revenue in the area, depend largely on coastal vistas, but are little influenced by the state of marine stocks. Option values are probably significant in marine diversity, but genetic diversity is orders of magnitude greater in terrestrial areas, so a similar distribution of option value is likely.

High consumptive use values, coupled with near open-access conditions to resources, has provided the private incentive to mine marine resource stocks. Regulations seldom have any power in these situations, especially under current levels of policing, and these conditions are usually best rectified through addressing property rights, preferably at a local level. Only under well-defined ownership, and in the absence of poverty, will resources be managed sustainably. However, it is recognised that many communities utilising marine resources in the CFR region are too heterogeneous to enable successful establishment of local controlling institutions. The second best option is the limitation of access to coastal areas, either through marine protected areas, or the limitation of access points to certain marine areas. This study has shown that at face value, the opportunity cost of establishing a no-take marine reserve is high. If it can be shown that the contribution of the reserve to future income due to conservation of resource stocks offsets the loss of future income due to overexploitation, then a marine reserve may be shown to have a positive social value, even if individuals perceive a net loss in the short term. Limited access points, as an alternative to no-take reserves, can serve to achieve massive reductions in catch without the same degree of negative perception. For highly immobile resources, as is the case for many of the more valuable resources, local-level community or individual ownership is probably the only solution.

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