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Subspecies and clines in the Springbok *(Antidorcas)*

Notes on Gazelles, 2

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Abstract

Studied the nature of geographic variation in the Springbok. There is only one species, *Antidorcas marsupialis* Zimmermann, 1780, but three subspecies can be sharply demarcated, despite the presence of wellmarked clines within at least two of them.

Introduction

Though not generally classed under the heading of "gazelle", the Springbok ist clearly one of a cluster of antelopes springing from that general stock. It seems probable that the currently accepted classification simply separates out a few distinctive types as genera – *Antidorcas*, *Procapra*, *Litocranius*, perhaps even *Antilope* – while the mass of more

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primitive forms is retained in *Gazella*. But the phylogeny of the recognized species has not been worked out, and until this is done there is little option but to continue to use the somewhat unbalanced scheme as at present. The genus *Antidorcas* certainly has considerable time depth, including as it does the fossil species formerly placed in a separate genus, *Phenacotragus* (Gentry, 1978).

The described taxa of living *Antidorcas* are only four in number. The genotype, *A. marsupialis* Zimmermann, 1780 (synonym *A. euchore* Forster, 1790) has as its type locality the Cape of Good Hope, where it is apparently now extinct. Lydekker (1914) described a subspecies *A. m. centralis* on the basis of headskin from further northeast (Deelfontein, Cape Province) with the forehead fawn in colour instead of white as in supposed topotypes. Blaine (1922) described a new species, *A. angolensis*, from Elephant Bay, Angola. The distinguishing characters were: larger size, with longer narrower head and axis of horns in line with frontal plane; in males, horns not so stout at base and, viewed laterally, less sinuous; in females, horns long and clearly annulated, resembling males' horns in shape; ears very large; colour brighter; the forehead always fawn, this colour being edged below with a brown border. In 1926 Thomas assigned a subspecies to Blaine's species: *A. angolensis hofmeyri* from Berseba, Southwest Africa. This would differ from the Angola form by its lighter colour with the lateral bands less dark, and no brown edging to the tawny forehead area; the horns are even longer. In some of these characters, *hofmeyri* approaches the more southerly forms, casting doubt on the species status of *angolensis*.

Material and methods

The material available for the present study was as follows: British Museum (Natural History), 27 skins, 40 skulls; Rijksmuseum van Natuurlijke Historie, Leiden, 4 skins, 8 skulls; Zoologisches Museum, Berlin, 3 skulls; Powell-Cotton Museum, Birchington, Kent, 2 skins, 8 skulls. There is thus a considerable excess of skulls over skins; and, when divided up by sex and locality, none of the samples is very large although some are not too bad and a good general view of geographic variation in the species is quite clear.

The available material was sorted into geographical samples, without prejudice as to subspecific allocation. Coverage of the species' distribution is incomplete, and some of the samples are small, but some interesting results emerged.

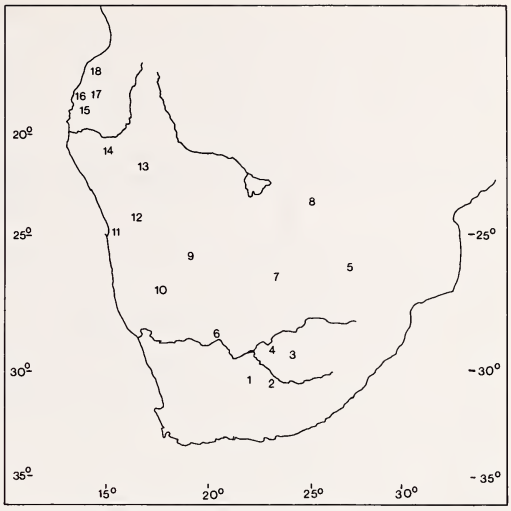
Results

Skins

Skins from Angola (including the type of *angolensis*) are fairly dark, brown-tawny; the lateral band is nearly black, the pygal band very dark brown. The face-stripes are thick and dark rich brown, and go two-thirds of the way to the muzzle. The forehead is medium brown, bordered anteriorly by a dark brown edging which forms a sharp transition to the white of the face. There are four skins in the British Museum and nine in the Powell-Cotton Museum; Plate XII of Hill and Carter (1941) agrees with them exactly.

Seven skins from the Kaokoveld (northern Namibia) are lighter, more fawnish; the lateral band may be nearly black but is usually dark brown; the pygal band is much lighter (medium brown) and thinner; the face-stripes are rather thinner, and usually less dark. The forehead is again brown, but there is no trace of a dark anterior border so that there is a less abrupt change to the white of the face. A skin from Etosha Pan, not far to the south, fits into this series; so does the type of *hofmeyri*, Berseba (considerably further south).

Nine skins from Botswana (Metsematluku, Chwai Saltpan and Maritsami, all in the southeast towards the Transvaal border) average slightly paler than the Namibian skins, and the pygal band is still more poorly developed; the forehead is often pale fawn. The nose-line may be present, as in the previous two series, or obsolescent, or absent altogether



Localities of museum specimens of *Antidorcas marsupialis. A. m. marsupialis:* 1 = Richmond; Deelfontein; 2 = Middelburg; 3 = Mahemfontein; Krugersdrift, by Bloemfontein; Dreifontein; 4 = Kimberley and Lombard. – *A. m. hofmeyri:* 5 = Sandfontein; 6 = Upington; 7 = Matsematluku; Maritsani River; Chwai Salt Pan; 8 = N'Kata; 9 = Rietquelle, by Aminuis; 10 = Berseba; 11 = Swakopmund; 12 = Karibib; 13 = Etosha Pan; 14 = Qoabendus and Otavi, Kaokoveld. – *A. m. angolensis:* 15 = Pico Azevedo, 70 km. S. E. of Mossamedes; 16 = Elephant Bay; 17 = Mossamedes Railway, 49 to 96 km; 18 = Equimina

leaving the nose white. In general these skins resemble the Namibian ones closely but may tend towards the following two series.

Three head-skins from Dreifontein, Orange Free State, are perhaps less pale overall than Botswana, and the face-stripes are very thin. The forehead is white in one of the specimens but pale fawn in the other two in which, however, this colour does not extend in front of eye level unlike the previous series.

Finally a single skin and a head-skin (type of *centralis*), in the British Museum, and four skins in Leiden, all from Cape Province, are less pale – a rich chestnut-brown – with a strong deep brown flank-stripe und well-marked dark pygal stripe; the face-stripes are dark; the forehead is brown or fawn in all, but as in the Orange sample this colour does not extend in front of the eyes and is not, of course, sharply bordered anteriorly; the nose is white in the three females, but with a brown smudge in three males. Roberts (1951) says, speaking apparently of Cape Province specimens, that the presence of brown on the forehead is variable.

We thus have a pale desertic type of skin in the centre of the range of the species (Namibia and Botswana), and a more strongly marked type in more mesic country to the northwest and south: these two types differing from each other in addition.

Skulls and horns

The skull and horn measurements are set out in Table 1. To those measured in museums personally have been added some measurements of numerous skulls from the Kimberley and Lombard regions given by Rautenbach (1971), and one from Karibib in Namibia by Roberts (1951). Botswana localities include N'Kate, well to the north of the area from which the skins come, but skulls from the two areas show no differences. Rautenbach states (1971: 103) that "the skulls from the Kimberley area were on the average slightly larger . . . than those . . . from the S. A. Lombard Nature Reserve" but the difference was non-significant; in anycase he gives only the one set of figures, which are thus all that can be used here although the standard deviations might, for this reason, be on the large side. Many more measurements were taken than are given here; significant differences between samples appeared only in those here listed.

As measured by greatest skull length, springbok from Kaokoveld and elsewhere in Namibia are the largest, followed by those from Transvaal, Botswana and Angola, then

Table 1

Skull measurements of *Antidorcas* samples

All measurements given in the article are in millimeters (see also GROVES 1969); C.P. means Cape Province, O.F.S. Orange Free State

	Horn length			Horn span			Horn base breadth			Horn antero-posterior			Skull length			Preorbital length		
♂ C.P	261.1	16.78	9	203.3	16.96	9	74.4	2.07	9	38.8	2.05	9	229.4	1.67	5	127.0	2.12	5
O.F.S.	229.0	–	1	197.0	–	1	70.5	–	2	219.0	1.73	2	219.0	1.73	3	120.0	–	2
Kimberley	288.0	29.40	63	–	–	–	–	–	–	–	–	–	223.0	6.90	65	–	–	–
Botswana	267.0	14.99	4	194.3	4.16	4	75.5	1.91	4	41.0	1.63	4	241.7	6.66	3	133.0	4.97	4
Berseba	299.7	27.93	3	238.7	10.07	3	79.7	2.08	3	40.7	2.89	3	239.0	(230, 248)	2	130.0	–	2
Karibib	272.0	–	1	–	–	–	–	–	–	42.0	–	1	247.0	–	1	–	–	–
Swakopmund	294.0	–	1	191.0	–	1	83.0	–	1	–	–	–	–	–	–	–	–	–
Kaokoveld	263.0	–	1	180.0	–	1	77.0	–	1	41.0	–	1	258.0	–	1	142.0	–	1
Angola	262.5	15.64	10	201.4	9.88	11	75.9	2.47	11	36.0	2.81	11	242.4	8.27	11	135.2	4.34	10
♀ C.P	163.3	21.53	6	120.0	23.00	6	56.4	2.70	7	16.6	1.72	6	219.5	5.20	4	122.0	3.16	4
O.F.S.	164.0	17.69	3	110.3	24.70	3	57.7	4.04	3	16.7	0.58	3	217.7	2.08	3	119.0	3.61	3
Kimberley	180.0	24.30	34	–	–	–	–	–	–	–	–	–	215.0	7.50	34	–	–	–
Transvaal	187.0	–	1	113.0	–	1	57.0	–	1	20.0	–	1	234.0	–	1	132.0	–	1
Botswana	228.0	23.35	5	155.2	23.78	5	61.4	2.51	5	21.0	1.70	5	228.0	6.06	4	125.0	3.74	4
Aminuis	167.0	–	1	95.0	–	1	63.0	–	1	–	–	–	–	–	–	–	–	–
Swakopmund	229.0	–	1	157.0	–	1	61.0	–	1	–	–	–	–	–	–	–	–	–
Kaokoveld	203.0	–	1	159.0	–	2	65.0	–	2	22.5	–	2	236.0	–	1	131.0	–	1
Angola	227.3	5.03	3	138.7	12.66	3	62.7	1.15	3	23.0	1.00	3	224.3	3.86	4	124.3	2.08	3

Cape Province, Kimberley and finally those from the Orange Free State. Relative to males, females are slightly larger in the south; mean skull length of females is 95.7 % of males for Cape Province and 96.4 % for Kimberley, compared to 94.3 % for Botswana and 92.5 % for Angola. The skull length differences are more dependent on the elongation of the preorbital region, which differs significantly between samples, than on that of the postorbital region. The breadth measurements (not given here) varied in the same direction as the length measurements but to a smaller degree; so that BLAINE's (1922) statement that the Angola race has a narrower skull is not substantiated.

Horns, in males, are longest in Berseba and Swakopmund but also very long in the Kimberley sample. The single male from the Orange Free State has extremely short horns. The females tell a different story: horns are very long in the Angola, Namibia and Botswana samples (a single specimen from Aminuis excepted), but short in the Cape and Orange samples with Kimberley and Transvaal being intermediate. These differences are reflected in the basal breadth (across both horns) and the anteroposterior basal diameter of a single horn: exactly as BLAINE and THOMAS stated, *angolensis* and even more *hofmeyri* have horns which are nearly as massive in females as in males, whereas in the southern forms they are thin and weak. In the northern forms, the females' horns are clearly annulated, which they never are to any noticeable extent in the southern forms. Table 2c shows how, in both length and anteroposterior diameter, the horns of females behave with respect to those of males in the various samples.

The last metrical character showing significant variation is horn span. The horns spread

Table 2

Skull characters in *Antidorcas* skull samples

a. Premaxilla type in Springbok skulls

	Type a	b	c	d
Cape Province	1	2	8	
Orange Free State		2	2	1
Botswana		1	6	1
Berseba		1		1
Karibib	1			
Kaokoveld	1		1	
Angola		8	5	

b. Presence of p^2

	present	alveolus	absent
Cape Province	5	3	2
Orange Free State	2	2	
Transvaal	1		
Botwana		1.5	7.5
Berseba		1	1
Kaokoveld	1	1	1
Angola	2	1	3

c. Horn characters

	Horn rings, male:			Female as % of male:		Tip-to-tip	
	Mode	Range	n	Horn length	Horn a-p	as %	of span
Cape Province	18	14–20	9	62.5	42.8	50.6	77.4
Orange Free State	18	–	1	71.6	48.4	48.2	65.9
Kimberley	17	10–25	63	62.5	–	–	–
Botswana	(20)	16–25	4	85.4	41.2	58.9	74.4
Berseba	–	19–20	2	–	–	47.6	–
Swakopmund	(22)	–	1	77.9	–	29.3	62.4
Kaokoveld	(18)	–	1	77.2	54.9	36.1	53.1
Angola	16	11–19	10	86.6	63.9	45.5	56.0

more in Berseba than in any other sample as far as males are concerned (Table 1); in females it is the Namibia and Botswana samples that spread most widely. From Table 2c (Tip-to-tip as percent of span), it can be seen that the tips are hooked in rather more in Kaokoveld and Angola, in both sexes, than in any other population.

The number of annulations on the male's horns is greatest in the desert forms (Table 1) as one might expect from their very long horns. Combining all the desertic samples together gives a mode of 19 rings, with a range of 16-22, for 7 specimens: on average a greater number than for other samples. The male horn length for Angola is the same as that for Cape Province, but the modal number of rings is two less.

In the Angola sample, a point contact of premaxilla with nasal (Type b in Table 2a) is most frequent; in all others, a greater degree of contact (Type c) is commonest. No contact (Type a) and premaxilla-nasal-contact greater than maxilla-nasal (Type d) occur sporadically.

The absence of the anterior upper premolar (P^2) is often cited as a difference between *Antidorcas* and *Gazella*. This is not the case (Table 2b) though the absence of the lower one is. It was noted when the premolar was present; when it was absent but the presence of an alveolus revealed its former presence; and when it was absent and there was no trace of any alveolus. It may be that some individuals never develop this tooth; but the usual state of affairs seems to be that it erupts but is shed during adult life. (Unfortunately RAUTENBACH [1971] has nothing to say on this matter, as his dental study was concerned exclusively with the mandibular set). As the approximate age range in each sample was comparable – almost no excessively aged animals, and juveniles were excluded for the analysis – the differences shown in Table 2b would mean that P^2 is shed much earlier in the Botswana sample than in the others. The ".5" values in the table refer to a skull in which an alveolus was detectable on one side but not on the other.

Simple inspection of the skulls shows another character, noted by BLAINE (1922), to be valid, at least on average: the frontal profile is straighter in the Angolan and desertic forms, as the horns lie back more in line with the frontal plane in most cases.

Discussion

The skull and horn measurement differences were tested for their significance (Coefficient of Difference, i. e. difference between means divided by sum of standard deviations, should be greater than 1.27 for a "90 % joint non-overlap" as required for conventional subspecific differentiation). Between Cape Province and Orange Free State samples, this function amounts to 3.06 in Skull Length; but as the standard deviations of both seem to be far too small, and the Kimberley sample falls between the two with a standard deviation that includes them both, this finding is rejected. As there are no other differences between the three samples – there are differences on average, but nothing approaching absolute – they may be placed in one subspecies.

The various desert samples, from Botswana and Namibia, are all much too small for any significant differences between them to emerge, although the size differences are quite large and there could well be a cline in increasing size from Botswana via southern Namibia to Kaokoveld; the Botswana sample also has smaller horns than the others. But the skins are virtually identical, and such characteristics as the high frequency of absence of P^1 and the numerous horn rings unite them all. Together they may be taken to form a second subspecies.

The Angola skulls differ at above the 1.27 C.D. level from Cape Province in male skull length and preorbital length, and in female horn length and basal disameters. The same measurements, except for horn basal breadth of females, differentiate Angola from Orange Free State; and, in the measurements available, from Kimberley. The Angola race therefore

forms a subspecies distinct on its measurements, as well as skin characters, from that of the Cape and Orange. As far as the desert race is concerned, there is much in common between it and the Angolan form, notably the large horns of the female, but there is a sharp break in other characters: the absence of the brown forehead margin appears quite suddenly in Angola, and the nearest Namibian population, from Kaokoveld, is in its extremely large size the least like the Angolan form.

Between the desert race and the southern form there seems equally to be a break; in skin characters, in size, and in female horn size. A female frontlet and horns from Upington, Orange River (B.M. 23.5.9.178), shows the full robusticity of the desert race; the sample from Kimberley, not too far from Upington, as far as its skull and horn characters go shows no approach to the desert race. Only the single female skull from Transvaal (Sandfontein) does so – large like the desert from, but short-horned though the anteroposterior basal diameter is large. The Sandfontein skull may perhaps represent an intergrade though it is certainly nearer the desert race; but the female frontlet from Aminuis, well within the range of the desert race, is another with short horns, duplicating the only *marsupialis*-like feature of the Sandfontein skull for which, unfortunately, no skin is preserved.

Roberts (1951) and Shortridge (1935) list external measurements; a few are recorded also for some of the museum specimens studied here. As Blaine (1922) noted, the ears of the Angola (and desertic) springbok are larger than those from the Cape. While Head and Body Length measurements encompass much the same range, Ear length is 133-147 in the Cape, 154 to 185 in N'Kate (Botswana), 170-185 in Berseba, 183-198 in Kaokoveld, and 174-190 in Angola (both sexes). Interestingly, shoulder height also varies: Cape 762-765, N'Kate 770-820, Berseba 810-860, and Kaokoveld 860-870; this suggests that the more northerly forms (at least from the desert areas) may be clinally longer-legged, or perhaps – remembering the different skull sizes – it would be better to describe them as "shorter-bodied".

The three subspecies classification of Springbok is therefore supported:

1. *A. m. marsupialis* Zimmermann, 1780: Cape Province, Orange Free State, southernmost Transvaal (Lombard). Synonyms *euchore, centralis.*
2. *A. m. hofmeyri* Thomas, 1926: N. Transvaal (Sandfontein), N. Cape Province (Upington), Botswana, Namibia (desert form).
3. *A. m. angolensis* Blaine, 1922: Angola, north to latitude of Benguela.

Conclusion

The Springbok demonstrates two modes of geographic variation: subspecies and clines. The three recognized subspecies are at once distinguishable on their external characters; there is a sharp break between them, as well, in size (as measured by skull length), and between *hofmeyri* and *marsupialis* in the horn length of the female. But when the subspecies have been elucidated there remains more to say about geographic variation.

Though the material is very scanty, a size cline runs through *A. m. hofmeyri* from south to north: Botswana/Berseba via Karibib to Kaokoveld in males; though no female skulls are available for Berseba or Karibib, the one from Kaokoveld is much larger than the mean, and even 2 mm larger than the maximum, for Botswana so implying the existence of the same relative size relationship. The horn-tips in both sexes turn progressively more inwards, and the basal diameter of the horns in the female increases, along the same cline. The smaller members of the cline abut on the range of the small *A. m. marsupialis*, but at least in males there is no overlap in skull size, while a cline within the nominate race itself runs in the opposite direction to that which would be expected in theory: it is the small end

of the cline (Kimberley and Orange Free State) that is geographically nearer to the large *A. m. hofmeyri.*

At the north western end of the range of *A. m. hofmeyri* occur the largest members of that subspecies; there is then a sharp break – presumeably, across the Cunene River – to *A. m. angolensis,* which in size resembles the small southern *hofmeyri,* and in external characters is quite different from all other races. The cline can therefore hardly even be described as "stepped": rather, it ends at the end of the range of *A. m. hofmeyri,* and starts afresh across the subspecies border in *A. m. marsupialis.*

What environmental variables control the size and horn clines can only be a matter for speculation at the moment. In the case of the difference between subspecies, it is evident that the colouration at least corresponds to aridity. The subspecies boundaries seem to be in the vicinity of major rivers: the Cunene in the case of *hofmeyri/angolensis,* and perhaps the lower Orange and Vaal in the case of *hofmeyri/marsupialis* (although one of the recorded nineteenth century migration routes crossed the Orange in the Prieska district (Shortridge 1934): probably of *A. m. hofmeyri,* as the Upington specimen (see above) is of this race); but these boundaries at the same time lie within fairly steep environmental gradients (the upper Orange, at least, has no such effect) so might be expected to interrupt gene-flow sufficiently to enable selection to proceed unchecked. The sharp size differentiation at the subspecies boundaries could itself function as an isolating mechanism. Field studies at the subspecies boundaries, if these boundaries still exist intact, should be of great interest as indicating not only whether the great rivers are crossed (the "trekbokken" of the western Cape certainly crossed the lower Orange) but whether there is any reduction of interbreeding in these zones, i. e. whether speciation is in progress.

This is, of course, a major reason why subspecies cannot merely be taken for granted; any revision of a species should start anew and try to discover whether subspecies exist at all, or whether the whole geographic variation can be ascribed to clines, or whether indeed – as in the present case – both modes of variation exist. It is also the reason why available samples must be broken down into the smallest viable units, and remain so broken: to lump, for example, all the Namibian and Botswanan samples into one series and calculate statistical parameters for "*hofmeyri*" would be to create an abstraction, to invent a population; and, in any case, to lose much of the significant information inherent in the geographic variation of the subspecies and the species as a whole.

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Zusammenfassung

Unterarten beim Springbock (Antidorcas)

Auf Grund morphologischer Kennzeichen (Schädel, Fell) sind drei Unterarten von *Antidorcas* gut zu charakterisieren: *Antidorcas marsupialis marsupialis* Zimmermann, 1780; *A. m. hofmeyri* Thomas, 1926 und *A. m. angolensis* Blaine, 1922. Obwohl jede Unterart von den anderen deutlich abgrenzbar ist, zeigen die beiden erstgenannten einige Variationen. An den Grenzen ihrer Verbreitung treten bei diesen Subspecies in stärkerem Maße Ähnlichkeiten mit den benachbarten Unterarten auf.

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BUCHBESPRECHUNGEN

Bond, C.; Siegfried, R.; Johnson, P.: **Antarktika**. Ein Kontinent rückt näher. Hannover: Landbuch Verlag 1980. 180 S., 101 Farbfotos. 68,– DM.

Die Bundesrepublik Deutschland ist seit 1978 Mitglied des Antarktisvertrags von 1959 und hat damit die Verpflichtung übernommen, durch „erhebliche wissenschaftliche Forschungsarbeiten" zur Kenntnis dieses Kontinents beizutragen. Der Aufwand der Bundesrepublik ist beachtlich: im Südsommer 1980/81 ist der Aufbau der deutschen Station auf dem Filchner-Schelfeis an der Weddell-See geplant, ein Polarforschungsinstitut wurde gegründet, ein Polarschiff wird gebaut, Forschungsprogramme werden finanziert. Der Untertitel des vorliegenden Buches ist daher für Deutschland besonders aktuell. Dieser großformatige Bildband, die deutsche Übersetzung einer südafrikanischen Ausgabe, besticht vor allem durch seine eindrucksvollen Farbfotografien von Landschaft und Tieren. An die ungewöhnliche Zusammenstellung sämtlicher Bildunterschriften am Ende des Buches muß sich der Leser erst gewöhnen. Im Text wird zunächst ein Abriß der Entdeckungsgeschichte gegeben, auf die Kontinentalverschiebungstheorie, die Eisentstehung und die dominierenden Umweltfaktoren Wind und Kälte wird eingegangen. Pinguinen, Albatrossen, Walen und Walfang, Robben und Robbenschlag und Krill werden Kapitel gewidmet. Das Schlußkapitel befaßt sich mit der ungewissen Zukunft der Antarktis, vor allem mit dem Antarktisvertrag, der die potentiellen Ressourcen der Antarktis noch bis 1991 vor der offiziellen Ausbeutung bewahrt. Das Buch ist eine gute, populäre Einführung in die Problematik dieses Kontinents.

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Bruemmer, F.: **Sattelrobben**. Traum und Tragik im Nordmeer. Hannover: Landbuch Verlag 1978. 174 S., 104 Fotos, davon 68 farbig. 58,– DM.

Im März jeden Jahres erreicht die von Tierschutzverbänden und der kanadischen Regierung geführte öffentliche Kontroverse über die Jagd auf Sattelrobben vor der Küste Neufundlands ihren Höhepunkt. Für 1980 hatten die Behörden, wie für die beiden Vorjahre, 18 000 Robben zur Jagd freigegeben, drei Viertel davon „White-coats". Die Höhe dieser Quote ist umstritten, und auch kanadische Biologen befürchten, daß sie den Niedergang der Art fortsetzen wird. Im vorliegenden, großformatigen Band wird die 200jährige Geschichte des Sattelrobbenschlagens anschaulich geschildert, und einige Fakten sollen hier erwähnt werden. Die Bestände der Front- und Golfherden bei Neufundland sind in dieser Zeit auf ein Zehntel ihrer ursprünglich angenommenen Größe von 10 Millionen geschrumpft. Insgesamt wurden dort etwa 60 Millionen Sattelrobben getötet, womit es sich um die wohl am intensivsten ausgebeutete große Wildsäugerart handelt. Der Höhepunkt der Verfolgung war 1850 erreicht, als durch die Beteiligung der Walfänger, die im Nordmeer kaum noch Beute machten, die Millionengrenze erschlagener „White-coats" überschritten wurde. Neben der Jagd bildet die Darstellung der Biologie der Sattelrobben ein weiteres Anliegen des Buches. Die Naturgeschichte der kanadischen Populationen wird in populärer Art nach dem derzeitigen Wissen geschildert. Ein Literaturverzeichnis rundet das Buch ab. Wenn man von Druckfehlern und einigen Übersetzungsmängeln absieht, handelt es sich um ein auch für Fachleute empfehlenswertes Buch mit eindrucksvollen Bildern. Allerdings hätte man sich zusätzlich einige andere als nur Robbenbilder gewünscht, die auch andere Aspekte der arktischen Meeresökologie hätten veranschaulichen können.

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