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Genetica. — *The number of bears living in the dolomites of Brenta.* Nota di CLAUDIO BARIGOZZI e ITALO BARRAI, presentata (*) dal Corrisp. C. BARIGOZZI.

RIASSUNTO. — Nella presente ricerca viene stimato il numero di Orsi bruni (*U. arctos L.*) viventi nel Trentino nell'intervallo che va dal 1956 al 1965. Le informazioni derivano da dati raccolti mediante questionari inviati a residenti nella zona abitata dagli Orsi (Adamello–Brenta), elaborati introducendoli in una formula che stima il numero degli orsi dal numero di incontri (includendo in questi tutte le osservazioni della presenza di un orso). Il risultato più probabile cade entro i limiti di 7 e di 14 individui, in buon accordo con precedenti valutazioni. La esigua consistenza numerica viene considerata un raro esempio di piccola popolazione isolata.

The estimate of the effective size of a population presents unusual challenges to the geneticist. Effective size, or effective number, has important consequences on the variation of gene frequencies in successive generations: if the effective number is small, genetic drift predominates in the process of fixation of an allele at a given locus; when it is large, genetic drift has practically no effect, and distribution of allele frequencies is sharply centralized.

In other words, a small effective size may have the same consequences as a large selection against one allele, and a large effective size may have the same consequences as stabilizing selection.

The problem of estimating effective size may be solved when the demographic parameters of a population are known, as often is the case in man; however, the solution is difficult when the interest is devoted to species where demography, genealogy and migrational parameters are unknown. A first crude approach is the estimate of the actual size or population number, which is greater than the effective size. Our aim in the present work, is the estimation of the population size of the brown bear (*Ursus arctos* L.) living at present in the Dolomites of Brenta, on the Adamello, and in the region of Lake Tovel (province of Trento).

The area which is inhabited by the bear comprises the Val Rendena with the lateral valleys, the Val di Genova, the region around the Presanella, the Val Vermiglio, Val di Noce and the Brenta group including Tovel lake. The persistence of this species in the area is an interesting phenomenon, since the bear is at the vertex of a pyramid of numbers, and the ecology of

(*) Nella seduta dell'11 marzo 1972.

the region is inadequate for the survival of the species. The questions we want to answer in the present work are:

1) If the estimate previously obtained empirically by one of us (Barigozzi 1963) on the same material is compatible with the present estimate.

2) If the bear population in the area is large enough to maintain the species, or if there is risk of extinction.

MATERIALS AND METHODS

During the period 1956–60 and 1964–65 questionnaires were sent to 26 local observers (game wardens, etc.) in the region inhabited by the bear. The distribution of the questionnaires sent, of the answers obtained is given in Table I. The questionnaire sent to the observers included the following questions:

1) Were bears seen in your zone? When? Adults or young? Was the coat color noted?

2) In the same period and zone, were tracks observed? Of how many individuals? Adult or young? When?

3) Have you had any other information on the activity of the bear in your area since spring? (Such as different signs of presence, animals killed and so on).

These were the key questions of the questionnaire from which it is possible to count the numbers of animals seen, the number of tracks, and the number of herbivorous animals killed by the bear, so that we may study the distribution of these parameters. For the estimation of the number of animals, we used a relation establishing a proportion between the number of encounters, the number of observers, the probability of encounter and the probability of reference of an encounter by an observer to whom a questionnaire was sent.

In formula,

$$I = N n P_i P_r$$

where I is the number of encounters, N the number of animals, n the number of observers, P_i the probability of encounter, and P_r the probability that an observer answers a questionnaire.

The estimate of N is then

$$N = \frac{I}{n P_i P_r}.$$

We use probability of encounter as synonymous to probability of observation, although " encounter " does not mean intersection of trajectories but only the sighting of the bear by the observer at any distance.

TABLE I.

GAME WARDENS OR OBSERVER	YEAR								LOCATION OF RESIDENCE
	56	57	58	59	60	64	65	Total	
BONI	+	+	+	+	—	+	+	6	Tione
COLLINI . . .	+	+	+	+	+	—	—	5	Pinzolo
STEFANELLI . .	+	no	—	—	—	—	—	1	Bolzano
MAFFEI . . .	+	no	no	—	—	+	+	3	Cles
CITRONI . . .	+	no	+	+	+	+	+	6	Bormio
MOLINARI . .	+	+	+	—	+	+	—	5	Breguzzo
GENTILINI . .	+	+	—	—	—	—	—	2	Malè
FERRARI . . .	+	+	+	+	—	+	+	6	Breguzzo
GHEDINA . . .	—	+	no	+	+	+	+	5	Stenico
BEZZI	+	+	+	+	—	—	+	5	Trento
TISI	—	+	no	+	—	—	—	2	Tione
MANINI . . .	—	+	+	no	—	+	+	4	Storo
SERAFINI . .	—	+	+	+	+	—	—	4	Trento
DE PAOLI . .	—	no	+	—	—	—	—	1	Trento
CATTANI . . .	—	—	+	—	—	—	—	1	Termon
KROTT	—	—	+	+	—	—	—	2	Pinzolo
DELL'EVA . .	—	—	—	+	+	+	+	4	Fucine
TODESCHINI .	—	—	—	—	+	no	+	2	Stenico
PANIZZA . . .	—	—	—	—	+	+	+	3	Cles
BONTEMPELLI .	—	—	—	—	+	+	+	3	Pellizzano
TOGNI	+	no	+	no	+	—	—	3	Daone
RUATTI . . .	—	—	—	—	+	—	—	1	Terzolas
BELFANTI . .	—	—	—	—	+	+	—	2	Tione
ALIMONTA . .	—	—	—	—	—	+	+	2	Madonna di Campiglio
CAVALLAR . .	—	—	—	—	—	+	+	2	Giustino
ONORATI . . .	—	—	—	—	—	+	+	2	Val Genova
TOTAL	10	10	12	10	12	14	14	82	

+ = answered; no = not answered; — = not sent.

We decided to estimate the probability of encounter from the distribution of the number of encounters with bear, tracks, and killed herbivores, under the assumption of Poisson and geometric distribution of these variables, and with the non parametric method.

RESULTS

Ninety-three questionnaires were sent to 26 observers; 82 answers were obtained. The distribution of the number of observers per number of questionnaires sent and for answer obtained is given in Table II. The probability of answer is $P_r = .88$.

TABLE II.

Questionnaires sent and answers obtained by observer.

QUESTIONNAIRE SENT	ANSWERS						TOTALS
	1	2	3	4	5	6	
1	2						2
2	2	6					8
3		2	2				4
4				2			2
5			2	1	3		6
6					1	2	3
7						1	1
TOTALS	4	8	4	3	4	3	26

Each answer gives information on the number of bears sighted, on the number of times that tracks have been seen, and on the number of attacks to herbivorous animals. The distribution of encounters (I), of tracks (T) and of killed animals (S) by observer and year is given in Table III.

In three questionnaires, the number of times footprints were seen was not given; in four questionnaires, the number of attacked animals was not given; the expected value was in this case substituted for the missing data, so that the substitution does not affect the values of chi squares.

In 1965, no observer answered the question of herbivorous animals killed.

a) *The number of encounters.*

In the periods covered by our investigation, 74 encounters were reported by the observers. The distribution by year and questionnaire is given in Table IV. The maximum number of sightings observed per year is 4. In

TABLE III.

	1956			1957			1958			1959			1960			1964			1965		
	I	T	S	I	T	S	I	T	S	I	T	S	I	T	S	I	T	S	I	T	S
1	0	1	0	0	1	4	0	1	0	0	0	0	2	5	1	0	3	9	1	2	0
2	0	1	4	0	3	2	0	0	3	4	6*	6	1	0	0	0	0	0	1	11	0
3	0	2	2	2	5	9*	0	1	0	4	6	5	1	0	9	1	2	0	0	1	0
4	0	2	2	0	2	11	1	3	1	1	3	0	1	2	1	3	3	5	0	2	0
5	3	0	3	1	3	7	0	0	0	3	2	0	4	8	17	1	2	2	0	1	0
6	1	1	0	0	2	0	1	2	1	4	6*	1	2	0	5*	2	5	1	0	1	0
7	0	1	3	0	2	4	0	0	0	0	1	0	0	0	0	0	3	0	0	1	0
8	1	2	2	1	2	3	3	0	0	0	0	1	3	11*	20	0	2	0	0	2	0
9	2	3	7	0	2	0	1	0	2	4	4	4*	0	1	0	0	4	0	1	1	0
10	0	0	0	0	1	0	0	1	0	0	1	0	1	1	0	0	2	0	0	2	0
11							3	3	9				1	0	2	0	1	6	0	2	0
12							2	2	3*				0	0	0	0	2	0	3	1	0
13																0	1	0	0	3	0
14																1	2	0	2	3	0
TOTAL	7	13	23	4	23	40	11	13	19	20	29	17	16	28	55	8	32	23	8	33	

* Estimated

1957 only four animals were seen; in 1959, twenty were seen. In the last two years of investigation, eight bears were seen each year; in these two years, the number of observers increased.

TABLE IV.

Distribution of encounters by year and answer.

ENCOUNTERS	YEAR							TOTALS
	56	57	58	59	60	64	65	
0	6	7	6	4	3	9	9	44
1	2	2	3	1	5	3	3	19
2	1	1	1		2	1	1	7
3	1		2	1	1	1	1	7
4				4	1			5
TOTALS	10	10	12	10	12	14	14	82

Footprints were seen 171 times (Table V); the maximum number was seen in 1965, when they were seen 33 times; one observer in this year reported having seen prints eleven times.

TABLE V.

Distribution of footprints by year and answer.

FOOT-PRINTS	YEAR							TOTALS
	56	57	58	59	60	64	65	
0	2		5	2	6	1		16
1	4	2	3	2	2	2	6	21
2	3	5	2	1	1	6	5	23
3	1	2	2	1		3	2	11
4				1		1		2
5		1			1	1		3
6				3				3
8					1			1
11					1		1	2
Totals . .	10	10	12	10	12	14	14	82

Herbivorous animals were attacked and/or killed 177 times (Table VI). The animals were sheeps, goats, calves, fawns; in two cases beehives were attacked close to houses. In 1960, 55 animals were killed by bears.

TABLE VI.

Distribution of killings of herbivores by year and answer.

KILLINGS	YEAR						TOTALS
	56	57	58	59	60	64	
0	3	3	6	5	5	9	31
1			2	2	2	1	7
2	3	1	1		1	1	7
3	2	1	2				5
4	1	2		1			4
5				1	1	1	3
6				1		1	2
7	1	1					2
9		1	1		1	1	4
11		1					1
17					1		1
20					1		1
Totals . . .	10	10	12	10	12	14	68

In the case of attacks, it is more difficult to establish a proportionality with the number of bears; one questionnaire states that nine sheep were killed on the same night of 13 June 1960 near Vermiglio. The same questionnaire mentions that a she-bear with one cub was seen on 25 May near Ossana, and she might be responsible for the killing of the nine sheep near Vermiglio.

b) *Estimate of the number of bears.*

The encounters, the finding of footprints, the attacks to herbivorous animals might be considered rare events; therefore, it would be useful to fit to the observed distributions (given in fig. 1) a Poisson distribution, so that it is possible to estimate the probability of encounter, P_i, with a maximum likelihood method.

The hypothesis of a Poisson distribution may be entertained for two main reasons; firstly, it is reasonable to assume that the senses of the bear are sharper and more on the alert than those of the observer, so that the bear has more chances to see the observer and avoid being seen.

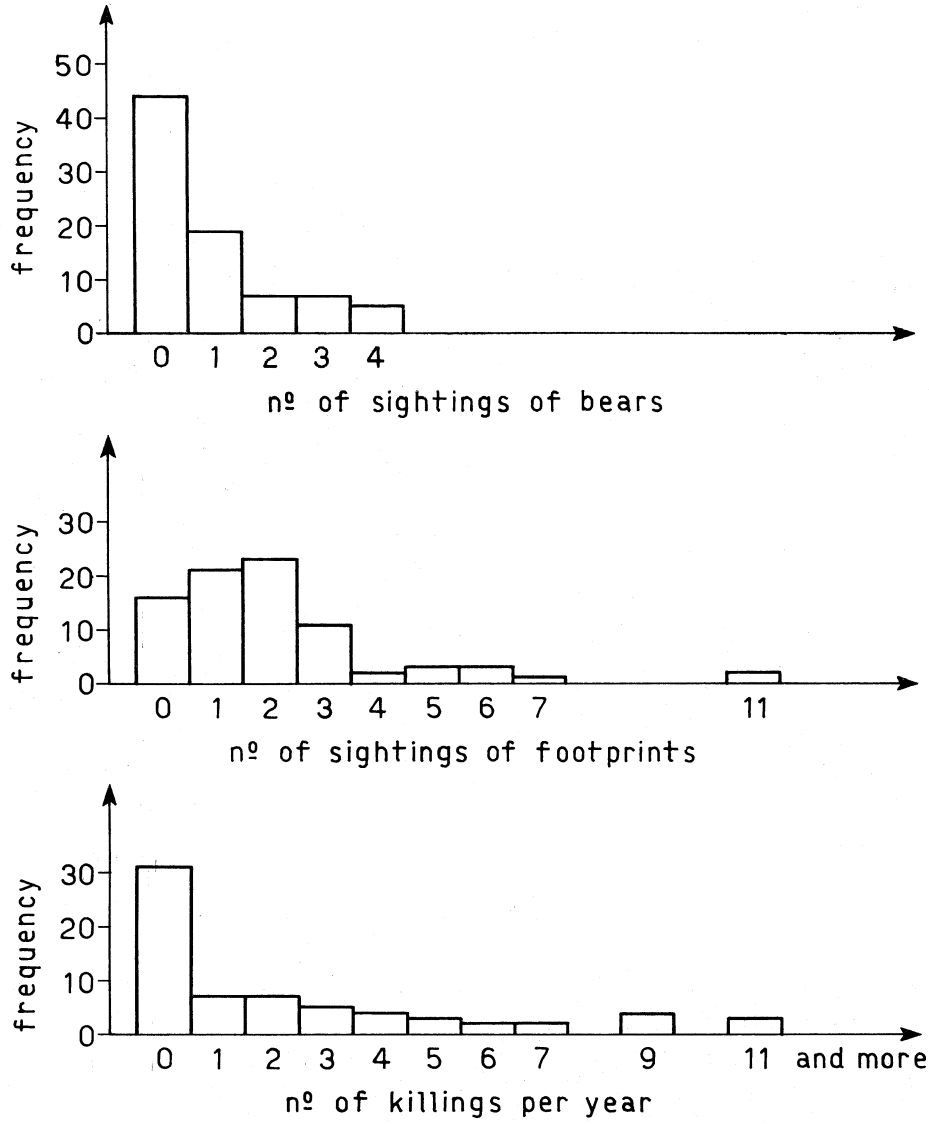

Fig. 1. – Diagrams of the frequencies of the different types of observations.

The Poisson distribution has less strength in the case of footprints or of attacks to herbivores. Tracks may be seen on soft ground, under favourable conditions. Rain, passing of other animals and of man will tend to cancel footprints more or less rapidly. The reporting of attacks on other animals may be more definite; particularly if domestic animals are killed, the news

circulates rapidly in the area, and game wardens may go and see for themselves if the bear is responsible for the killing. As an alternative to Poisson, it is possible to consider the geometric distribution. In such case, the probability of x encounters is:

$$P(x) = P_i^x (1 - P_i)$$

where the encounters, or the tracks, or the killing are considered as single sequences of events in a given period.

If an a priori distribution is not needed, one may estimate empirically the probability of an observation, applying the concept of statistical probability, through the ratio between the number of encounters and the number of answers obtained. In the case of sightings of bears from our material, this ratio is number of animals seen (38) to number of questionnairs answered (82) namely 0.46.

We computed the probability of encounters for the sighting of bears, of footprints, and for the killings of other animals. In the three cases, the probability was calculated assuming Poisson and geometric distribution of the events, and no a priori distribution. In such way, we obtained nine estimates of the number of bears, where the basic formula is

$$N = \frac{I}{P_i P_r n} .$$

Both I and n are constant, and the error of N depends on the variability of P_i and P_r. The errors of P_i and P_r were computed both empirically and with the method of maximum likelihood in the case of a priori distributions. Distributions were fitted using standard Fortran IV programmes for the Poisson and the geometric. We computed the fiducial interval of N at the 1 % level of probability, given the many components of uncertainty in the estimates. The error of N is

$$\sigma_N = \pm \frac{I}{n} \frac{1}{(P_i \pm 3\sigma_{P_i})(P_r \pm 3\sigma_{P_r})}$$

where σ_{P_i} and σ_{P_r} are the errors of P_i and P_r. The results of the analysis are given in Table VII. The estimates of the number of bears, obtained with the different methods, are surprisingly similar. The values of N range from 6 to 14, with a mean at 9. The fiducial intervals of the number of bears, obtained from the sighting of animals, have a lower limit of 4 bears (Poisson) and an upper limit of 13 bears (empiric probability).

It is interesting to note that the geometric distribution fits the observed distribution of sightings ($\chi^2 = 5.76$, not significant). All other tests for goodness of fit are highly significant.

From the distribution of the number of times footprints were seen, one obtains lower limit of 7 animals from Poisson and empiric, and an upper limit of 14 animals (from the geometric distribution).

TABLE VII.

Estimate of the number of bears.

	BEARS	FOOTPRINTS	KILLINGS
Encounters	74	171	177
Observers	26	26	26
P_r	0,88 ± 0,03	0,88 ± 0,03	0,88 ± 0,03
P_i empirical	0,46 ± 0,06	0,80 ± 0,04	0,54 ± 0,06
P_i Poisson	0,59 ± 0,04	0,88 ± 0,02	0,93 ± 0,02
^{2}	***	***	***
P_i geometric	0,47 ± 0,04	0,68 ± 0,03	0,72 ± 0,03
^{2}	n.s.	***	***
Empirical N	7	9	14
1 1/2 limits	5–13	7–13	10–24
Poisson N	6	9	8
1 1/2 limits	4–8	7–10	7–10
Geometric N	7	11	11
1 1/2 limits	5–10	9–14	9–13

*** = ^{2} highly significant;
n.s. = ^{2} non significant.

The number of killings of herbivores might seem, for the reasons stated above, a poor substitute for the estimate of the number of bears; however, the lower limits of N are consistent with those obtained from the footprints. The upper limit is 24 bears, obtained from the empiric probability.

Taking these results at their face value, one might expect that as few as four animals may be active in the area, and as many as twenty four might be active.

The average of lower limits is 7; the average of upper limits is 13 bears.

DISCUSSION

The findings of the present study practically confirm those obtained by Barigozzi in 1963 using the data for the period 1956–60. Barigozzi, with another procedure, concluded that only 10–12 bears lived in the area; the present estimates range from 6 to 14, with an average of 9.

We believe that at the present time the number may have decreased, although every year we have news of a she-bear with one cub having been sighted. This presence of young might speak in favor of survival for the group in the Adamello–Brenta area. Our belief that the number is on the decrease, is due to the fact that the animals, being such a small group, are highly inbred (or will rapidly become so).

We have practically no information on the genetic heterogeneity in the group; some animals have been reported as having a specific coat colour, which would speak in favor of at least some residual variability. Further, we cannot exclude that this group is free from deleterious genes affecting fitness, so that it might withstand inbreeding for many more generations. Whether or not it can withstand spreading of tourism and urbanization in the area, is a different question.

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