

# Changes in the breeding variables of the Mediterranean Monk seal (*Monachus monachus*) colony of Cabo Blanco Peninsula after a mass mortality episode

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*Summary.* – The breeding variables of the Mediterranean monk seal colony of Cabo Blanco peninsula were studied after a mass mortality episode that drastically reduced their size and altered their age-structure. A comparison of breeding variables data of the pre and post mortality event (1994-1997 versus 1997-2000) indicates : a reduction of annual productivity, an increase of the birth rate and of the young mature females in the reproductive tasks, and in other respects, changes in the use of caves for birth locations. The only variable that did not change was pup survival. The causes of these changes are discussed and suggested explanations are given relating to : decrease in the inter-birth interval, immigration, availability of breeding habitat and the effects of human interference in the breeding caves during the mass mortality episode. The availability of breeding habitat was proposed as a possible limiting factor that avoid the local recovery of the colony. Reoccupation of open beaches as breeding habitat is proposed as conservation tool for the species recovery.

*Résumé.* – Les conditions de reproduction du Phoque moine de Méditerranée dans la colonie de la péninsule du Cap Blanc ont été étudiées après un épisode de mortalité massive qui a réduit considérablement cette colonie et altéré sa structure d'âge. Une comparaison des données variables de la reproduction avant et après cet épisode (1994-1997 et 1997-2000) indique une réduction de la productivité annuelle, un accroissement du taux des naissances et des jeunes femelles matures dans les tâches reproductives, et aussi des changements dans l'utilisation des grottes comme lieux de naissance. La seule variable qui n'a pas changé est la survie des jeunes. Les causes de ces changements sont discutées : la diminution de l'âge de la première reproduction, l'immigration, la non-disponibilité d'un habitat de reproduction et les effets de l'interférence de l'homme dans les grottes de reproduction au cours de l'épisode de mortalité en masse, sont des explications envisagées. La non-disponibilité d'un habitat pour la reproduction pourrait être le facteur limitant qui empêche le rétablissement local de la colonie. La réoccupation des plages comme sites de reproduction serait un moyen de favoriser le rétablissement de l'espèce.

**KEY WORDS :** Mediterranean monk seal, *Monachus monachus*, western Sahara, productivity, breeding rate, pup survival, habitat, conservation.

## INTRODUCTION

In recent years, there has been an increase in concern over the incidence of marine mammal mass mortalities throughout the world (Harwood and Hall 1990). The Mediterranean monk seal (*Monachus monachus*), one of the most endangered species in the world (IUCN 1996), suffered a two month mass mortality episode in 1997, in the species' largest world-wide aggregation site, that of the Cabo Blanco Peninsula (Morocco-Mauritania). The mortality episode, attributed most likely to intoxication through the consumption of prey items contaminated with paralytic shellfish poison saxitoxins (PSPs) (Hernández *et al.* 1998 ; Reyero *et al.* 1999), reduced the size of the colony, estimated at 317 individuals (CV = 0.16 ; 95 %, CI : 237 to 447) before the event, to 109 individuals (CV = 0.14 ; 95 % ; CI : 86 to 145) afterwards (Forcada *et al.* 1999). This mainly affected the adult population, resulting in a severe change in the age composition of the colony. As consequence, was hypothesised that this change is likely to : 1) reduce the reproductive potential of the colony due to the reduction of the number of reproductively active individuals and the increased contribution of young, recently matured individuals to reproductive tasks (Forcada *et al.* 1999) and 2) increase the pup survival rate due to the decreased in the density of hauled out individuals inside the breeding caves, that allows mothers to maximise the survival of their pups (Gazo *et al.* 1999a). The present paper compare the breeding variables of the colony three years after the episode with those obtained during four years before in order to examine if there has been the changes mentioned before. Also consider the factors which may have contributed to these changes.

*Study area and methods*

The Mediterranean monk seal colony of Cabo Blanco is located in the peninsula which bears the same name, and is situated in the southern coast of the western Sahara desert (21°02'N - 17°03'W). The peninsula borders with the Guerguerat territory to the north, and extends southward to the end of the Cabo Blanco lighthouse. The coast of the peninsula is made up of a succession of very high cliffs, occasionally interrupted by sandy beaches of eolic origin. The coastline where the seals live consists of almost 15 km of cliffs, named « Costa de las Focas », containing several deep caves with large beaches inside, where the seals haul out and breed (see description in Marchessaux 1989 and González *et al.* 1997). The area is characterised by high marine biologic productivity due to the effect of a continuous and potent oceanic upwelling (Mittelstaedt 1983). Coastline is exposed to storms and large oceanic swell that are frequent during fall and winter (Nistal and Vega 1997).

The number of pups born in the colony, the neonate survival (number of pups that survive to the age of two months), the perinatal sex-ratio (the frequency of males and females born), the reproductive category of mothers and the location of the births (cave-1 or cave-3), were recorded from July 1997 to December 1998 and from July to December 2000. Data was collected using the same methodology applied in previous studies (González *et al.* 1997 ; Gazo *et al.* 1999b, 2000a ; Samaranch and González 2000). This consists of : 1) monitoring the breeding caves to record births and to identify neonates individually, using the differences in their ventral patch design (Badosa *et al.* 1998), 2) marking pups with plastic tags applied to their rear flippers (Temple Tag Inc. P.O. Box 369, Temple, Texas, USA and Dalton Supplies, Henley-on-Thames, Oxon, UK) estimating their age based on the external morphology (González *et al.*

TABLE 1. – Reproductive histories of identified females monk seals. Filled = parturient ; open = non-parturient or not seen. I-S = immature size seal ; A-S = adult size seal.

Female Identification	1995	1996	1997	1998	1999	2000
H-7	I-S					
H-TI	I-S					
H-3	I-S	I-S				
H-2	A-S					
H-1	A-S		A-S			
H-PHI	A-S					
H-RA	A-S					
H-11	A-S					
H-8	A-S					
H-35	A-S					
H-26	A-S					
H-37	A-S					
H-55	A-S	A-S				
H-17	A-S	A-S				
H-12	A-S	A-S	A-S			
H-11		I-S				
H-65		I-S				
H-70		I-S				
H-51		I-S				
H-45		I-S				
H-PI		I-S				
H-96		I-S		I-S		
H-60		I-S	I-S	A-S		
H-55		A-S				
H-74		A-S	A-S	A-S		
H-77		A-S				
H-67		A-S				
H-77		A-S				
H-MA		A-S				
H-69		A-S				
H-81		A-S				
H-CU		A-S				
H-FG			I-S			
H-RA			I-S			
H-40			I-S	I-S		A-S
H-PR			I-S	I-S		
H-82			A-S			
H-16			A-S			
H-10			A-S			
H-61			A-S			
H-19			A-S			
H-36			A-S			
H-12			A-S	A-S		
H-CO			I-S			
H-M7				I-S		
H-16/00						I-S
H-11/00						I-S
H-18/00						I-S
H-17/00						I-S
H-02/00						I-S
H-06/00						A-S
H-25/00						A-S
H-15/00						A-S
H-20/00						A-S
H-10/00						I-S
H-22/00						A-S
H-21/00						A-S
H-14/00						A-S
H-23/00						A-S

1994 ; Gazo *et al.* 1999b) and 3) estimating the size category of the mothers using the same methodology described in Samaranch and González (2000).

The presence or absence of pups and mothers from the caves was assessed using two methods : 1) observations from a hanging platform (known as « guindola ») located at the entrance of the caves (see details in González *et al.* 1997) and 2) observations made with a video camera (CCTV Panasonic, model WV-CP610 and Grundig Fax 8301) fixed to the roof at the entrance to caves 1 and 3. The camera, which has a powerful zoom focus, covers approximately 70 % of cave-1's and 90 % of cave-3's beach surface and is capable of vertical-horizontal movements. Images from hauled-out seals were received on a TV colour monitor (Panasonic, WV-CM140) connected to a video cassette recorder (VHS Pal Panasonic AG-6124E), located in an observational hide out at the top of the cliff. The camera was manoeuvred by remote control from this hide.

A pup has no possibilities of survival without maternal attendance until the age of 2 months (the moult to younger stage, see Gazo *et al.* 1999b). The disappearance of a pup from the cave was considered as a case of mortality whenever a pup was absent from its birth cave or from any other caves in the area, and the mother was observed searching for the pup in the cave. On the basis of past research experience in the study area and given the topographic configuration of the coast and the direction of the prevailing winddriven surface currents, pup mortality must be ascertained by monitoring the 40 kms of beaches south of the breeding caves for dead stranded or lost pups. These beaches were thus regularly patrolled with a four-wheel vehicle in 36 occasions in 1997, 48 in 1998 and 24 in 2000. The six pups born during the mortality episode (four found alive and two dead) were excluded from the present analysis.

Two study periods were defined in order to compare this data with at previously obtained before the mass mortality episode : 1) the pre-mortality period, from March 1994 (beginning of data collection in the study area) to May 1997 (when the mortality episode began), and 2) a post-mortality period, from July 1997 (when the records of monk seal deaths in the colony, attributed to the episode, ceased) to December 1998 and from July 2000 to December 2000 inclusive. 1999 was not included.

The variables analysed were :

- 1) *Pup Survival Rate (PSR)*, defined as the proportion of pups born and monitored that reached youngster stage (2 month old). The six pups that were rescued and reintroduced to the colony in 1996 (1), 1997 (4) and 1998 (1), were considered as dead pups for the purpose of the PSR. The data for the period 1995-1997 were from Gazo *et al.* (2000a)
- 2) *Birth rate (BR)*. In a previous paper (Forcada *et al.* 1999), it was assumed that all the animals included in the categories 'Medium-sized seals' (immature-size) and 'Large gray seals' must be considered as adults and involved in reproduction. However, it was observed that 'Medium-sized seals' characteristics (class C in Samaranch and González 2000) appears at 18 mo and that females of this colony could reach sexual maturity at the age of 2,5 yr. (Gazo *et al.* 2000b). Therefore, the inclusion of all 'Medium-sized seals' as reproductive animals were overestimating the number of female potentially reproductive and consequently, may introduce a downward bias in the BR estimate. Unfortunately, and due to the lack of data about the proportion of individuals of this category engaged in reproduction we considered all 'Medium-sized seals' in BR calculation. Thus, the estimates calculated are considered as the lower limit for the Birth Rate.

On the other hand, not all the individuals included in these two categories are females. In a sample of 119 seals (64 males and 55 females) photoidenti-

fied before the mortality event (Samaranch and González 2000), the 37.5 % of the seals identified corresponding to the morphological class C (immature size) were females, and the 95.6 % of the seals identified corresponding to the morphological class D (grey adult-size) were females. The 100 % of the seals identified as morphological class E (black adult-size) were males (Table 1).

Then, and taking into account these considerations, we estimated the annual birth rate as the ratio between the annual pup production (lower limit for the population productivity as it does not account for pups unobserved) and an index of potentially reproductive females (IPRF). Each year we calculated the IPRF as the number of reproductive females of immature size plus the number of adult-size females.

We estimated the number of immature-size females seals of the colony assuming that the 37.5 % of the number of immature-size seals (Medium size seals in Forcada *et al.* 1999) were females.

In the same way, the number of adult-size females was calculated assuming that a 95.6 % of the Large-size seals (morphological class D) estimated for the colony (Forcada *et al.* 1999) were females.

## RESULTS

The annual productivity of the colony dropped to less than half that which was registered before the mortality episode (Table 1). However, in the last year (2000) the productivity seems to recover to similar levels to the years before the mortality, 28 and 36 pups during july-december of 1995 and 1996 (Gazo *et al.* 1999b).

TABLE 2. – Number of pups born annually (Annual pup production) ; number of pups survived to the age of two months (Pup survival) ; number of perinatal pup males (M) and females (F) (Sex-ratio) ; number of pups born in cave 1 (C-1) and born in cave 3 (C-3) (location of births) ; n.d. = non data;

	Annual pup production	Pup survival	Sex ratio		Location of births	
			M	F	C-1	C-3
1994	52	n.d.	n.d.		n.d.	
1995 (April-Dec.)	>44	20	10	11	15	12
1996	58	30	27	25	7	46
1997 (Jan.-May)	11	2	3	4	2	5
<i>June</i>						
<b>Mass-mortality</b>						
1997 (July-Dec.)	18	5	3	5	6	3
1998	25	14	13	8	10	12
2000 (July-Dec.)	>23	13	13	8	7	10

The PSR after the mortality was 0.57 ( $\pm 0.46-0.70$ ;  $n = 56$ ; 95 % confidence limits), similar than obtained before 0.52 ( $\pm 0.42-0.61$   $n = 99$ ; 95 % confidence limits), being the differences not statistically significant ( $t = 0.74$ ;  $p > 0.01$ ;  $df = 154$ ).

The sex-ratio of neonates, which was equivalent before the event (1 : 1,  $n = 80$ ), favoured slightly the males after it (1 : 1.3,  $n = 50$ ).

Before the episode the births occurred most frequently in cave 3 (72 %,  $n = 87$ ) than in cave 1 (28 %,  $n = 87$ ). Although, after the episode there was a significant fall in births frequency in cave 3 (52.1 %,  $n = 48$ ) with respect cave 1 (47.9 %,  $n = 48$ ), being the differences statistically significant ( $\chi^2 = 5.51$ ;  $p < 0.05$ ;  $df = 1$ ).

The proportion of Immature size and Adult-size involved in reproduction is not similar.

The number of immature-size females with pups before the mortality was 3 in 1995 ( $n = 15$ ); 9 in 1996 ( $n = 20$ ) and 6 in 1997 ( $n = 18$ ); and after was 4 in 1998 ( $n = 7$ ) and 6 in 2000 ( $n = 14$ ) (Table 2). The proportion of immature-size females with pups before the mortality was 33.9 %;  $\pm 22.2-46.1$  ( $n = 53$ ; 95 % confidence limits) and increased after the event to 47.6 %  $\pm 26.1-68.1$  ( $n = 21$ ; 95 % confidence limits) not being the differences statistically significant ( $t = 1.14$ ;  $p > 0.01$ ;  $df = 73$ ).

After the episode, the estimated BR resulted notably higher than previously, but not significantly (Table 3).

TABLE 3. – Number of Immature-size (I-S) individuals of the colony from Forcada *et al.* 1999; number of immature-size females (I-SF); number of adult-size (A-S) from Forcada *et al.* 1999; number of adult-size females (A-SF); the index of potentially reproductive females (IPRF) and the estimated birth rate (BR). In brackets confidence limits at 90 %.

	I-S	I-SF	A-S	A-SF	IPRF	BR
1994	84 (53-115)	32 (20-43)	124 (90-158)	119 (86-151)	150 (106-195)	0.34 (0.26-0.49)
1995	92 (60-123)	35 (23-45)	117 (82-149)	112 (78-142)	146 (101-188)	> 0.30 (0.23-0.43)
1996	92 (60-120)	35 (23-45)	139 (105-174)	133 (100-166)	168 (123-212)	0.34 (0.27-0.47)
1997	38 (22-53)	14 (8-20)	28 (14-43)	27 (13-41)	41 (22-61)	0.43 (0.29-0.82)
1998	31 (15-45)	12 (6-17)	29 (14-43)	28 (14-41)	39 (20-58)	0.63 (0.42-1.27)

## DISCUSSION

The most notorious results obtained were : 1 ) the Pup survival rate (PSR) seems not to be limited by a density dependent factor as indicated by the unchanged PSR variables of both periods and 2) the reduction of the reproductive potential of the colony, was not as high as expected and it is linked to an increase in the Breeding rate (BR).

According to our results, the PSR seems to be regulated by factors that have not changed in both periods such oceanographic conditions, a factor which has been demonstrated to be related to high neonatal mortality in the colony (Gazo *et al.* 2000a).

There are some considerations about the increase of the BR, that need to be explained. In many pinnipeds species, it has been shown that young mothers have a lower reproductive success than older ones (Riedman 1990). BR should have decreased after the mass mortality, due to the increase in number of the reproductive immature-size females of the population. Nevertheless, the obtained results point the opposite.

There are some hypothesis that can explain or can be related with the increase of the BR after the mass mortality :

- 1) the inter-birth interval for all females may have declined ;
- 2) individuals of the colony which were not breeding may have begun breeding ;
- 3) individuals of the colony which were breeding in other caves not detected before the massive mortality, may have shifted to breed in caves 1 and 3.

We do not have enough information about the first hypothesis. In relation with the second one, it is possible that any dense-dependent factor which was limiting the BR before the mortality event, as food resources or habitat availability, is now not limiting due to the lower numbers of individuals of the colony.

About the third one, we know that before the mortality, pups that definitely were not born in caves 1 and 3, appeared annually in the colony. Ie. in 1995, the most notorious year, ten pups which did not born in the caves 1 and 3, appeared in the colony. This supports the previously claimed existence of another unverified breeding area, some kilometres to the north (Marchessaux 1997 ; González *et al.* 1997 ; González unpublished data). Therefore, it is possible that reproductive females that were breeding in other areas, could have travelled to the colony due to an increase of availability of breeding habitat.

In our opinion, the increase of habitat availability is the fact which better explains the results obtained. In this context, the following facts need to be taken into account :

- Females of this colony only give birth on a type of beaches inside caves which are not covered during high tide and which are protected from waves (Marchessaux 1989 ; González *et al.* 1997).
- Caves with those characteristics are very scarce in the region (Francour *et al.* 1990). Our surveys performed from 1993 to 2000, only detected two caves, (caves 1 and 3), where births regularly take place (González *et al.* 1997 ; Gazo *et al.* 2000).
- Inside the breeding caves females show aggressive behaviour during parturition to other individuals (Layna *et al.* 1999).
- Adults were the population fraction most affected by the massive die-off, being reduced the size of the adult's females population more over a 50 % (Forcada *et al.* 1999).

In many pinnipeds, one of the causes of the low reproductive success of young mothers is their lower success in competence for the best habitat (Riedman 1990). In our opinion, before the mortality event, possibly young females could be displaced to sub-optimum habitats, where either they do not breed, or breed in caves suboptimal where pup survival success is lower, or in caves far away of the colony (ie. the « Arco » cliffs area ; see González *et al.* 1997). Under this situation researchers would not detect these females and births during observations (regular observations are only performed in caves 1 and 3). This situation would explain the low BR detected in the colony before the massive die-off, based only in caves 1 and 3. The decrease in seals abundance due to the mass mortality is likely to lessen intraespecific females competi-

tion for breeding habitat, and would allow young females to access for breeding in caves 1 and 3 and then, be detected by researchers. This fact would have produced the detected increase of the BR in the colony. In case of confirmation of the above hypothesis, it would be expected that BR would decrease again if the colony will recover to population levels prior the mortality event.

In this sense, it would be also expected that BR would remain high, at least at post-mortality levels, if optimum habitat availability increase and if it is occupied by young females. Optimum habitat for monk seals in the Atlantic seems to have been open beaches in islands and sand banks, where in historic times are records of large aggregations of seals (Monod 1948 ; González, unpublished data). Seals disappeared from these habitats due to human persecution, surviving those populations which lived in caves or beaches protected by cliffs (González, unpublished data). It has been suggested that this habitat is sub-optimal for the monk seal due the constraint that suppose to the breeding success (Sergeant *et al.* 1978 ; Marchessaux 1989). The reproductive cost of breed in caves, in addition to other factors under study, it would explain the absence of recovery of the Cabo Blanco colony registered during the last years (Forcada *et al.* 1999).

In this context, a conservation strategy for the recovery of this monk seal colony must be addressed toward a reoccupation of optimum habitats - open beaches - that will not only benefit pup survival - pups more protected against storms - but also will make easier an increase of the colony BR. In this sense, it has been proved that with no human disturbances, immature-size females of the other surviving Mediterranean monk seal population in the Atlantic, the Desertas colony (Madeira archipelago), have reoccupied recently open beaches, abandoned long time ago, as breeding habitat and improved the reproductive success of the colony (Pires and Costa Neves 2000). Human disturbance over the breeding habits of monk seals, could also be related with the increase in the frequency of stampedes away the hauled-out individuals inside the Cabo Blanco caves, detected one month after the mortality event, for no apparent reason in comparison with this behaviour during the years before the event (Cappozzo *in* UB 1994-98). The frequent human entries to cave-3 during the mortality episode, could explain this behaviour, and the decrease of the use of cave-3 as a place of births after the mortality episode.

Future monitoring of the colony is recommended in order to continue the study on the effects of this changes on the habitat occupancy, demography and survival of the monk seal colony and the effects of human disturbance in the occupancy of caves and beaches.

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