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CHANGES IN MORPHOLOGY WITH AGE IN MEDITERRANEAN MONK SEALS (*MONACHUS MONACHUS*)

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ABSTRACT

In order to describe the pelage and external appearance of the Mediterranean monk seal (*Monachus monachus*) and prepare an age-sex classification guide, 120 seals from the Cabo Blanco Peninsula colony in the Western Sahara/Mauritania were periodically photographed between 1993 and 1996. Analysis of the pigmentation pattern, pelage color and pattern of natural markings of each seal established 48 phenetic types, which were, in turn, arranged in five groups (morphological classes) with multivariate cluster analysis (UPGMA). The variables that best define these groups are size and color. The variation related to relative size, sex and age of 26 identified seals monitored over three years showed that: (1) after each molt, external appearance varied considerably only in non-adults, while adult appearance was invariable; (2) marked sexual dimorphism exists in adults' external appearance; and (3) a remarkable similarity of adult and neonate pelage exists. With these results, we propose an age-sex classification guide to facilitate monk seal identification in the field.

Key words: Mediterranean monk seal, *Monachus monachus,* Western Sahara-Mauritania, pelage, sex and age classification, coloration, UPGMA.

Knowledge of species polymorphism and phenetic variability is important because of their evolutionary significance and for conservation of biodiversity (Vida 1978, O'Brien and Mayr 1991). In recent times the loss of this variability has been increasing, especially in threatened species (Beltrán and Delibes 1993, Van Zyll *et al.* 1995). The Mediterranean monk seal (*Monachus monachus*) was very numerous centuries ago but currently is found in small, fragmented and isolated populations (Reinjders *et al.* 1993) and is therefore

considered to be critically endangered (IUCN 1996). Knowledge of its phenotypic variability is important as a tool for studying the age-sex structure of the population and for the management of the species.

External appearance, especially pelage color pattern, can be used as a sign of phenotypic variability in vertebrates. Pinniped pelage is usually greyish or brownish; darker above than below and varying through several transition pelages until it reaches the final or adult pelage. Individual variation and environmental factors (chemical composition of the water and substrate, amount of water and rookery-derived stain on the pelage, scars, and freshness of pelage since last moult) affect pelage, making it silvery, brownish or dark grey (Scheffer 1958, 1964).

Neonatal and adult pelage of the Mediterranean monk seal was described by Hermann (1779), Buffon (1782), Cuvier (1813) and Carruccio (1893) and variation by Cabrera (1914), King (1956) and Marchessaux (1989). However, descriptions of the transition pelages and their variability are lacking, leading to a situation in which, for example, an adult female and her fetus with differences in external appearance were interpreted as the result of hybridization between *Monachus monachus* and *Phoca groenlandica* (Troitzky 1953). In this context, variation in external appearance of Mediterranean monk seals was recently attributed to the existence of two types of pelage "albiventer" and "silver white" (Sergeant *et al.* 1978), and the existence of external sexual dimorphism in adults was discounted (Marchessaux 1989, Riedman 1990, Reeves *et al.* 1992).

The only existing sizeable colony of the species, estimated at 317 individuals during the period 1994–1996 (Forcada 1998), is found on Cabo Blanco Peninsula (Western Sahara-Mauritania). An initial visual inspection of almost one hundred seals from this colony, between May and August 1993, revealed extensive variability in pelage and external appearance (González *et al.* 1996).

In this paper, we describe the external appearance and pelage of monk seals from the Cabo Blanco colony and propose a new methodology to assign individuals to age-sex classes in the field that does not involve handling them.

Methods

Study Area

The Cabo Blanco Peninsula (21°02'N, 17°03'W) is located in the southern coast of Western Sahara-Mauritania (see details in González *et al.* 1997). To the north, this peninsula borders the Guerguerat territory and to the south it ends at the Cabo Blanco lighthouse. The coast is made up of a succession of very high cliffs, occasionally interrupted by sandy beaches of eolic origin. The coast has been shaped by various factors: horizontal nature of the sedimentary rocks and their various make-ups, severe erosion by the sea, changes in the sea-level, the NNE-SSW trade winds, and sand deposition. The Cabo Blanco Peninsula is weathered with a humpy topography of decomposing and shapeless fossil dunes interspersed with rippling hillocks of fine yellow sand. Its

terminus has a sloping beach of white sand, 25 m high. The land formations continue below the sea; the contiguous bed usually consists of gently-sloping sands upon sedimentary rocks. The result is an extensive continental platform—one of the world's best fishing grounds—with 200-m depth only reached off La Agüera 12 km to the west. Human presence in the area is limited to three settlements: La Agüera (Western Sahara), Nouadhibou, and Cansado (Mauritania).

The coastline where the seals live consists of almost 15 km of cliffs named Costa de las Focas, containing several caves where the seals haul out on the beaches inside (see description in Marchessaux 1989, González *et al.* 1997). The colony is composed of individuals of all ages, and on several occasions up to one hundred individuals have been observed hauled out at the same time. Females give birth throughout the year in two main breeding caves separated by 1.1 km.

Data Collection

About 4,000 photographs of seals were taken following a method previously developed (Forcada 1998). To minimize disturbance to the colony, observations were logged from cliff tops above cave entrances or above areas where seals gathered. Most of the photographs were of swimming seals, which meant that the body parts most often exposed were the head, neck and dorsal area of the flanks. Some seals with large and obvious marks were identifiable in the field either with the naked eye or binoculars. Seals were photographed during ten photo-identification sessions, each lasting approximately 15 d, between May 1993 and April 1996. Scars, especially those resulting from interaction between seals, were obvious on all seals except pups, which did not present clear and permanent marks (Grau *et al.* 1994). We selected 120 non-pup, non-molting seals of known sex where possible and for which good quality photos of head, neck, dorsal, and ventral areas were available. A total of 2,322 useful photos were examined. The reliability of the identification of monk seals with photographic techniques was assessed using slides collected on the surveys. The ability of researchers when grading slides according to photographic quality and external features studied was assessed. Experiments designed to evaluate the ability of researchers to compare sets of slides showed no differences in matching success, with scores of 100% of correct matches for all researchers (Forcada 1998).

The pelage variability of pups has already been studied (Badosa *et al.* 1998); here we include a description of the pups in order to provide a more complete picture of the pelage changes throughout life.

Standard length of seals found dead ashore, mainly during an epizootic die-off in May–June 1997, and those captured for tagging were measured following Scheffer's methodology (1967). The sex of 84 males and 55 females was established during photoidentification sessions, postmortem examinations or individual captures by direct observation of the genital opening in males or the four teats in females (King 1956).

We first characterized animals by age (using behavioral and size criteria or known-aged tagged animals). We tagged 12 pups a few days old with plastic Temple Tag type tags (Temple Tag Inc. P. O. Box 369, Temple, Texas, U.S.A.) and Supertag (Dalton Supplies, Henley-on-Thames, Oxon, U.K.) applied to the rear flippers between the fourth and fifth digit following the method used for *Monachus schauinslandii* (Henderson and Johanos 1988) and monitored them for up to a maximum of 32 mo. Variation in pelage with age was studied in these 12 tagged individuals and in 14 other non-tagged seals of unknown day of birth but individually identified. For these we either had photos over a relatively long period or changes were observed following the annual molt (Grau *et al.* 1994, Forcada 1998). We defined the following criteria for assigning a seal to one of the four age classes as in *Monachus schauinslandi* (Stone 1984): (1) pup: dependent on the mother, without signs of sexual maturity and growing; (2) juvenile: not dependent on the mother, without signs of sexual maturity and growing; (3) subadult: growing, some occasionally with signs of sexual maturity; and (4) adult: not growing and showing signs of sexual maturity. Pups were not included in the multivariate analysis (describe below).

Characters Analyzed in Multivariate Analysis

Relative size—During the first observation session (May–August 1993), a scale of relative sizes was established: the smallest seals were classed as 1 and the largest as 4, those slightly larger than 1 were classed as size 2, and those slightly smaller than size 4 were assigned to class 3. Experiments designed to evaluate the ability of researchers to match the sizes showed no significant differences among observers (Forcada 1998).

Pelage pattern—The body was subdivided into three regions: head (including throat and nape), back, and belly (Fig. 1, 2). Eight characters were defined based on local discoloration in the pigmentation and changes in the color pattern:

Head region:

(1) Nape
continuous, pigmentation distribution uniform (Fig. 1a)
discontinuous, pigmentation distribution interrupted (Fig. 1b)

(2) Throat
continuous (Fig. 1c)
discontinuous (Fig. 1a)

(3) Hood
absent, differences in shade between upper part of head and sides and face of head (Fig. 1a)
present, upper part of head darker than face and sides of head (Fig. 1c)

(4) Frontal hood
present, hood extends to nostrils, leaving "mask" around eyes (Fig. 1e)
absent, does not extend beyond eyeline (Fig. 1f)

(5) Lateral hood
present, hood extends over outer ear spreading in sideburn shape (Fig. 1d)
absent, stops above ear (Fig. 1c)

Back region:

(6) Back:
continuous (Fig. 2a)
discontinuous, pigmentation distribution interrupted (Fig. 2b).
(7) Dorsal sash:
present (Fig. 2c)
absent (Fig.2a, b)

Belly region:

(8) Belly:
continuous (Fig. 2d)
discontinuous: pigmentation interrupted presenting yellowish white patch, squarish in shape, in which anterior edge coincides approximately with center of body and ends caudally between umbilical scar and genital slit (Fig. 2e).

Pelage color—As it is the largest and most visible area, the dorsal region (back) was chosen for focus in the study of pelage coloring. Following the first visual inspection, six color types (black, gray-black, medium-gray, light-gray, chestnut-gray and patchy-gray) were established. These were subsequently matched to colors specified in a commercial color reference manual used for the graphic arts and industry, the Pantone Color Formula Guide, (PANTONE Inc., 55, Knicker Rd., Moonachie, New Jersey, U.S.A.). The guide provides a simple method of color specification showing over 500 colors printed on coated and uncoated paper, each with numerical identification and mixing formula. As a point of reference a type individual was chosen for each color. Thus black corresponds to Pantone black and seal No. 211; dark-gray to Pantone 405c and seal No. 1; medium-gray to Pantone 425c and seal No. 20; light-gray to Pantone 431 c and seal No. 180; chestnut-gray to Pantone 411c and seal No. 11; and patchy-gray to seal No. 38, which has different shades of gray patches on its back.

We thus coded the seals for 18 two-state characters: size 1, size 2, size 3, size 4, black, dark-gray, medium-gray, light-gray, chestnut-gray, patchy-gray, nape, throat, hood, frontal hood, lateral hood, back, dorsal sash, and belly. Using these data, a presence/absence (or in the case of some characters, "continuous/discontinuous") matrix was created and a group analysis performed. The group analysis method defines groups of cases or features on the basis of qualitative or quantitative criteria (distances or similarities), and as it uses a non-parametric multivariate statistic, it is not important how the data are

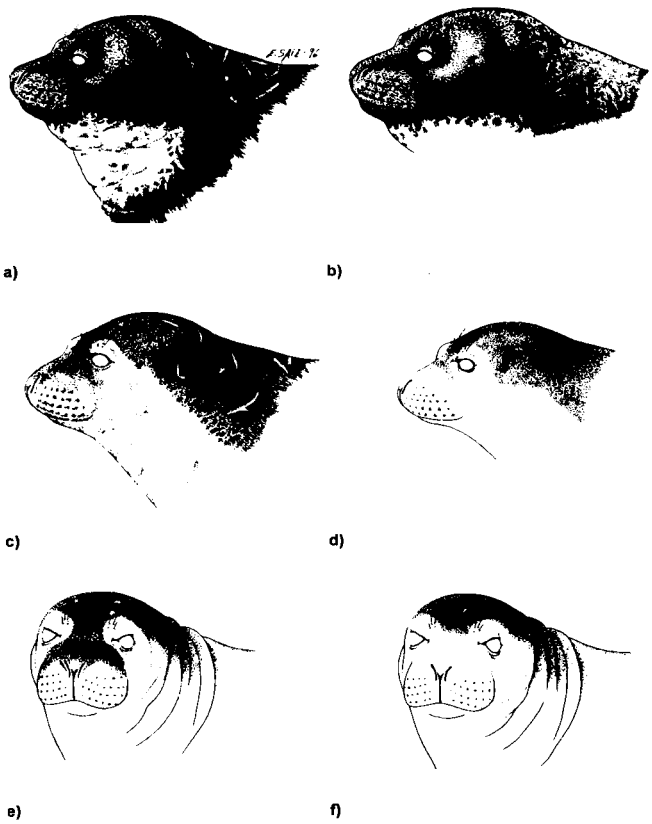

Figure 1. Variation in external appearance of pelage on head; see text for explanation.

distributed (Alvarez 1996). We chose cluster analysis because it does not involve predefined groups (Sneath and Sokal 1973). All the variables included in the analysis contribute equally to group formation. We used UPGMA (Unweighted Pair-Group Method, Arithmetic average), in which the analysis begins with as many groups as cases, and groups of phenetic types take shape in successive steps until a complete matrix of similarity or dendrogram is obtained.

Results

The 120 seals were grouped into 48 morphotypes (actual permutations of characters states) (Table 1, Fig. 3). However, seven of them covered 40% of the seals examined, possibly because these types are relatively more stable temporally than others.

The results of the cluster analysis allows the morphotypes to be put into five groups: A, B, C, D, and E (Fig. 3); pups are added as class O. The variables that best define the groups are size and color (Table 2). Class A includes smaller

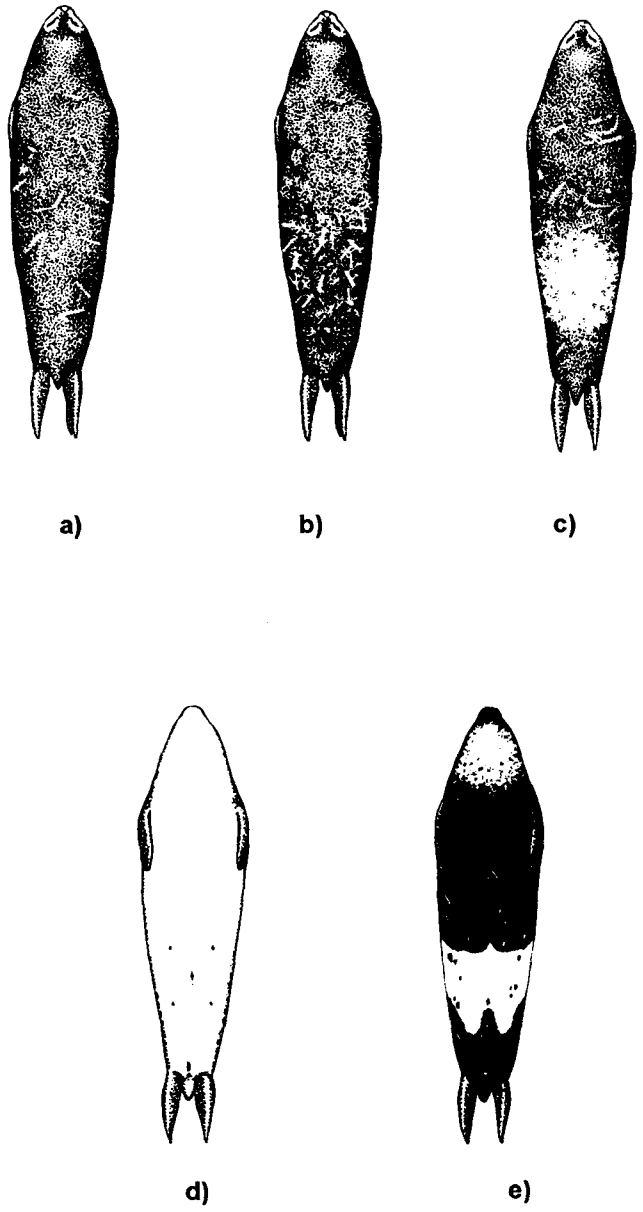

Figure 2. Variation in external appearance of pelage on back (a, b, c) and belly (d, e); see text for explanation.

and light-gray seals; Class B contains slightly bigger seals than A, often dark-gray; Class C medium-sized and often medium-gray seals, and D and E include bigger seals, D being dark-gray and medium-gray, and E black. These groups correspond, in the same order, with those defined previously as youngster,

Table 1. Frequency of occurrence of 18 characters in morphological classes defined by UPGMA analysis, (a) size and color, (b) pelage pattern. See text for definitions of characters and states a) & b).

	Morphological class									
Character	A		B		C		D		E	
(a)										
Size										
1	1		0		0		0		0	
2	0		19		0		0		0	
3	0		0		28		0		0	
4	0		0		0		58		15	
Color										
Black	0		0		0		0		15	
Dark-gray	0		12		9		20		0	
Medium-gray	0		4		14		25		0	
Light-gray	1		0		0		0		0	
Chestnut-gray	0		3		5		8		0	
Patchy-gray	0		0		0		4		0	
(b)	a)	b)	a)	b)	a)	b)	a)	b)	a)	b)
Nape	1	0	19	0	26	2	55	3	0	15
Throat	1	0	19	0	26	2	58	0	4	11
Hood	1	0	19	0	28	0	58	0	0	15
Frontal hood	1	0	18	1	26	2	52	6	0	15
Lateral hood	0	1	5	14	13	15	24	34	0	15
Back	1	0	12	7	6	22	3	55	0	15
Dorsal sash	0	1	0	19	0	28	22	36	0	15
Belly	1	0	19	0	28	0	58	0	0	15

juvenile, medium-sized seal, large-sized seal, and large black male (González *et al.* 1996).

Morphological class duration—The pup age class (morphological class 0) lasts a maximum of three months, giving way to Class A. The first seals with characteristics from Class A appear from 69 d on average and last until age 9 mo (n = 9). The first seals with Class-B characteristics appear at 7 and last until 23 mo (n = 12). Class C appears at 18 mo (Fig. 4), but duration is unknown at present. The age when Classes D and E begin and the duration are also unknown.

Sequences in occurrence—Figure 4 shows the order in which the classes appeared over the study period. It is apparent that all seals in Class A moved to Class B. All except one seal (No. 318), which disappeared for some time, moved from B to C. Three seals (Nos. 76, 4, 66) passed from C to D, three others (Nos. 87, 52, 379) went from D to E and four (Nos. 53, 86, 58,132) went from C to E. Thus, the order of occurrence of the classes probably has three types of sequences: Sequence 1: A-B-C-D; ends in adult seals with gray pelage, corresponding to adult females; Sequence 2: A-B-C-D-E; ends in black

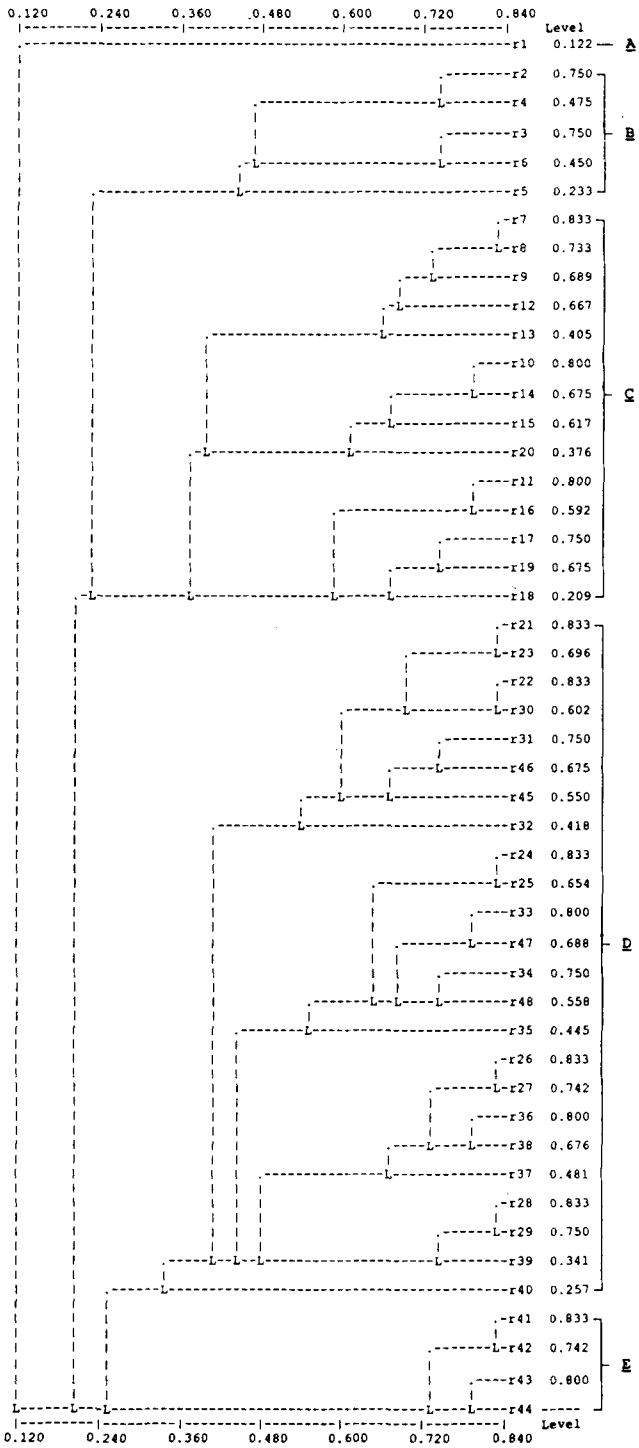

Figure 3. UPGMA phenogram of similarity between 48 phenetic types. r is phenetic type. Figures represent value of coefficient of similarity, and letters stand for morphological groups established.

Table 2. Correspondence between external features and morphological groups defined by cluster analysis. Morphological classes C and D share average length.

Morpho-logical class	Features	Ave. length (cm)	Sex	Time span (mo)	Age category
O	Nape and throat continuous No hood Back continuous Belly discontinuous Black	108.0 s.d. = 10.7 n = 38 max. = 138 min. = 0.74	male/female	0–3	pup
A	Nape and throat continuous Hood present Frontal hood No lateral hood Belly and back continuous Light-gray	144.4 s.d. = 10.4 n = 8 max. = 158 min. = 135	male/female	2–9	pup/juvenile
B	Nape and throat continuous Hood present Frontal hood No lateral hood Belly and back continuous Dark-gray	173.5 s.d. = 19.0 n = 6 max. = 180 min. = 146	male/female	8–22	juvenile/subadult
C	Nape and throat continuous Hood present Frontal hood Lateral hood Belly continuous Back discontinuous Medium-gray or dark-gray	237.9 s.d. = 10.8 n = 50 max. = 262 min. = 210	male/female	18–?	subadult/adult

Table 2. Continued.

Morpho-logical class	Features	Ave. length (cm)	Sex	Time span (mo)	Age category
D	Nape and throat continuous Hood present Frontal hood Lateral hood Belly continuous Back discontinuous Dorsal sash Dark-gray and medium-gray		male/female	?	subadult/adult
E	Nape and throat discontinuous No hood Belly discontinuous Back discontinuous No dorsal sash Black	252.5 s.d. = 11.8 n = 39 max. = 270 min. = 210	male	?	adult

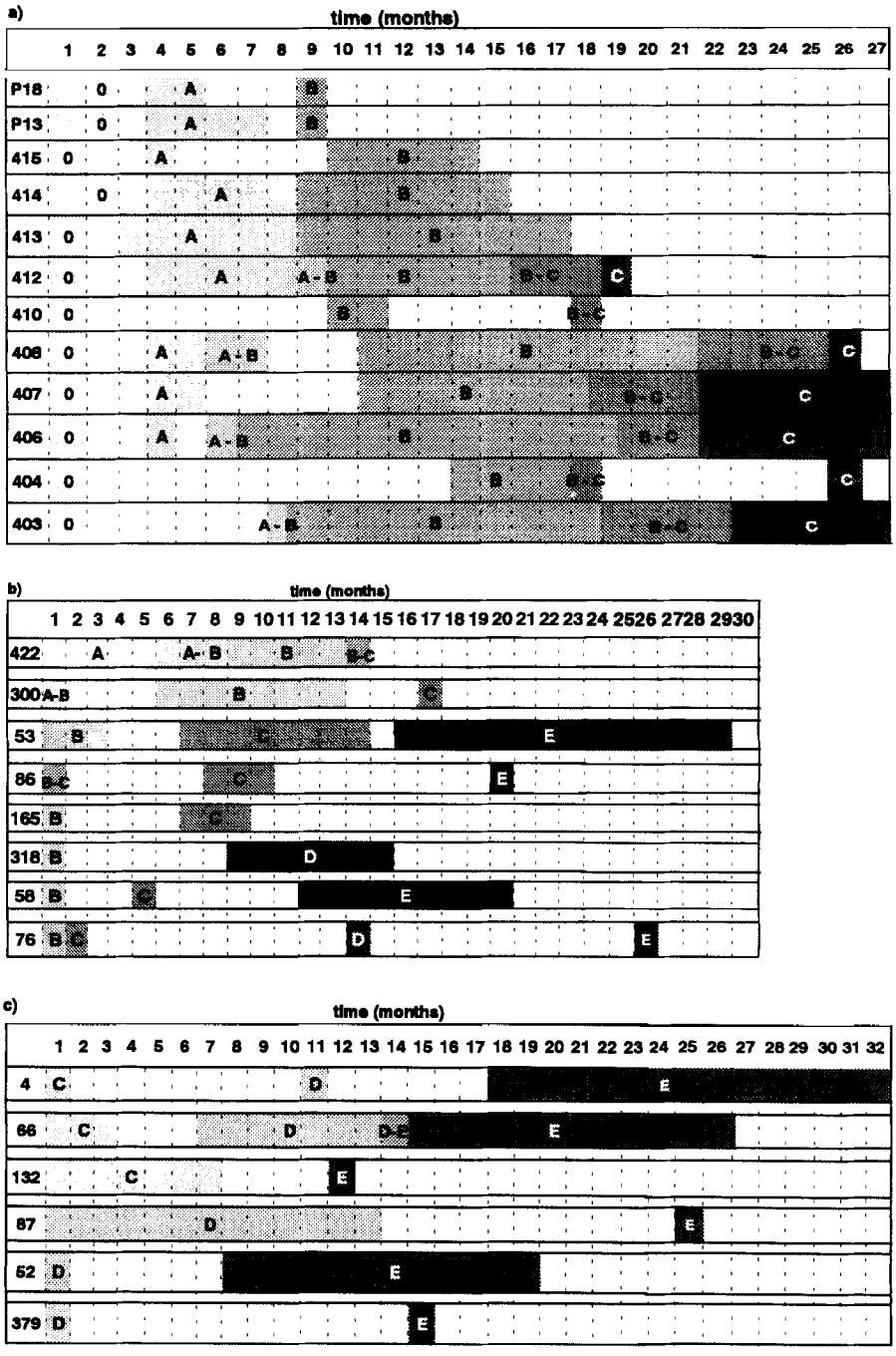

Figure 4. Order in appearance and duration in months of morphological classes in individuals monitored from birth (a); from morphological classes A and B (b) and from morphological classes C and D (c). Figures in left column are identification numbers of individuals. O represents pup. White area in sequence represents period of time individual not observed.

Table 3. Distribution of the sexes (in percentages) in relation to morphological classes.

	A	B	C	D	E
Males (n = 64)	3.57	2.38	16.66	2.38	75.0
Females (n = 55)	3.63	3.63	10.90	81.81	0

adult males; and Sequence 3: A-B-C-E; seals pass directly from subadult to adult black males without passing through Class D as in the other sequences.

Sexual maturity and age classes—We recorded seven Class-C females who were sexually mature (four pregnant) with standard lengths 223, 226, 229, and 234 cm; three were seen caring for and suckling young. In the literature, females of standard lengths 219, 278, and 213 cm were cited carrying fetuses (Gavard 1927, Troitzky 1953, Mursalöglu 1964). A 185-cm 4-yr-old female from the Saharian colony and another 195 cm long and 3–4 yr old from Greece had already ovulated (Marchessaux 1989, Cebrián 1993). This indicates that some females are sexually mature and can breed from Class C onwards.

We found that male standard length ($\bar{x}$ = 251.9; n = 37; SD = 11.1) was sligthly greater than that of females ($\bar{x}$ = 242.4; n = 39; SD = 9.8), the differences being statistically significant (t = 3.93; $P < 0.001$). In previous studies, no significant differences were found (Marchessaux 1989). The only sexual differences in morphological classes detected were that in Class D females predominated and in E there were only males (Table 3).

Class-A seals exibited pup and juvenile behavior, those from Class B showed juvenile and subadult behavior, those from C and D had subadult and adult behavior, and those from Class E exibited only adult male behavior (González *et al.* 1996, University of Barcelona-University of Las Palmas 1998).

Discussion

Mediterranean monk seals in the wild can be assigned to one of the age-sex categories proposed in this study. Given its usefulness and the fact that it does not involve handling and can be employed at a distance, we propose that this classification method be used in future studies (Fig. 5a, b).

As we have pointed out, monk seal appearance changed gradually between neonatal and adult pelage in a continuous process such that any intermediate stages that may be described represent arbitrary increments. Most of the 48 phenetic types defined are phases in continuous processes. Seals in the molt stage were excluded from our study; this affected the apparent frequency of some transition stages, *e.g.*, chestnut-gray. On several occasions seals with reddish pelage were observed, which was probably due to iron oxide precipitates on the hair shaft as occurs in *Phoca vitulina* (Allen *et al.* 1993). The iron ore in Cansado Harbor, 30 km south of the colony, is a source of ferric oxide in the water that the seals frequent.

There is a noticeable similarity in pelage pattern and coloring between pups

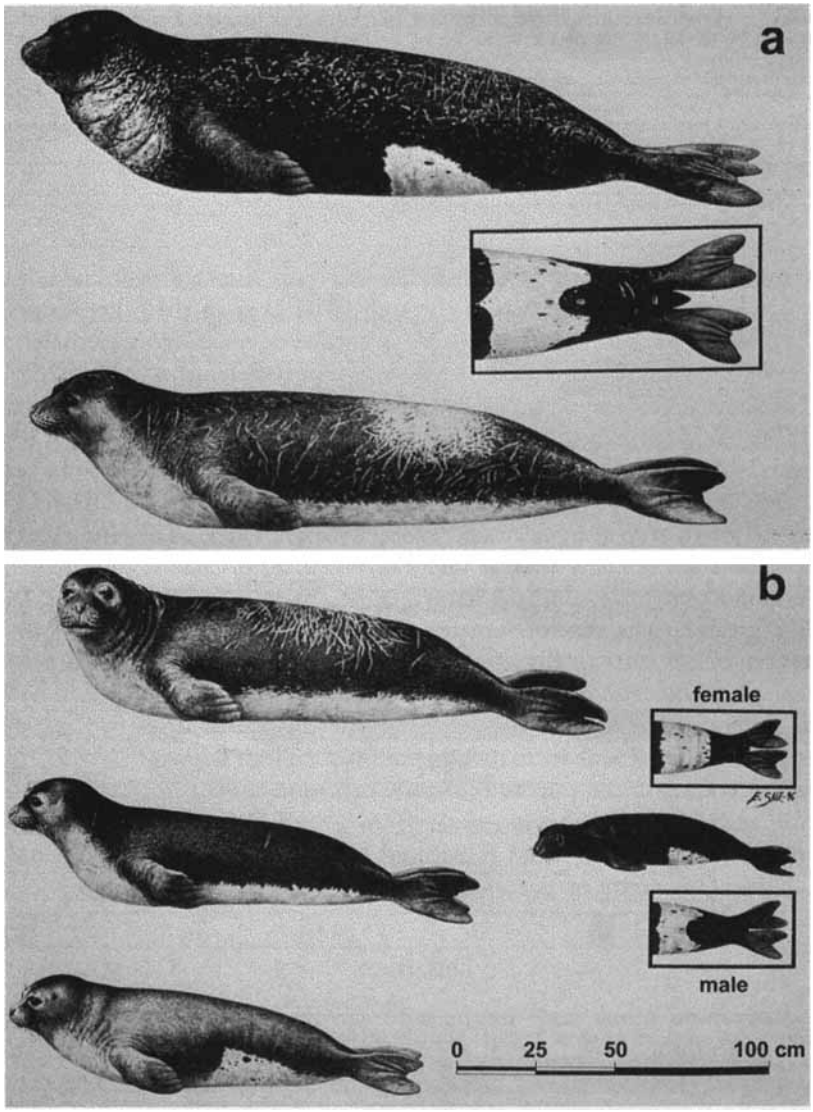

Figure 5. General external appearance of morphological classes defined in the text; (a) from top: Class E (black male) and detail of their belly; Class D (large-sized seal); (b) from top: Class C (medium-sized seal), Class B (juvenile), Class A (youngster), and at right: Class O (non-moulted pup) and detail of belly of female (top) and male (below) pups.

and black adult males that it would be interesting to investigate. Discoloration of the pelage due to the local absence of pigmentation on certain parts of the body (throat, nape and back) altered the pelage pattern. No doubt the fact that *Monachus* has the shortest hair of all the pinnipeds (Ling 1970) is significant in this. The fact that these dorsal marks appeared to be more common

in females than in males suggests they are caused by injuries inflicted by males during mating as observed in Hawaiian monk seals (Hiruki *et al.* 1993). The dorsal marks were less pigmented and therefore more obvious than similar marks on Hawaiian seals. Given that females haul out mostly in caves on the Saharian coast, while in Hawaii they do so on beaches, differences in exposure to daylight and in subsequent regeneration of melanin in the skin may account for the difference.

In general, in Otariidae (and the genus *Mirounga*) the pairing system is polygynous, copulation is on land and males defend terrestrial territories and exhibit marked sexual dimorphism (Stirling 1983). In the Phocidae, the pairing system is not clearly polygynous, copulation takes place in the water, males defend aquatic territories, and there is no obvious sexual dimorphism (Stirling 1983). In *Monachus monachus,* copulation is in the water and the males defend aquatic territories (Marchessaux 1989, University of Barcelona-University of Las Palmas 1998). The species exhibits marked sexual dimorphism in pelage color and in behavior more like the Otariidae. Once again, here *Monachus monachus* presents features from both groups. Therefore, a through study of *Monachus monachus,* the pinniped with the oldest recorded fossils (Ray 1976), would be very important in clearing up the much debated subject of evolutionary trends in pinnipeds (Bonner 1990).

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