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Pugmarks and the biology of the Bobcat, *Lynx rufus*

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Abstract

The maternal behavior, dispersal of cubs and associations with an adult, male consort of a 7-year-old female bobcat (*Lynx rufus floridanus*) are described. Data are based on foot tracking and direct observations from June 1980 to August 1981. Pugmarks were used to identify movements of individuals who were identified by facial patterns, size, and color patterns. Cubs born in May 1980 (one male, one female) received solid food at 8 weeks of age, nursed for 4 months, and at 9 months of age dispersed to opposite ends of the home range. They left the area at 14 months of age when their mother traveled with another litter. Consorts shared a home range, and sometimes rested together away from cubs. The male traveled widely in the range and occasionally left it, while the female moved within the boundaries. Methods of conspecific identification and communication included olfaction and vocalization.

Introduction

Bobcats (*Lynx rufus*) are a valuable natural resource both esthetically and in the control of rodent and lagomorph populations. Knowledge of their spacial and temporal occupation of an area is needed, particularly with regard to the movement of adults and the dispersal of young. This is important for proper management, especially in Florida and other states where they are hunted and their habitat continues to be destroyed. Present knowledge of the social interactions of the bobcat is derived from compilations of observations of hunters, naturalists, and pet owners (SETON 1929; GRINNELL et al. 1937; YOUNG 1958; VAN WORMER and TERRES 1964), from radiotelemetry studies (PROVOST et al. 1973; BAILEY 1974; HALL and NEWSOM 1976; KITCHINGS and STORY 1978; GUENTHER 1980), and from breeding data on captives (MEHRER 1975). Bobcats are solitary, except for a strong social bond between a female and her dependent cubs. The presence of a consort within the home range of the female has been observed (MCCORD 1973; GUENTHER 1980). BAILEY (1973) and KITCHINGS and STORY (1979) report on the dispersal of young from their natal home range.

A female bobcat (*L. r. floridanus*), born in 1974, has produced cubs each year since 1976 and she is habituated to me (WINEGARNER and WINEGARNER 1982). In 1980 I found that travels of individual bobcats may be monitored on the sandy soils of central Florida by following their pugmarks. In this paper I discuss the history and value of tracking

pugmarks and present data on the movements and behavior of the habituated female, her adult male consort and her cubs (1 male, 1 female) from May 1980 through August 1981.

Study area and methods

The bobcats were studied at the Archbold Biological Station and adjacent property, 12 km south of Lake Placid, Highlands County, Florida, USA (27° 11' N, 81° 21' W). The precise site was determined by the movement of the bobcats. The area encompassed diverse microhabitats within low and scrubby flatwoods associations with scattered seasonal ponds and bayheads on the Station (WOOLFENDEN 1969), and improved and native pastures with bayheads to the west (Fig. 1). The flatwoods are pine-palmetto-oak savannas with a preponderance of oak (*Quercus inopina*) and saw palmetto (*Serenoa repens*) in the shrub layer and scattered Florida slash pine (*Pinus elliotti*) and Florida sand pine (*Pinus clausa*) in the canopy. After heavy rains scattered prairies with poor drainage become seasonal ponds which connect man-made ditches and ponds with Lake Annie to the north. Islands of broad-leaved evergreen forests, locally called bayheads, are dominated by loblolly bay (*Gordonia lasianthus*), redbay (*Persea borbonia*), and sweet bay (*Magnolia virginiana*) and occur in permanently wet areas of the prairies.

The climate is characterized by frequent summer rainfall and dry winters. Total rainfall from June 1980 through August 1981 was 133.9 cm with rain reported on 147 days. Seventy percent of this rainfall occurred during the two summer seasons (June through August) with 31 cm in 35 days in 1980 and 68 cm in 64 days in 1981. Average maximum and minimum summer temperatures were 34.4 °C and 20.3 °C, respectively. Corresponding values for winter temperatures (December through February) were 22.3 °C and 5.6 °C. Temperatures below 0 °C occurred on 19 days. Average diurnal temperature varies about 15 °C. Dew is present most mornings of the year.

Firelanes and trails extend through most of the study area, and are used by bobcats in travel. The toe pads of the bobcats leave impressions (pugmarks) in the sand and differences in the pugmarks were used to identify the movements of the bobcats. When I saw bobcats I traced their pugmarks onto transparencies that were placed over a 15 × 23 cm pane of glass mounted in a wooden frame. This frame was made level over the pugmarks by adjusting flat-headed bolts in each corner. A fine-point, felt-tip pen was used to trace the pugmarks onto the transparency.

Tracking of pugmarks was usually done in the morning while the sand was moist with dew. Soil moisture was recorded and additional tracings were made under a variety of soil conditions. I was able

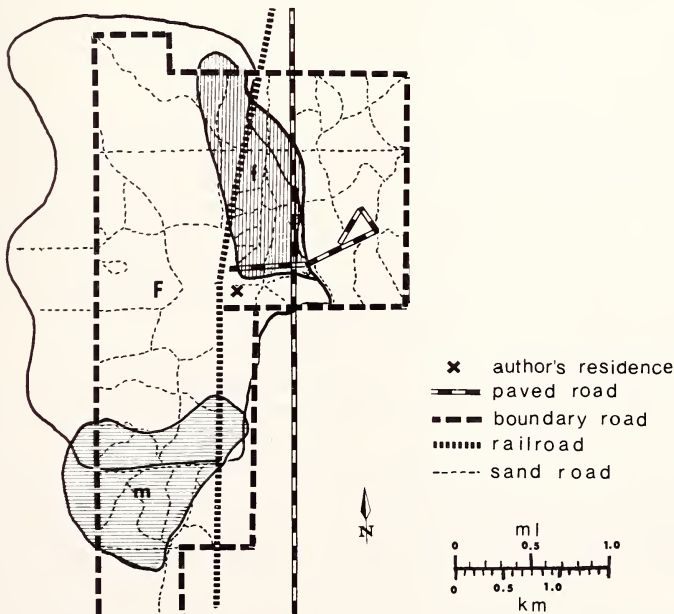


Fig. 1. Home range of an adult female bobcat (F) and the area used by the male cub (m) and the female cub (f) before their final dispersal

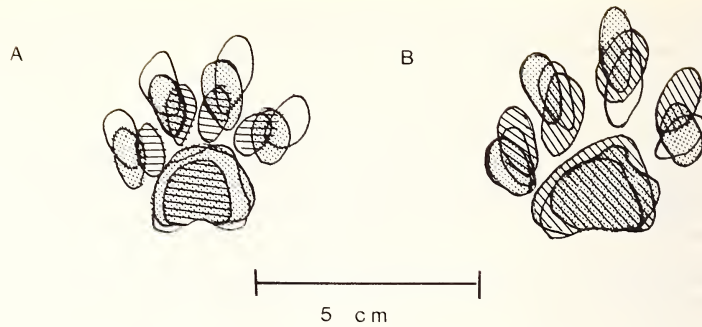


Fig. 2. Tracings of the pugmarks of bobcats. A. Open = resident female, stipples = male cub, and lines = female cub. B. Open = resident female, stipples = non-resident male, and lines = resident male

to identify the pugmarks of 3 adults and 2 cubs with ease. The pugmarks of the habituated, adult female were easily distinguished from those of the other adults, both males, on the basis of size and position of the pads (Fig. 2). Pugmarks of the cubs were smaller than those of the adults. The pugmarks of the male cub were broad compared to those of the female cub (Fig. 2). Tracks made as a bobcat walks were traced; when a bobcat runs the hindpads tend to land in the impression made by the forepads.

Identification of felids by their pugmarks is not a new technique. KOFORD (1977) identified those of the puma (*Felis concolor*) in California with photographs. In Nepal, McDUGAL (1977) studied a population of tigers (*Panthera tigris*) by remembering the nuances between the pugmarks. In India, PANWAR (1979) and CHOUDHURY (1971) used tracers to observe the differences in tiger pugmarks.

In this study frequent observations of the female were possible because my residence is in her range (Fig. 1). Bobcats were also identified by size, facial markings, and color patterns. Of the two cubs born in 1980, the male was larger and his pelage was spotted. Bobcats were observed 138 times; from fleeting glimpses to hours at a midday refuge. Over 1,600 km were walked to determine the movements of the cats and data were mapped daily. Distances were calculated on the graphics tablet of a computer. Observations were tape recorded and transcribed daily.

Results

In 1980 the habituated female bobcat gave birth during the first week of May in a dense bayhead. Birth was determined by her physical appearance. I tracked her to the den until 28 June when the cubs were moved 1.2 km east to a low flatwoods. I first saw these cubs, when they were 11 weeks old, as they traveled from their low flatwoods refuge enroute to a third site about 0.86 km eastward in a stand of rosemary (*Creatiola ericoides*). Here, the cubs wandered over about 0.4 ha. From July until September, they moved within the center of the range and occupied refuges from 2 to 6 days. A stand of rosemary or palmetto (*Serenoa repens*) was always nearby and used as shelter.

The cubs continued to nurse regularly until the end of the fourth month, but I first saw cubs receive food from their mother at about 11 weeks of age. She dropped a cotton rat (*Sigmodon hispidus*) in front of them and called. Food was generally eaten by the first cub to reach it. Cubs were observed to fight over food on only two occasions and low intensity threats with the head raised while sitting and growling left one cub backing away. As the cubs matured, they chased, mouthed, and slapped their mother as she growled and made it more difficult for them to take food from her. If the cubs did not chase their mother for food she either dropped it in front of them or ate it herself. Occasionally food was not eaten and it was covered with vegetation either by a cub or the mother and retrieved before leaving the area. Stomachs, gizzards, beaks, feet, feathers, and fur were found uncovered. The cubs played with small prey, especially insects, and stalked and attacked most moving objects.

Occasionally, when alarmed, the young gave high pitched distress calls, and the female rendered a reassuring "yeow-yeow", which brought the cubs to her. When the female attempted to keep the cubs from following, her call was an "arf-arf" like the sound of a small barking dog.

Olfaction was an important form of intraspecific communication. Usually when leaving an area, the female sprayed a mist from the anal region, without scraping, in a rest area. To greet their mother, cubs often raised their tail onto her shoulders or flank and sprayed. Until the cubs were four months old the mother licked their anal region and then they usually rubbed under her chin. Cubs were groomed by their mother and each other before and after rest and play periods. Social licking was common until the cubs dispersed.

Bobcat scrapes (BAILEY 1972) were not common on firelanes during the summer, however in late August the female began to scrape about every 100 m on the firelanes in the center of the range. These scrapes in the sand were made by alternate strokes of the hind feet while the posterior portion of the body was lowered. Liquid, probably urine containing secretions of the anal sacs, was placed in them. Scrapes were made on bare sand and in leaf litter. During September and October when the cubs were 5 and 6 months old, respectively, they occupied four different areas near the perimeter of the range and scrapes were made around these areas. The cubs began to hunt with their mother along the range boundaries. The family occupied an area for 2-6 days as they did at earlier refuges, but moved to another area more frequently as the cubs matured. From 23 November onward scraping intensified and scrapes were as common as every 50 m along the trails until February.

A liquid from the anal region was sprayed on vegetation, especially palmetto, while standing and without scraping, throughout the year.

The dispersal of cubs began in December at 8 months when they were first observed to leave scent in scrapes along a trail. By January one or both cubs frequently traveled alone, but when traveling together during the first 2 weeks of that month all three cats sometimes scraped beside each other. For example, on 2 January 1981 the cats left the vicinity of my residence at 0750 hours, moved east 0.38 km, crossed a paved road, and walked north 1.64 km. At intervals of 20 to 75 m they each left scrapes within a meter of each other on five sites and two scraped together on two additional sites (one contained feces) as they traveled. The last day that the family moved together was 15 January 1981, as they walked south on the west boundary of the Station. The male cub remained in the southern portion of the home range. For the next 5 days the mother and her female cub remained together in the central and northeast part of the range until the female cub established herself in the northeast (Fig. 1). There was no indication that the cubs were together again after they became established on opposite sides of the family range.

The mother traveled to each end of the range almost every day until 26 January. During this 12 days, she passed within 200 m of my residence on four occasions, but did not stop as she otherwise did when this near. After 26 January the tracks of the mother were not found in portions of the range occupied by the cubs, but only along boundaries of the new, temporary ranges of the cubs, adjacent to her own, where she had traveled during their dispersal. Data from a 1982 litter indicate the female chases and strikes a cub who returns to her domain.

Records of pugmarks indicate the home range of the female in 1980 from the birth of the cubs until their dispersal in January 1981 was 6.45 km². In January, her home range was reduced to 4.68 km² when she temporarily vacated about 1.77 km² for use by her cubs. The male occupied 0.65 km² in the south plus an additional 1.04 km² to the south of her range. The female cub acquired 1.12 km² of her range from her mother and occupied an additional 0.22 km² to the northeast (Fig. 1).

By mid-June 1981 the adult traveled with another litter. The cubs born in 1980 were now about 14 months old. Their pugmarks were no longer found and the female again

traveled the full 6.45 km² of her home range. In July and August I continued to regularly track in the area but neither the cubs nor their pugmarks were observed.

In this study the first time I observed interaction among adult bobcats was on 8 September 1980. Before sunset the female entered a 20 m wide firelane from a footpath in front of me, looked at me and crouched to the ground near shrubs in the center of the firelane. After her low calls, a male came onto the firelane from the path, approached her from the front, passed her until their bodies were parallel and close, and then continued across the firelane. He walked down the path for 10 m and sat until the female got up and trotted toward him. The male, whose pugmarks were easily identified by two splayed toes on his left forepaw, occupied the range with the female. Six hours before this meeting the male cub, partially hidden in the vegetation, had growled periodically for over an hour after his mother had carried food to him. I do not know if the adult male was present then, but the cubs were left behind when the adults left the area. On four subsequent occasions this male was near the family for as long as five hours.

The consorts spent time together prior to the 1981 breeding season. As the cubs dispersed I frequently found the tracks of the male near the female. A viscous substance sprayed on vegetation commonly marked trails from late in January through March 1981. On 23 and 29 January the pair used the same road. On 23 January tracks of the female and her male cub were together. Temporal sequence is unknown but both entered a dry pond, and the tracks of the female came out of the pond, through vegetation and onto the road where her consort left tracks this night. The cats left in opposite directions. The tracks of the male cub indicate that it came onto the road 0.5 km north of its mother and circled back into the vegetation.

On 26 January the consorts had traveled northwest through the center of their range on the same road. During the next two days the consort was not found, but the female was seen on 27 January in the field and at my residence. She was unusually amicable. Two of her scats were found and neither was in the usual type of scrape. The next day tracks showed that she traveled south alone. On 29 January the consorts walked on the same roads for over 1.83 km in the same direction. Both cats sprayed the vegetation and the female sprayed twice in the yard at my residence on that day. Small, wet, brown feces were found on the firelanes and paths until 6 February. I believe these to be signs of estrus. On 3–4 February and 6 February an adult male from the northeast was tracked in the northern end of the home range of the female, while her consort was in the southwest. From 15 to 19 February the tracks of the consort were found on paths traveled by the female about 24 hours earlier. On the morning of 19 February their tracks met from opposite directions and turned into the vegetation; the cats parted before 0945 hours. I tracked the male 1.34 km to the west and the female over 1.50 km to the north before 1130 hours. Their tracks crossed again on 23 February. On 24 February she was in the same area as her consort and the male from the northeast, and on 26 February an open wound, approximately 5 × 15 mm, was observed on the nape of the female. On 4, 7, 17, and 30 March the consorts continued to cross paths. When observed on 14 March from 0.3 m, the female was obviously pregnant. She gave birth to her sixth litter on 4 or 5 April 1981. The consort was with the female on 20–22 April and 8–9 May for several hours in midday as she rested about 2.12 km from her den.

Discussion

Tracking and observations of bobcats revealed that in Florida cubs remained near their birthplace for about 2 months. Four of seven other litters of this female were also first seen when they were 2 months old (WINEGARNER and WINEGARNER 1982). After the cubs were 3 months old their propensity to hunt and play increased and the mother moved them into new areas of the home range. This provided them with a knowledge of their natal home

range and experience in hunting. In Idaho, BAILEY (1973) first observed movement of bobcat cubs after they were 3 months old.

In 1980 both cubs in this study remained with their mother for 9 months. From January and until June 1981 they occupied space at opposite ends of their natal home range and utilized areas familiar to them. In July 1981 a new litter began to travel with their mother. The 1980 offspring were not found in July or August and probably dispersed.

In Tennessee, KITCHINGS and STORY (1979) reported that a radiocollared male and female "juvenile" both settled in an area "remote from their rearing grounds" that was not utilized by their parents. Their data indicate that the settlement areas of the 2 cubs overlapped. No data were presented on the amount of time the cubs were with their mother. BAILEY (1973) reports that in Idaho young disperse from their natal home range and he was able to recapture 5 marked cubs as adults and they were 10–29 km from their birthplaces. In my study pugmarks indicated that bobcats disperse from their natal area after a period of solitude in a familiar area.

The temporary tenure a cub assumes in the home range of its mother insures that a home range is occupied. The independent cubs did not disperse until the next litter moved from the natal den, and the reproductive success of their mother was apparent.

Bobcats are seasonal breeders. CROWE (1975) found that male bobcats in Wyoming undergo annual cycles of testicular development and regression with apparent reduction in testis volume during the summer months. As a tentative schedule of spermatogenic capacity he reports that sperm production begins during September and October with mature males fecund from this period until spermatogenesis is arrested probably in the summer months. In my study the consorts were together in September 1980 when the female had cubs of traveling age and from January through May for several hours. In Idaho, BAILEY (1974) found tracks to indicate two adults were together in November. He did observe a pair of bobcats during the breeding season accompanied by two nearly year-old cubs. In Nepal, McDUGAL (1977) found that a tigress often keeps $\frac{2}{3}$ grown cubs with her while in the company of a male.

LEYHAUSEN (1979) notes the preference of female cats for a certain male. My observations confirm a relatively monogamous relationship between a pair and I believe they share the responsibility of maintaining home range boundaries. The male traveled more widely than the female when she cared for 3 to 9 month old cubs. Radio-tracking data of BAILEY (1974) in Idaho and GUENTHER (1980) in Florida indicate that mobility of males was greater than females during spring and summer when the home ranges of a pair overlapped. In my study the only time an adult other than the consort was with the female was when she showed signs of estrus.

Bobcats are polyestrous with two or three cycles a year (CROWE 1975; MEHRER 1975). Estrogen levels of captive animals in North Dakota were highest in April, June and August. The average heat period lasted 7.5 days. A highly significant association between behavioral patterns and cytological appearance of the vagina was observed at every stage of the estrous cycle and propensity for increased motor activity during proestrus was evident (MEHRER 1975). The Floridan female moved to each end of the home range at least daily during the last two weeks of January. This may have been a result of her proestrous condition. During this period she dispatched her cubs to opposite ends of the home range and was able to make her reproductive condition known to the consort and the males in adjacent home ranges. She was believed to be in estrus from 29 January to 6 February (9 days). Signs of heat were similar to those I observed during her 1978 breeding season; moist feces, a tolerant and tranquil disposition and spraying on the vegetation. Captive females (MEHRER 1975) urinated and rubbed themselves about the head and shoulders on every available object in a "seemingly random manner" until they finally came into estrus and were friendly toward a male. While KLEIMAN (1974) noted flank rubbing, rolling on the back, and lordosis as the best signs of heat in the tiger, MEHRER (1975) associated

rubbing and rolling with proestrus in the bobcat. I have observed head rubbing and rolling in previously sprayed areas, while the female was with mobile cubs. MCCORD (1973) found evidence of "running encounters" and "ambush-behavior" during estrus while tracking bobcats in the snow, but this was not evident in the sand.

Most mating probably occurred with the consort male. Males in adjacent home ranges and perhaps transients are probably attracted to the female in the breeding season by the scent she sprays along the boundaries. Consorts associated for several hours for 2-3 days at a time during late January and until May 1981. Only during estrus and pregnancy was another male from an adjacent home range tracked near the female in her home range. The attraction of males to females during and after breeding was probably the reason for the male-male home range overlap reported for bobcats (BAILEY 1974). MCCORD (1973) found tracks of a female on 12 March followed by three males (one was the consort) and on 21 March her tracks were found with a non-consort male. SCHALLER (1967) found that tigers, who also travel widely in estrus, are sometimes followed by several males.

In 1981 the Floridan female gave birth 57 ± 1 days after the last day of estrous behavior. This is within the 50-60 day gestation period reported for bobcats (YOUNG 1958). To verify existing data MEHRER (1975) induced estrus with pregnant mare serum gonadotropin (PMSG) and a bobcat gave birth 67 days after the last date of breeding. He noted that the PMSG extended gestation in the puma, as it did in the domestic cat (COLBY 1970).

An extension of male-female associations into the pregnancy period occurs in other felids and other mammals. Domestic cats (SCOTT and LLOYD-JACOB 1955) and tigers (KLEIMAN 1974) may exhibit estrous behavior and even mate when not in heat and when pregnant. The consort in my study rendezvoused with the female during pregnancy and away from the den site in the second and fifth weeks after parturition. Domestic cats, the European wildcat (*Felis silvestris*), and the fishing cat (*Prionailurus viverrinus*) exhibit false heat a few weeks after the birth of the young (LEYHAUSEN 1979). The association of consorts at this time may be important to maintain their bond. In my study the pair continued to associate after the cubs dispersed.

The use of pugmarks to identify and study bobcats is a valuable technique on sandy soils of Florida and has been useful in other geographic locations. In 1953 BRUCE described the long established method of cat hunters in California as one of identifying and following tracks. Snow tracking has generally been an accepted means of collecting data on bobcats in the north. In Massachusetts (MARSTON 1942) and in Minnesota (ROLLINGS 1945) home ranges of 47-104 km² and 39-52 km², respectively, were determined in this manner. In the south where, according to radiotelemetry studies, smaller home ranges of 3-5 km² in South Carolina (MARSHALL 1969) and 6-14 km² in Florida (GUENTHER 1980) were reported the task of direct monitoring of a group of bobcats is feasible.

Monitoring by pugmarks eliminates the need for trapping, and time required to trap a bobcat can be considerable. In Idaho, BAILEY (1973) found that it required an average of 567 trap nights to initially trap an adult cat and 1,020 to recapture one. In Florida with more accessible terrain GUENTHER (1980) averaged 1 cat in 64 trapnights. Transient and trap shy animals may never be monitored and distort the final interpretation of the data. Scent marks and other aspects of the animals behavior may go unnoticed.

In Florida a scent station census technique has been used to count bobcats (BRADY 1979). At a scent station a meter circle of sifted soil is cleared, and an odorant is placed in the center and tracks are reported. The identification of pugmarks of individuals would provide a better index of bobcat populations. The sex of a female can be determined when she travels with cubs. The sexes of cubs in a litter could provisionally be determined by the larger pugmarks of the male cubs.

If our knowledge of the bobcat is to continue to expand we must acquire more data on the activity of individual bobcats at close range. Pugmarks provided information on the movements and behavior of bobcats in this study but further assiduous testing of the technique is necessary to determine its feasibility when monitoring larger populations.

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Zusammenfassung

Fährten und Biologie vom Rotluchs, Lynx rufus

Bei einem 7 Jahre alten weiblichen Rotluchs (*Lynx rufus floridanus*) werden mütterliches Verhalten, Ausbreitung von Jungtieren und Assoziationen mit einem adulten männlichen Individuum beschrieben. Die Angaben basieren auf Fährtenanalysen und direkten Beobachtungen von Juni 1980 bis August 1981. Zur Analyse von Ortsveränderungen wurden die charakteristischen Fußabdrücke der durch Gesichtszeichnung, Größe und Farbgebung unterscheidbaren einzelnen Individuen benutzt. Die Jungen (1, 1), im Mai 1980 geboren, erhielten im Alter von 8 Wochen feste Nahrung und wurden 4 Monate lang versorgt. Im 9. Lebensmonat vereinzelt sie sich in entgegengesetzten Regionen des mütterlichen Aktionsraumes. Dieses Areal verließen sie, 14 Monate alt, als die Mutter erneut Junge führte. Adultes Männchen und Weibchen teilten den Aktionsraum miteinander, und gelegentlich ruhten sie gemeinsam, von den Jungtieren entfernt. Das Männchen durchstreifte den Aktionsraum weit und verließ ihn gelegentlich, während das weibliche Tier sich ausschließlich innerhalb der Grenzen aufhielt. Identifikation und Kommunikation der Geschlechter beinhaltete Geruch und Vokalisation.

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Feinstrukturelle Untersuchungen am Gefrierbruchpräparat von Lungenalveolen der Krabbenfresser- (*Lobodon carcinophagus*) und Weddellrobbe (*Leptonychotes weddelli*)¹

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Abstract

*Freeze fracture investigations of the pulmonary alveoli of the crabeater- (*Lobodon carcinophagus*) and Weddell seals (*Leptonychotes weddelli*)*

The fine structure of the blood/air barrier in the lung of two species of Antarctic seals (*Lobodon*, *Leptonychotes*) was studied by application of the freeze fracture technique. The tight junction of the alveolar epithelium is composed of 3-6 sealing strands which are interconnected by abundant anastomosing strands, thus creating a net-like structure. Between endothelial cells of the alveolar blood capillaries only 1-4 sealing strands, which are only loosely interconnected, build up the tight junction. Since these figures fall within the range of terrestrial mammals it is inferred that the principal barrier for fluid movements in the pulmonary alveoli of all mammals - independent of their way of life - is located in the alveolar epithelium. The temporarily high hydrostatic pressure which can rest upon the diving seals has obviously no effect on the morphology of the tight junctions in the blood/air barrier. The pneumocytes II contain numerous large lamellar bodies, the individual smooth lamellae of which usually are stacked upon each other. The smooth alveolar surface-film is marked by wavy grooves.

Einleitung

Ziel der vorliegenden Untersuchung ist die Darstellung der Alveolarepithelien und der Blut/Luftschranke in der Lunge von *Lobodon carcinophagus* und *Leptonychotes weddelli* im Gefrierbruchpräparat. Diese Technik ist besonders geeignet, funktionell wichtige Strukturen wie Zellkontakte und andere Membrandifferenzierungen im Elektronenmikro-

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