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A Video Surveillance System for Monitoring the Endangered Mediterranean Monk Seal (*Monachus monachus*)

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Abstract

The components and specifications of a surveillance system developed in a pilot study to monitor Mediterranean monk seals (*Monachus monachus*) are presented. The system consisted of two B/W CCD cameras, infrared illuminators, a CCTV video web server, and photovoltaic solar panels, and it was operated under harsh outdoor conditions for three and a half months. It enabled the recording of rarely observed aspects of the Mediterranean monk seals' social and reproductive behaviour, as well as provided a method to document demographic parameters of the local seal population. Advantages of the system include its non-invasive nature and its autonomous operation, while the primary disadvantage is the high initial cost, which should decrease as technology continues to improve. This system could prove to be a valuable tool in the conservation of critically endangered seal species such as the Mediterranean monk seal.

Key Words: Mediterranean monk seal, *Monachus monachus*, behaviour, conservation, videography, National Marine Park of Alonnisos, Northern Sporades, Greece

Introduction

The collection of baseline biological information is an essential prerequisite for the effective protection of endangered species. In the case of the critically endangered Mediterranean monk seal (*Monachus monachus*), small population size and inaccessibility of its habitat, which consists of coastal caves and beaches on remote islands or near cliff-bound continental coastlines, have hampered scientific research. The profound lack of knowledge of basic biological parameters in turn has negatively affected the design and implementation of effective conservation actions (Reijnders et al., 1988; Brasseur et al., 1997).

Remote photography has a long history and numerous applications in wildlife research (Cutler & Swann, 1999). Recent advances in technology and cost reduction are making remote videography techniques increasingly popular in modern conservation biology and have been applied in numerous animal studies using various types of equipment (Sykes et al., 1995; Stewart et al., 1997; Delaney et al., 1998). Because of the inherent difficulties involved in the study of the Mediterranean monk seal, attempts to remotely monitor the species have had mixed success at all the primary areas of the species distribution (Freitas, 1994; Badosa et al., 1998; Dendrinos et al., 1998; Layna et al., 1999; Mo et al., 2001; Gucu et al., 2004). All previous studies involved monitoring a cave, either from a base camp situated nearby or by entering caves in regular, short time periods to retrieve data and replace the recording medium. The application, however, of such a methodology might be problematic: the placement and operation of a base camp at some of the remote and inaccessible locations of habitat preferred by monk seals might be difficult, while weather conditions or mother/pup pairs that might be highly susceptible to disturbance within a cave might also restrict access to the cave.

This paper describes the design, logistical constraints, and results obtained during the pilot study deployment of a non-invasive, state-of-the-art surveillance system developed to monitor a Mediterranean monk seal pupping site in Greece. Greece holds the largest remaining population of this species (Brasseur et al., 1997).

Materials and Methods

Study Area and Study Species

The study was carried out within the National Marine Park of Alonnisos, Northern Sporades (NMPANS), a complex of islands located in the northwestern Aegean Sea that has been identified as extremely important to the survival of the Mediterranean monk seal (Schultze-Westrum, 1977; Kouroutos et al., 1986; Dendrinos et al., 1998). NMPANS was established in 1992 and extends over approximately 2,200 km^2 (Figure 1). Recent research indicates that it is the most important pupping area for the species in the northeastern Mediterranean, with a mean annual pup production of seven pups (Dendrinos et al., 1998).

The cave chosen for this study was among the most frequently used pupping sites for Mediterranean monk seals within NMPANS' core zone (Dendrinos et al., 1998; MOm, 2005). Located in a small bay on the southwestern side of the island Piperi, the cave had a small above-water entrance (8.3 m width, 1.2 m height, 2.0 depth) facing to the southwest that leads through a 6-m-long corridor to a beach. The 60 m^2 beach was covered with small pebbles. The mean dome height of the cave near the beach was 1.5 m and sloped gently down toward the end of the beach.

Camera Surveillance System

We constructed our surveillance system from high-performance components in order to maximize operation under all weather conditions for several months, while at the same time requiring minimum effort for maintenance. We used two waterproof, black and white, charge-coupled device (CCD) circuit-board video cameras. The solid state 12 V cameras were equipped with F2.0, 80º lenses, an external microphone, and a 12 LED infrared light source. Tests carried out within the cave indicated that the single LED infrared light source did not illuminate the cave sufficiently. We therefore installed an additional 12 LED light source next to each camera. To ensure maximum coverage, cameras provided a minimum of 380 lines of resolution and were mounted with steel rock bolts to the roof of the cave and in opposite directions to each other. Installation of the unit in the cave was conducted during midday hours of July as research in the NMPANS indicated that monk seal presence within caves during this time period was lowest (Dendrinos et al., 1994).

The in-cave system was connected with the power source and monitoring equipment through a 100-m-long coaxial power cable. The power source consisted of a charger and three rechargeable 12 V, 120 Ah batteries connected in parallel. These batteries were powered by two photovoltaic polycrystal solar panels (12 V, P_{max} = 110W). Monitoring and recording equipment consisted of a CCTV Video Web Server with a 40GB HD (Model: Convision V610A; Convision Systems GmbH, Braunschweig, Germany) and a portable PC (Hewlett Packard, Pentium III, 60GB). Control of the Web server and data download was facilitated through a 10-Mbit Ethernet connection with the portable PC and operation of the *ConvisionSafe*

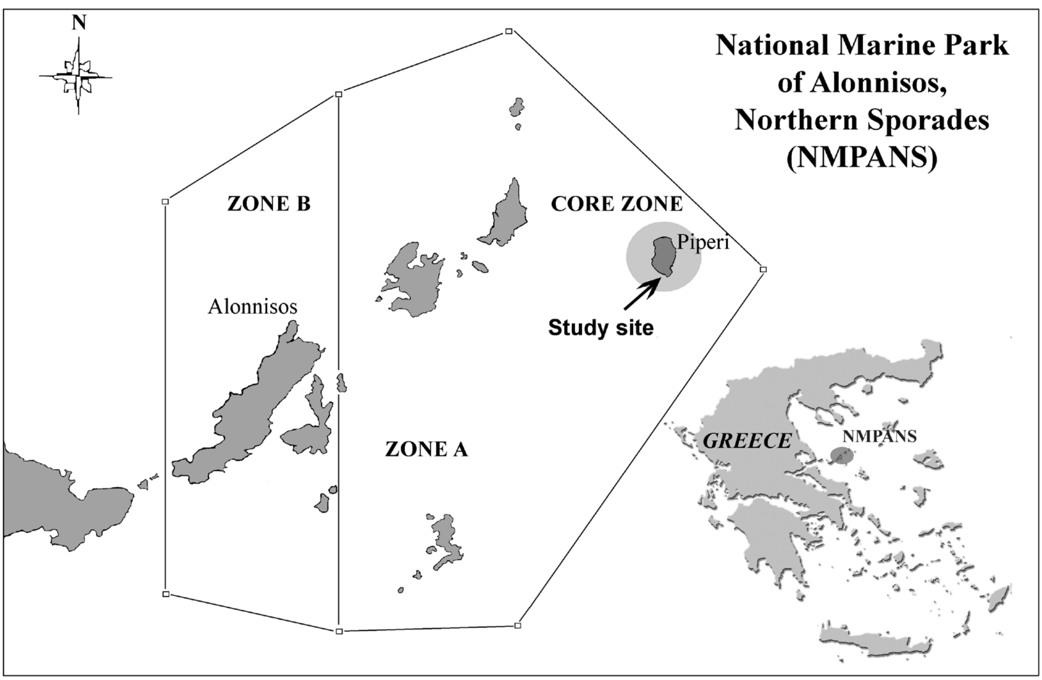

Figure 1. Map of the National Marine Park of Alonnisos, Northern Sporades, indicating the location of the study site

Version 2.0 software. The server recorded in-cave activity on a 24-h basis with low resolution (2 frames/s, image size 384 × 288 pixels). This resolution was chosen to ensure small data volume and resulted in one field visit every 5 d for data retrieval. All equipment outside of the cave was installed at a distance of 100 m from the cave entrance at a small plateau overlooking the cave. The Web server and rechargeable batteries were placed in a weatherproof storage casing.

The principal components of the system are given in Table 1. The total cost for the equipment of the video surveillance system was 10,300 €.

Individual monk seal identification was based on the natural scars and markings of the animal, as well as on the general morphological characteristics of the species (Badosa et al., 1998; Dendrinos et al., 1999; Samaranch & Gonzalez, 2000).

Table 1. Equipment and units required in a closed-circuit video system for monitoring a Mediterranean monk seal pupping site

Component	Units required
Waterproof B/W CCD video camera	2
12 LED infrared light source	2
Coaxial and power cable	100 m
12 V, 80 Ah battery	3
Charger	1
12 V photovoltaic polycrystal solar panel	2
CCTV Web server (40GB HD)	1
Portable PC	1

Results

The surveillance system was installed on 28 July 2003 and, following a 2-d testing period, operated on a 24-h basis from 30 July until 15 November 2003 when severe storms damaged the coaxial cable connecting the equipment to and from the cave. From a total of 2,500 h of cave monitoring, 272 h (10.8%) showed the presence of seals in the cave. The sightings recorded during the monitoring period were too limited to carry out statistical comparisons (i.e., comparisons of habitat use between different age classes or of haulout patterns throughout different periods of a day), yet too detailed to be fully described. Therefore, only key findings of these sightings relative to population parameters, habitat use/haulout patterns, and social and reproductive behaviour are presented herein.

Population Parameters

In total, during the study, 30 sightings were made (Table 2), of which we were able to individually recognize seven different seals. We identified four adult females and one female pup occupying our study site; two more juveniles were present in the cave, but their gender could not be determined. The pup was approximately 1-wk-old when first observed and was not born at the study site.

Habitat Use/Haulout Patterns

Our study site provided a haulout area (i.e., beach) for the seals throughout the entire monitoring period. Monk seal activity within the cave was recorded for the first time in mid-September when an adult female visited the cave. Increased use of the cave was recorded from the end of September to mid-October when it was visited regularly by a single adult female, a juvenile, and a lactating female with her female pup. Cave visits occurred when sea conditions were calm and the beach in the interior of the cave was not washed out. From the end of October onward, in-cave conditions deteriorated because of strong, southerly winds and waves washing out the beach; no further use of the cave was recorded. When animals were recorded in the cave, hauling out of adult females exhibited a pattern, starting in the early evening hours (i.e., between 1900 to 2100 h) and ending in the morning hours (i.e., between 0700 to 1000 h). This pattern did not apply to the lactating female, which remained hauled out in the cave with her pup during the day. Juveniles did not exhibit any distinct haulout patterns.

Social and Reproductive Behaviour

The maximum number of individuals observed simultaneously at the study site was four (two adult females, one juvenile, and one female pup). We did not observe any kind of interaction between the two adult females. There appeared to be a partitioning of the haulout area; the lactating female always occupied the right, larger section of the beach, whereas the other adult female always remained at a small crevice at the left section of the haulout area. There were no regular interactions between the juvenile and the other occupants of the cave. On two occasions, however, when the juvenile approached the newborn pup and the lactating female, the latter aggressively defended its "position" by attacking the approaching juvenile. On one occasion, the lactating female actively pursued the juvenile out of the cave and, while doing so, trampled over her newborn pup (Figure 2). Two incidents of the mother feeding its pup and regular muzzle-to-muzzle contacts were also recorded.

Table 2. Mediterranean monk seal sightings recorded during the monitoring period (28 July to 15 November 2003); for more information on sightings 3, 7, 16, 18, 27, and 29, please visit www.aquaticmammalsjournal.org/Video/index.htm.

Sighting	Entry hour	Entry date	Exit hour	Exit date	ID	Duration
1	2200	15/09/03	0700	16/09/03	Juvenile 1	9 h
2	2200	19/09/03	0800	20/09/03	Ad 1	10 h
3	2000	20/09/03	0800	21/09/03	Ad 1	12 h
4	1000	27/09/03	0815	28/09/03	Ad 2	22 h
5	1000	27/09/03	1032	28/09/03	Pup	24 h
6	1100	27/09/03	0125	28/09/03	Juvenile 2	14.5 h
7	0130	28/09/03	0815	28/09/03	Juvenile 2	7 h
8	0820	28/09/03	1027	28/09/03	Ad 2	2 h
9	1028	28/09/03	1032	28/09/03	Ad 2	5 m
10	1033	28/09/03	1226	28/09/03	Ad 2	2 h
11	1033	28/09/03	1226	28/09/03	Pup	2 h
12	2251	28/09/03	0700	29/09/03	Ad 2	8 h
13	0430	29/09/03	0800	29/09/03	Ad 2	3.5 h
14	0430	29/09/03	0800	29/09/03	Pup	3.5 h
15	0848	29/09/03	0852	29/09/03	Pup	5 m
16	1940	29/09/03	0700	30/09/03	Pup	11.5 h
17	1940	29/09/03	0700	30/09/03	Ad 3	11.5 h
18	0030	30/09/03	0730	30/09/03	Ad 1	7 h
19	0330	30/09/03	0700	30/09/03	Juvenile 2	3.5 h
20	2200	30/09/03	2205	30/09/03	Juvenile 2	5 m
21	1900	30/10/03	0700	01/10/03	Ad 2	12 h
22	1800	01/10/03	1100	02/10/03	Ad 1	17 h
23	1900	01/10/03	1200	02/10/03	Ad 2	17 h
24	1900	01/10/03	1200	02/10/03	Pup	17 h
25	1900	02/10/03	0800	03/10/03	Ad 1	13 h
26	0227	03/10/03	0236	03/10/03	Juvenile 2	5 m
27	2000	21/10/03	0600	22/10/03	Ad 3	10 h
28	2100	22/10/03	0700	23/10/03	Ad 4	10 h
29	2100	23/10/03	0800	24/10/03	Ad 3	11 h
30	2100	23/10/03	0800	24/10/03	Ad 4	11 h
Total		30 sightings				272 h

Discussion

Since conservation efforts for the critically endangered Mediterranean monk seal began, the acquisition of baseline information on its biology and the development of non-invasive research methodologies have been the priority for identified conservation actions (Johnson & Lavigne, 1998). The development of the current surveillance system worked effectively towards achieving these conservation goals.

Monitoring the monk seal cave enabled the collection of data on the composition of the colony and confirmed the importance of the study site for the local monk seal population. In addition, habitat use and haulout patterns observed during the study were in accordance with results from previous area studies (Dendrinos et al., 1994, 1998) and studies performed in the eastern Mediterranean (Güçlüsoy & Savas, 2003; Gucu et al., 2004). Finally, the operation of the system enabled the recording of monk seal behaviour that otherwise would have been difficult to obtain through field observations. Previously, aggressive behaviour of a lactating female had only been recorded once, also with the use of remote videography (Layna et al., 1999).

Once the system was installed in the field it proved to be easily operated, it was maintenance free, and it operated even under harsh outdoor conditions. Only following a severe storm was the connection between the in- and out-cave components of the system damaged and operation of the entire system compromised. It is therefore of utmost importance that special attention is given to the fixed installation of the cables to prevent damage by strong wave action. Another important problem that we encountered, despite modifications during testing, was relative to the infrared light source. The strength of the light sources

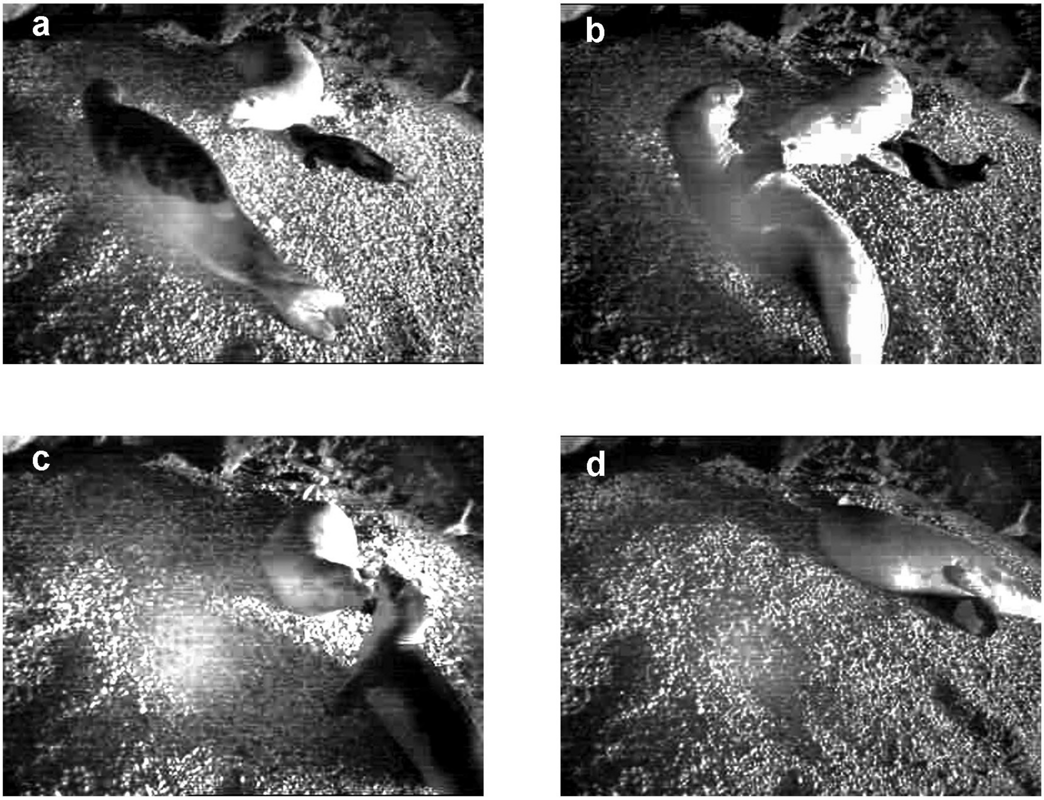

Figure 2. Sequence of images from the CCTV system showing an aggressive interaction between a lactating Mediterranean monk seal and a juvenile. From top left to bottom right: a. Juvenile Mediterranean monk seal approaching a lactating female and its pup; b. lactating female charging against the juvenile and biting it at its left fore flipper; c. lactating female chasing the juvenile away; and d. lactating female pursuing the juvenile and trampling over its newborn pup. For more information on this interaction, please visit www.aquaticmammalsjournal.org/Video/index.htm.

provided diminished as distance from the camera increased and at night; for example, a moving seal at the farthest end of the cave was not clearly visible. Additional or stronger light sources are required. Improvements to reduce costly field visits for data retrieval could include the installment of larger data storage media and the use of data links, which could transmit data to a more accessible location.

Non-invasive, remote-monitoring techniques are currently widely applied in the study and protection of cryptic and endangered species. The application of the system described herein shows that it can be used in a cave to monitor monk seal habitat without human interference. This system can be applied in remote locations and is therefore particularly suitable in all key monk seal habitats throughout Greece, Turkey, and Madeira. Considering the current improvements in technology and the ongoing cost reduction, such a system could become a valuable tool in the study and conservation of the Mediterranean monk seal.

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