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THE ENDANGERED MEDITERRANEAN MONK SEAL *Monachus monachus* IN THE IONIAN SEA, GREECE

Aliki Panou, Jürgen Jacobs & Dimitris Panos

Zoologisches Institut, Universität München, Seidlstrasse 25, D-8000 München 2, Germany

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Abstract

The declining population of monk seals on the Ionian islands of Kefalonia, Ithaca, and Lefkada, Greece, was studied from July 1986 to April 1988. The study included (1) individual identification, (2) number of sightings, (3) use of caves, (4) damage to fishing gear, and (5) deaths. Three hundred and ninety-seven sightings of about 18 seals (including eight pups) were recorded. Maximum sightings occurred in June/July 1987; most sightings were of solitary animals. Twenty of 126 surveyed caves (16%) were used by seals. There were preferences for specific caves. There was no evidence of a diurnal pattern of cave use. Fishing trips near the study sites were monitored, and 136 of 1864 (7·3%) reported damage by seals to fishing gear. Significant correlations were found between sightings, cave use, and damage to fishing gear and/or catch. In an experiment we demonstrate that one seal may cause considerable damage in one night. Mortality data of 25 years show that most of 34 reported deaths were caused by deliberate killing (62%) and accidents in fishing gear (24%). Suggested measures for mitigating the decline of monk seals include (1) establishing protection zones, (2) compensating fishermen for losses, and (3) expanding public awareness programmes.

INTRODUCTION

The Mediterranean monk seal, *Monachus monachus* (Hermann 1799), is threatened with extinction in the immediate future. In early times it was common throughout the Mediterranean. Homer described vast herds of seals on the beaches 'counted by fives' by the immortal Proteus, servant of Poseidon (*Odyssey*, Book IV, verses 400 ff.). Seal hunting was important in classical Greece (King, 1956). The ancient Greek district of Phokis on the Gulf of Corinth and the colony of Phokaea on the Aegean coast of Turkey (now Foca) were named after the seal, and Phokaea even had seals on coins (Sergeant *et al.*, 1978). During the last century populations have declined, in part due to exploitation for pelts, skins and oil. At the turn of the century, the mediterranean monk seal was probably a rare species. It is now listed as one of the worlds six most threatened mammals (IUCN, 1984).

In 1978 international concern for *M. monachus* led to the adoption of an action plan by the First International Conference on monk seals in Rhodes, Greece. This plan gave highest priority to (1) establishment of a network of reserves, (2) broad public awareness campaigns, (3) reduction of pollution, and (4) study of the biology and ecology of the species (Ronald & Duguy, 1979). Similar action plans were approved at the Second Conference in La Rochelle, France (Ronald & Duguy, 1984), and a Joint Expert Consultation in Athens (IUCN/UNEP, 1988).

Conservation efforts in Greece began in 1976 in the Northern Sporades (Anon., 1976; Schultze-Westrum, 1976). In 1981, a presidential decree gave complete protection to monk seals. Several studies were carried out in the Northern Sporades (Matsakis *et al.*, 1985), and a national park is now being established there. Another initiative was started in the Ionian Sea (Harwood *et al.*, 1984) where the seal population may have a fair chance of survival (Goedicke, 1981). The Greek government has since declared its intent to establish a protection zone in this region (IUCN/UNEP, 1988).

It was in this conservation context that this study was undertaken. Our aim was to confirm and extend earlier studies on the biology and ecology of the threatened species (Harwood, 1987). In addition, interactions between seals and fishermen were monitored and correlated with other seal activities. This information is necessary for the optimal location of protection zones. For a full account of our study, which also included public awareness programmes, see Jacobs and Panou (1988). Here we report on (1) the identification of individual seals and an estimate of population size, (2) sightings of seals by ourselves and informants, (3) the use of caves, (4) frequencies of damage to fishing gear, and (5) records of seal deaths.

PRESENT DISTRIBUTION, POPULATION DECLINE AND ITS CAUSES

The original range of *M. monachus* extended through the whole Mediterranean basin including the Black Sea up to Odessa, the Atlantic coast, the Canaries and Madeira. During the last two decades, the total population has probably dwindled to less than 600 individuals distributed in a checkerboard fashion (Sergeant *et al.*,

1978; Boulva, 1979; Reijnders *et al.*, 1988; Marchessaux, 1989; Council of Europe, 1991). Figure 1 indicates the distribution and its change during the last 20 years. Eighty to 400 individuals are believed to live in Greek waters (Vamvakas *et al.*, 1979; Marchessaux, 1989; Council of Europe, 1991), and about 50–100 on the Turkish Mediterranean coast (Mursaloglu, 1964; Berkes, 1976, 1978; Sergeant *et al.*, 1978; Berkes *et al.*, 1979). Another 50–100 animals may still exist along the North coast of Africa (Norris, 1972; Maigret *et al.*, 1976; Rosser *et al.*, 1978; Bougazelli, 1979; Lloze, 1979; Avellá & Gonzales, 1984*a*). Some scattered individuals have been recorded from the Yugoslavian coast (Anon., 1976; Ronald, 1984). In the Black Sea a few animals may still live along the Turkish coast, and a small colony perhaps exists in Bulgaria (King, 1983). The species is extinct in Spain, Italy (including Sardinia), France, Egypt, Israel and Lebanon. The Atlantic population is now isolated and may constitute a subspecies (van Bree, 1979). Some 100 animals live along the northwest coast of Africa, and about 10 individuals have survived on Desertas Islands, Madeira (Avellá & Gonzales, 1984*b*). The Canary population is extinct. For recent surveys and estimates see Sergeant *et al.* (1978), Sergeant (1984), Marchessaux (1989), Anselin *et al.* (1990), and Council of Europe (1991).

Since it is difficult to obtain reliable data from animals that are rarely seen, all estimates of population size are questionable. But there is little doubt of the species' decline. Boulva (1979) calculated rates of decrease for various regions. Goedicke (1981), using Boulva's average value of 13% per year, estimated that most colonies in the Mediterranean will be gone by 2000. Chief causes of the decline put forward have been (1) fragmentation of the population and loss of its coastal habitat by expanding human activities, mainly tourism, and (2) deliberate killing, mainly by fishermen (e.g. Sergeant *et al.*, 1978; Jacobs & Panou, 1988; Marchessaux, 1989). Except for the relatively undisturbed African population along the Atlantic coast, seals today almost never haul out on exposed beaches or rocks. Caves seem to be the only sites left for pupping and resting. Since suitable caves are probably rare they may constitute a limiting factor for reproduction and the survival of pups. Furthermore, low densities and fragmentation of the populations may reduce the chances of finding a mate. Pollution is also discussed as a possible factor but its potential impact is difficult to assess at the present time (van Haaften, 1979; Jacobs & Panou, 1988; Marchessaux, 1989). Viral infections responsible for the recent catastrophic mortality of seals in the North Sea have not yet been shown to affect the Mediterranean species. It is unknown whether local inbreeding occurs, and if so, whether it could have deleterious effects.

METHODS

The study area

The study area (Fig. 2) comprised the three islands of Kefalonia, Ithaca and Lefkada in the Ionian Sea. Also included were the small uninhabited islands of Atokos, Arkoudi, Formicula and Sessoula. Our activities were concentrated on the Ithaca channel between Kefalonia and Ithaca. The channel, which is about 20 km long, was chosen because it had been studied before (Harwood, 1987), and because seals were known to be present at this location. It is sheltered from storms, permitting undisturbed surveys through most of the year. The area is inhabited by few people. The most important fishing harbour of the channel is Stavros (Ithaca) with 13 professional fishermen. The only other harbour, Fiskardo (Kefalonia), is now mainly used by tourists, with only one or two professional fishermen.

One hundred and forty-three caves are known in the study area (Harwood *et al.*, 1987; Jacobs & Panou, 1988), including 106 on Kefalonia, 20 on Ithaca, 12 on Lefkada, four on Atokos, and one on Arkoudi (Fig. 2).

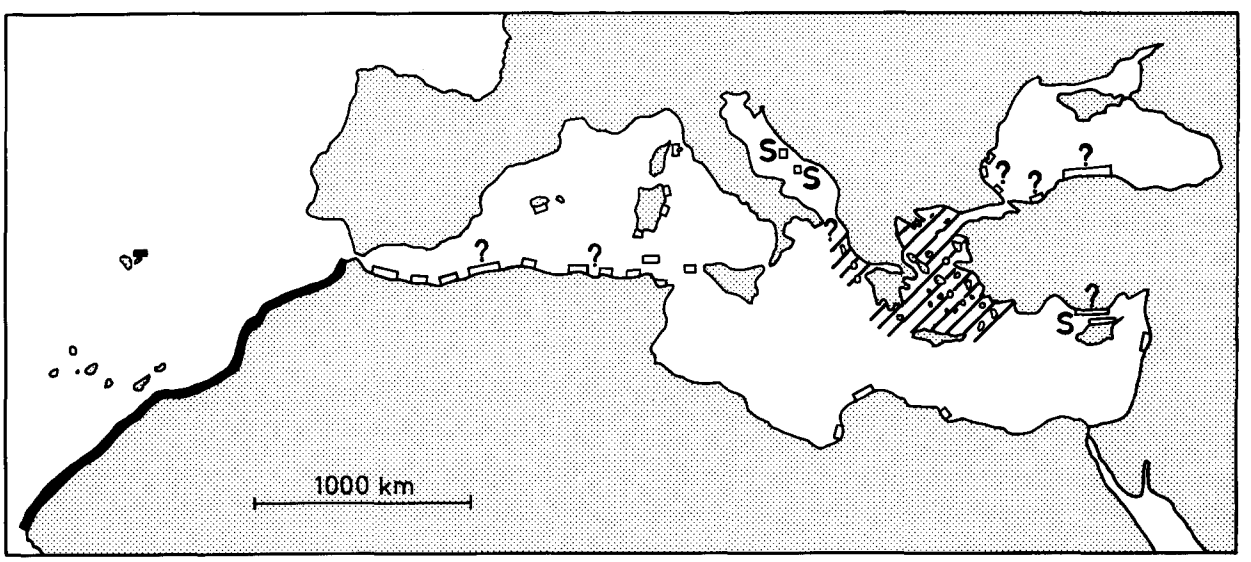

Fig. 1. Distribution of the mediterranean monk seal. Solid bars (West African coast, Madeira) and hatched area: estimated present distribution; ?, presence uncertain; S, scattered sightings; solid and open bars and hatched area, estimated distribution 1970–1977 (Sergeant *et al.*, 1978).

Our surveys were concentrated on the 11 caves on the Ithaca channel. Sizes ranged from about 2 to 1000 m^2, depths from 1 to 30 m, and heights from <1 to >10 m. For more information and maps see Harwood (1987) and Jacobs and Panou (1988).

Population size and sightings

The data were collected during a 22-month period from July 1986 to April 1988. Population size was estimated on the basis of observations of seals identified by colour, size, and individual marks (scars, etc.). In some instances, reports from trustworthy people were included. Double counts were avoided by comparison of dates and locations of records. Sightings included own observations and reports by others. Most of our own data were collected during cave surveys. Occasionally seals were sighted from land or during trips with fishermen. The assessment of reliability of informants was based on our familiarity with them and local conditions, and not on concordance with our own observations.

Cave use

From July to December 1986, the caves of the Ithaca channel were surveyed 1–10 times per month (see also Harwood, 1987). From February 1987 to April 1988, surveys were made about 20 times a month and mostly during the day. Some of the caves were visited less frequently than others due to bad weather conditions (e.g. on the exposed north coast of Kefalonia, see Fig. 2). Surveys outside the channel were usually made 1–2 times per month or less.

From July 1986 to January 1987 the caves of the Ithaca channel were surveyed 1–10 times per month, and almost daily from February onwards. Caves in other parts of the study area were examined about 1–2 times per month. Direct encounters with seals as well as tracks and sleeping depressions on the caves' beaches were counted as evidence of cave use. Tracks and depressions were evaluated and then smoothed over. Faeces and fur were occasionally found but only when seals or tracks were also present.

Damage to fishing gear

From July to September 1986 we accompanied the fishermen of the Ithaca channel on selected trips in order to record damage caused by seals. This method proved time-consuming, and allowed coverage of only a limited number of fishing trips. During the first half of December 1986 and from March 1987 to April 1988, interviews were conducted daily to determine the number and percentage of fishing trips where damage occurred on that given day. Interviews covered all trips, locations, and fishing methods in the channel and the surroundings, and also provided a means to collect information of seal sightings.

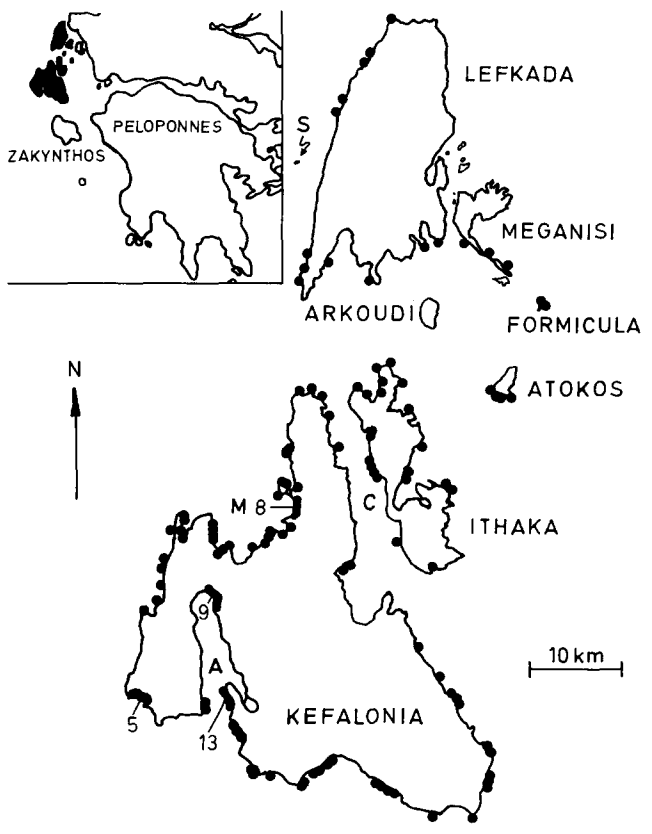

Fig. 2. The study area in the Ionian Sea, Greece. ●, location of individual caves surveyed by Harwood (1987) and by us. If there are several caves, this is indicated by number. A, Bay of Argostoli; C, Ithaca channel: M, Gulf of Myrtos; S: Sessoula.

RESULTS AND DISCUSSION

Individual seals, pups, and population size

The number of individual seals seen by us or reliable informants is shown in Table 1. They ranged from 6 to 15 animals per three-month period, with an average of 8·7. Altogether 18 seals were identified by colour and size. Colours showed a surprising range of variation, from pale light beige, to almost white, to silvery grey, several shades of grey and brown, to very dark and almost black (see also Sergeant *et al.*, 1978; Berkes *et al.*, 1979). The ventral side was always whitish or yellowish except for one large pale female with a dark belly. Light spots on the back were observed on two occasions. Pups were mostly dark or black.

The number of seals identified (18) is considered to be a minimum. There were several sightings or tracks of uncertain identity. The number of individual seals actually observed is thought to be close to 25, which is similar to estimates of Verriopoulos (1985). Eight (44%) of the 18 animals were pups (seven of them observed between July 1986 and January 1987), two (11%) medium-sized or small (≈1·5 m), four (22%), of normal size (≈2·0 m), and four (22%) large (≥2 m). Although the size classes are approximate (except for the pups), they indicate a small but reproducing population.

The breeding season is said to last from May to November with a maximum in September and October (King, 1983). Our data generally fit into this broad range

Table 1. Number of seals identified by colour or size
O, own observations; R, Reports by others; T, tracks in cave

July–September 1986	Ithaca channel	2 ad. (1♂)	O, T
(Σ = 15 seals)	Gulf of Myrtos	1 ad. (♀); 1 subad.; 3 pups	O, T
	SW Lefkada	2 ad.	R
	Atokos	1 ad.	T
	Argostoli Bay	1 ad. or subad.	T
	S & SE Kefalonia	1 ad.; 3 pups	O
October–December 1986	Ithaca channel	1 ad. (♂); 1 new pup	O, T
(Σ = 9 seals)[a]	Gulf of Myrtos	1 ad.	O, T
	SW Lefkada	2 ad.	R
	Argostoli Bay	1 ad.	O, T
	S & SE Kefalonia	1 ad.; 2 pups	O
January–March 1987	Ithaca channel	2 ad. (1♂); 1 subad.; 1 pup	O, T
(Σ = 6 seals)[b]	Gulf of Myrtos	1 ad.	O
	Argostoli Bay	1 ad. or subad.	R
April–June 1987	Ithaca channel	3 ad. (1♂); 1 juv.	O, T, R
(Σ = 10 seals)	Gulf of Myrtos	1 ad.	O, T, R.
	SW Lefkada	2 ad.	R
	Formicula	1 ad.	R
	Argostoli Bay	1 ad. or subad.	R
	S & SE Kefalonia	1 ad.	R
July–September 1987	Ithaca channel	2 ad. (1♂); 1 juv.	O, T
(Σ = 9 seals)	Gulf of Myrtos	1 ad.	O
	SW Lefkada	2 ad.	R
	E Ithaca/Atokos	1 ad.	R
	Argostoli Bay	1 ad. or subad.	R
	S & SE Kefalonia	1 ad.	R
October–December 1987	Ithaca channel	2 ad. (1♂)	O
(Σ = 6 seals)[c]	SW Lefkada	2 ad.	R
	Ithaca	1 ad.	R
	S Kefalonia	1 ad.	R
January–April 1988	Ithaca channel	1 ad.	R
(Σ = 6 seals)[d]	Gulf of Myrtos	1 ad.	R
	Argostoli Bay	1 ad. or subad.	R
	S & SE Kefalonia	2 ad.; 1 pup	R

[a] No information from Lefkada.
[b] No information from Atokos.
[c] No information from Argostoli.
[d] No information from S Kefalonia.

but there were exceptions (cf. Table 1). The maximal litter size is not known. Avellá (1979) mentions two females with one foetus each, and two with a pair of foetusses. Troitzky (1953) stated that the monk seal only has a pup every alternate year. The large female seen in the same area as the three pups (8 July 1986; see Table 1) had given birth to a dark pup the year before (Hiby *et al.*, 1987). This could indicate that a female may reproduce in successive years.

Dispersal of monk seals in or near the study area was not determined. One large male was observed in the Ithaca channel for 24 consecutive months before it disappeared. It was also recorded on the west coast of Kefalonia near Assos, about 20 km from its 'home' cave (Hiby *et al.*, 1987). Ranges from <15 km to >50 km have been reported in the literature (e.g. Sergeant *et al.*, 1978; Berkes *et al.*, 1979; Reijnders & Ries, 1989). The animals identified in this study appear to remain in the vicinity of the islands of Kefalonia, Ithaca and Lefkada. Some exchange between these islands and with Zakynthos is possible.

Sightings

Most of our own sightings were made during checks in the caves of the Ithaca channel. From July 1986 to April 1988 82 sightings were recorded, including 76 in the channel, three in the gulf of Myrtos, two in the bay and harbour of Argostoli, and one near Skala, SE Kefalonia. All sightings were of solitary animals. Most (64) of the channel sightings were of the same large and distinctly coloured male which was a resident in the channel for two years (November 1985 to November 1987, see also Hiby *et al.*, 1987). The other 12 sightings involved a minimum of five seals including one pup (Table 1).

Three hundred and fifteen sightings were made by reliable informants in the vicinity of Kefalonia, Ithaca, Lefkada, and several small islands (Table 2). In 302 (96%) of the cases, the observed seals were solitary. Two seals were seen in 10 cases, three in two cases and five on one occasion. This pattern, where most sightings are of solitary animals, seems to be typical at the present time. It is consistent with information from other parts of Greece (Verriopoulos, 1985; Verriopoulos & Kiortsis, 1985), Turkey (Berkes *et al.*, 1979), and the Mediterranean coast of Morocco (Avellá & Gonzales, 1984*b*). Most seals (288 cases, 91%) were seen in the water, 16 (5%) on beaches, six (2%) hauled out on rocks, and five (2%) in caves. This distribution does not necessarily reflect the activities of seals but rather the

Table 2. Seal sightings by fishermen, local people and tourists in the study area (see Fig. 1), July 1986–April 1988

Area	No. of sightings	% of total
Area used by Ithaca channel fishermen	239	75·9%
Ithaca channel	169	
N Ithaca (Afales Bay)	32	
N part of Myrtos gulf	20	
SW Lefkada	16	
Arkoudi	2	
Argostoli harbour & Koutavos lagoon	20	6·3%
S & SW Kefalonia	18	5·7%
Bay of Argostoli	11	3·5%
S Myrtos gulf: Zola/Cape Atheras	5	1·6%
E. Ithaca, Atokos & Formicula	9	2·9%
Skala/Poros, SE Kefalonia	4	1·3%
W coast of Lefkada	4	1·3%
S Ithaca	3	0·9%
S Lefkada	1	0·3%
E Lefkada	1	0·3%
Total	315	

distribution of the observers (Table 2). Two hundred and eleven (67%) of the observations came from fishermen at sea, 60 (19%) from other local persons, 34 (11%) from tourists and 10 (3%) from sailors on tourist ships.

Figure 3 shows the month by month distribution of sightings. A seasonal course is suggested in both our own observations and in the reports of informants. There were few observations in winter 1986–87. An increase in spring 1987 toward a maximum from April to July was followed by a decrease in the fall and winter months of 1987–88. However, long-term studies would be needed to substantiate a true seasonality.

The temporal pattern also partly reflects the activities of observers rather than seal behaviour or abundance. We ourselves were absent for half of December and January, which contributes to the low number of sightings for that period. During the cold season (November to April) fishing activities and tourism were generally reduced. Most of the few sightings came from fishermen (85%), the rest from other local observers. In summer (May to October) 18% of the sightings were reported by tourists or sailors working in the tourist branch. Finally, poor weather and rough seas in the autumn and winter may account for some reduction in the number of sightings during these seasons.

However, there were also changes due to seals: in the course of our daily cave surveys beginning in February 1987, we recorded a steep increase of sightings in March and April and then a decrease again. As mentioned before, during this period most sightings and evidence in caves came from one resident male seal. Since our own activities did not change, we believe that the observed changes reflect seal activity. The low number of sightings and evidence in caves after November 1987 coincides with the disappearance of the resident seal. The monthly number of sightings (Si1, Si2, Si3 in Table 7) correlated well with the fraction of

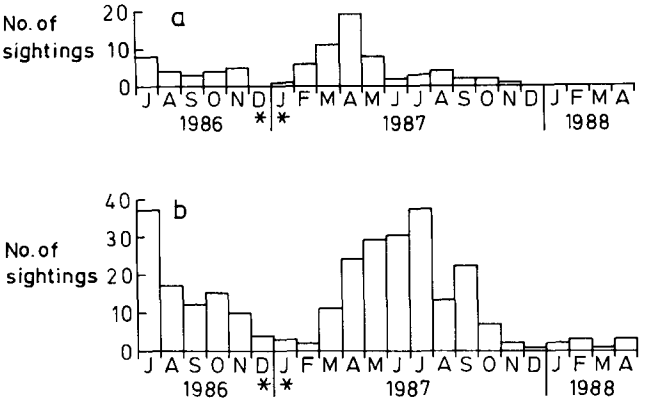

Fig. 3. Temporal distribution of sightings in the study area, 1986–1988. (a) Own sightings; (b) sightings by others. *, monitoring incomplete.

caves used per month (PERCA in Table 7). This parameter was largely independent of the observers' activities and not based on a single seal.

Daily rhythms

Reports in the literature about a daily pattern of monk seal activity are not consistent. According to Sergeant *et al.* (1978), Moroccan fishermen reported high activity in early morning and evening. A similar pattern was observed by Sergeant himself on Madeira, while Boulva is cited as having received reports of mainly diurnal feeding activities. Bareham and Furreddu (1975) noted that on Sardinia (1970–72) cave entries were mainly in the morning and exits late in the afternoon and very early in the morning. Hiby *et al.* (1987) obtained data with flashlight photographs, mainly of the resident male in one cave in the Ithaca channel. The data show a maximum of cave entries in the evening (eight of 17 entry values), and irregular times of exit ($n = 9$). Our own data from the same cave based on 61 encounters between July 1986 and November 1987 (again almost exclusively with the resident male) did not indicate any daily pattern (Table 3). The correlation between the day time of our visits and the day time of encounters is almost perfect ($r = 0{\cdot}98$), which indicates an even diurnal distribution of cave use. But we lack systematic data on entries and exits.

Table 3. Diurnal distribution of seal encounters in cave 45, between 2 July 1986 and 1 November 1987

Time of day	Number of visits	Number of encounters	Encounters per visit (%)
00:00–04:00	5	2	40%
04:00–08:00	15	6	40%
08:00–12:00	67	27	40%
12:00–16:00	43	13	30%
16:00–20:00	36	12	33%
20:00–24:00	4	1	25%
00:00–24:00	170	61	36%

Almost all encounters involved the resident male seal which disappeared at the beginning of November. Later on the cave was no longer used.

Table 4. Cave use by seals in the study area

	Ithaca Channel	Other areas	Total
Number of caves surveyed	11	115	126
Caves with evidence of seals	10	10	20
Total number of visits to caves	2854	671	3525
Visits to caves used by seals	2764	182	2946
Number of cases with evidence	326	18	344
% of visits with evidence	11·8%	9·9%	11·7%

Cave use

Altogether 3525 surveys were made, 2854 to the 11 caves of the channel and 671 to 115 caves elsewhere (Table 4). In the channel all but one cave were found to be used by seals. Outside the channel evidence was detected in only 10 of the 115 caves but this may be due in part to the low number of visits. There also may have been more caves per seal. In many parts of Kefalonia the number of caves per km coastline is appreciably higher than in the channel, especially in the Gulf of Myrtos (see Fig. 2).

As with sightings, cave use was greatest in summer 1987. This was seen in the number of days per month evidence was detected in a given cave as well as in the percentage of caves used per month (Fig. 4(b) and (c)). The frequency of cave use may be estimated from the fraction of caves per survey trip that showed any sign of occupation. If all 'active' caves (that is caves where a sign of occupation was found at least once during the 22-month study) are included in the calculations, the average value is 11·8% for the channel caves and 9·9% for the others. In a comparable study in 1985–86, Hiby *et al.* (1987) found a frequency of 15·5%. For all data combined, evidence was found at least once in 20 (16%) of 126 caves visited by us. For these 20 caves, the average percentage of evidence per survey was 11·7%. If the observations are combined with the data of Hiby *et al.* (1987), then 27 (19%) of 143 known caves showed evidence of seal use in 12·5% of the surveys. Considering the low number of animals, this suggests an active use of caves, and supports the assumption that the monk seal is mainly a coastal species.

The monk seals in this study preferred certain caves, as indicated by the number of surveys where evidence was found in a given cave, and by the number of months in which a cave was used. Ninety percent of all evidence of cave use came from only four caves (Fig. 5(a)); three of them showed evidence of use at least once during 50% of the surveyed months (Fig. 5(b)). The data are dominated by cave 45, home of the large male mentioned before. Fifty percent of all evidence was found in cave 45 while 28% was found in cave 43. Both caves were used at least once during 17 months (Fig. 4(a)).

There were shifts in cave preference (Fig. 4(a)) but the parameters that determine cave suitability are unknown. These might include size, depth, size of the entrance or the inner beach, sand or pebble beach, protection from wave action, distance of the inner

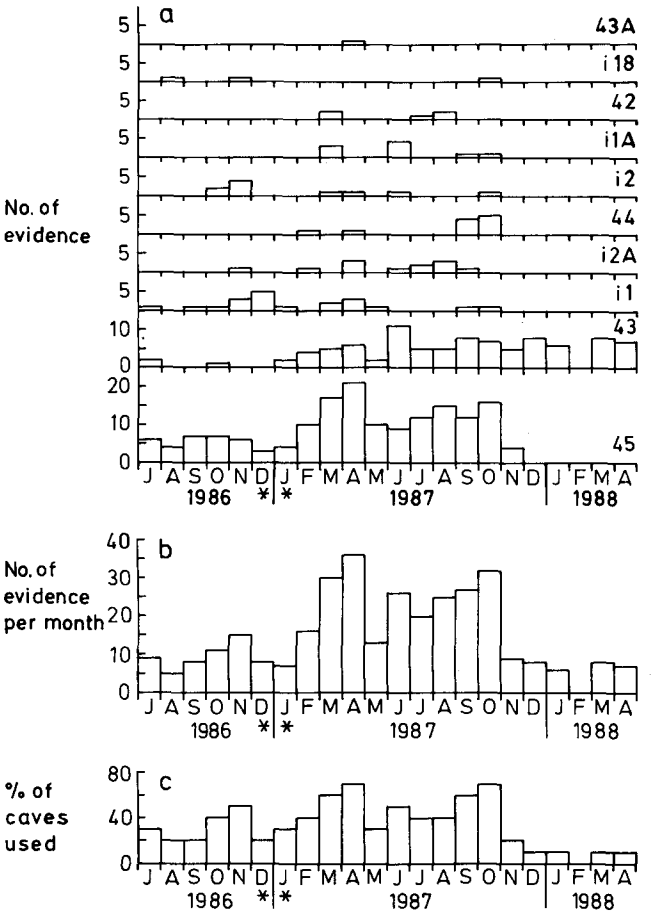

Fig. 4. Monthly distribution of the evidence of seals in caves of the Ithaca channel. (a) Numbers of evidence found in the 10 caves used by seals—cave identification numbers are shown on the right; (b) sum of the values of (a); (c) percentage of caves with at least one item of evidence. *, monitoring incomplete.

beach from the entrance, distance of the cave from peopled beaches, or vicinity to fishing nets. The most frequently used cave, 45, is medium in size (≈ 100 m²), has a broad entrance (diameter ≈ 7 m), a low ceiling, and a subdivided beach. It is well-isolated from people. Cave 43, second in rank, is the largest of all caves

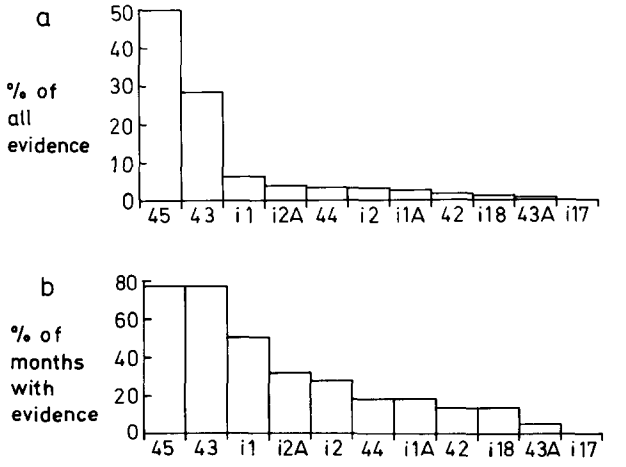

Fig. 5. Ranks of the Ithaca channel caves used by seals. (a) ranked by the percentage of all evidence (the evidence in cave 45 came mostly from one seal); (b) ranked by the number of survey months with at least one item of evidence.

(≈ 1000 m²). Its interior is well-sheltered from storms. It has a low and hidden entrance (diameter ≈ 2 m), a long deep tunnel opening toward a high hall with several beaches Cave i1, third in rank, is medium in size (≈ 80 m²), has a broad beach entrance (diameter ≈ 3 m), and is also well-sheltered. But it is immediately adjacent to a beach often frequented by people. Cave i2A, fourth in rank, is only 100 m distant from the harbour of Stavros with its regular boat traffic. It is very small (≈ 20 m²) and has a relatively large (4–7 m) beach. There is the possibility of habituation once a seal has made a choice, a continued preference for a cave with which an animal has become familiar.

Damage to fishing gear

A test of damage

Monk seals damage fishing gear (Schultze-Westrum, 1976; Marchessaux & Duguy, 1977; Berkes *et al.*, 1979), tearing characteristic holes about 20–30 cm in diameter that may be distinguished from damage by dolphins, morey eels, crabs, etc. Fishermen have often asserted that the damage inflicted by a single seal may be substantial. To test this claim, we placed a new trammel net (70 m long, 2 m high) in front of cave 45, the home of the large resident male, for seven nights. Each night, between 10 and 50 fish were caught in the net. In two of the seven test nights the seal was encountered in the cave. In the morning after these two nights, 21 and 18 typical seal holes were found in the net. No damage was recorded on the other five occasions when the seal was not seen. Although the evidence is circumstantial because we did not actually see the seal tearing the net, we conclude that the fishermen's claim is correct, and one seal may indeed administer considerable damage in one night.

Damage during fishing trips

The fishermen covered a rather large fishing area (Table 2) throughout the year, although to a lesser extent in winter (fewer fishermen, shorter ranges, and fewer trips per fisherman). A total of 1864 fishing trips were monitored, and on 136 (7·3%) damage was reported. Table 5 summarizes the percentages on a monthly basis along with seal sightings during the trips. The following may be noted: (1) There were substantial monthly fluctuations of damage (column (e)), from no damage at all (after January 1988) to almost 22% in December 1986. On the whole there was a gradual decline after May 1987. (2) The sightings (column (c)) show the seasonality already discussed (Fig. 3, where the fishermen's reports are included). (3) Instances of damage were about twice as frequent as sightings near the net (columns (e) and (c)). (4) Sightings with concurrent damage were reported about twice as often as sightings without damage. (5) If damage occurred, it was on average associated with sightings in about half of the cases. The association was also high in months with little damage or sighting (after September 1987).

In Table 6 the damage is analyzed by fishing gear. Three types of gear were used: (1) Gill nets reach from the surface to the bottom. They are always set close to the shore and extend away from it into the open water. The fish are caught between the net filaments, usually behind their gills. (2) Trammel nets are set close to the bottom, near the shore or on shoals. They consist of three vertical layers. The fish are caught in pockets of the fine-mesh inner net as it is pushed through the wider openings of the outer net. (3) Bottom long lines consist of a series of baited hooks on a line close to the bottom. Usually only one type of gear was used at a time. Inshore trammel nets had the highest frequency

Table 5. Percentile distribution of fishermen's reports of seal sightings and damage to fishing gear during fishing trips

Month	No. of trips (No. of damage) events	Percentage of fishing trips with					Percentage of seal sightings at damaged gear
		Sightings without damage (a)	Sightings with damage (b)	Sightings (c = a+b)	Damage without sightings (d)	Damage (e = d+b)	
Dec. 86	55 (12)	1·8	3·6	5·4	18·2	21·8	16·7
Mar. 87	103 (17)	1·9	4·9	6·8	11·6	16·5	29·4
Apr. 87	158 (14)	2·5	3·2	5·7	5·7	8·9	35·7
May 87	138 (24)	4·3	8·0	12·3	9·4	17·4	45·8
June 87	153 (13)	2·0	5·9	7·9	2·6	8·5	69·2
July 87	218 (24)	3·7	6·4	10·1	4·6	11·0	58·3
Aug. 87	127 (6)	2·4	3·1	5·5	1·6	4·7	66·7
Sept. 87	154 (8)	0·6	3·9	4·5	1·3	5·2	75·0
Oct. 87	120 (8)	0	1·7	1·7	5·0	6·7	25·0
Nov. 87	88 (3)	0	1·1	1·1	2·3	3·4	33·3
Dec. 87	130 (4)	0	1·5	1·5	1·6	3·1	50·0
Jan. 88	96 (3)	0	1·0	1·0	2·1	3·1	33·3
Feb. 88	108 (0)	0	0	0	0	0	—
Mar. 88	92 (0)	1·1	0	1·1	0	0	—
Apr. 88	124 (0)	0	0	0	0	0	—
Total	1864 (136)						
N		15	15	15	15	15	12
Mean		1·35	2·95	4·31	4·40	7·35	44·8
SE		0·37	0·64	0·99	1·32	1·74	5·48

Table 6. Distribution of damage at different fishing gear, based on reports presented in Table 5

Type of fishing gear	No. of fishing trips	No. of damage events	Damages per fishing trip
Bottom long lines	299 (16·0%)	4 (2·9%)	1·3%
Trammel nets offshore	235 (12·6%)	18 (13·2%)	7·7%
Trammel nets inshore	100 (5·4%)	13 (9·6%)	13·0%
Gill nets	766 (41·4%)	59 (43·4%)	7·7%
Mixed gear	464 (24·9%)	42 (30·9%)	9·1%
Total	1864	136	7·3%

of damage, followed by offshore trammel nets and gill nets. Bottom long lines were damaged least, perhaps because the fine nylon line on the bottom and the few fish usually caught are rarely discovered. The 42 damage events reported from 'mixed gear' trips involved only gill nets (18 cases) or inshore trammel nets (17 cases). Seven cases could not be assigned.

According to reports by fishermen, torn or chewed fish in the nets indicated that seals fed on just about everything (Sparidae, Serranidae, *Mullus*, etc.). These observations support the view of Marchessaux and Duguy (1977) that monk seals are opportunistic predators.

Correlations between damage, sightings, and use of caves

The monthly data on damage, sightings and cave use suggested parallel variations. Therefore, Pearson's correlation coefficients were calculated (Sokal & Rohlf, 1981; SPSS, 1988) after checking that the distributions did not appreciably deviate from normal (Table 7, Fig. 6). Using Spearman's or Kendall's rank correlation did not alter the levels of significance. The following results were obtained: (1) The two monthly parameters of cave use (evidence/cave and percentage of caves used) were almost perfectly correlated (Fig. 6(a)). The situation is similar for the monthly values of damage (damage events/month vs percentage of fishing trips with damage,

Table 7. Correlation (Pearson's coefficients) between monthly values of cave use, seal sightings and damage to fish gear and catch[a]

January 1987 to April 1988 (n = 15). [ ], not significant $p >$ 0·05; *, $p \approx$ 0·06; all other values significant with $p <$ 0·05

	PERCA	DAM	PERDAM	Si1	Si2	Si3
EVCA	0·98	0·48*	[0·30]	0·60	0·59	0·57
PERCA		0·53	[0·38]	0·61	0·59	0·57
DAM			0·81	0·79	0·80	0·81
PERDAM				[0·40	0·42	0·41]

[a] EVCA, numbers of evidence per cave;
PERCA, percentage of caves used by seals;
DAM, number of damage events;
PERDAM, percentage of fishing trips with damage;
Si1, number of seal sightings in the Ithaca channel;
Si2, number of seal sightings in the area used by the Ithaca channel fishermen;
Si3, number of seal sightings in the whole study area.

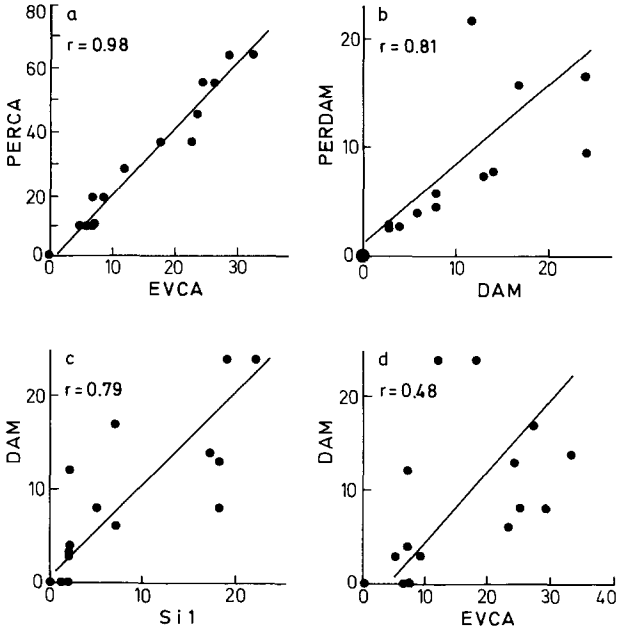

Fig. 6. Plots of some of the correlations between the monthly values of seal sightings, cave use by seals in the Ithaca channel, and damage to fishing gear or catch in the fishing area of the Ithaca fishermen (Table 7). The r-values are Pearson's correlation coefficients. (a) Percentage of caves in the channel with at least one item of evidence (PERCA) vs amount of evidence per cave (EVCA); (b) percentage of fishing trips with at least one damage event (PERDAM) vs number of damage events to fishing gear (DAM); (c) number of damage events to fishing gear (DAM) vs seal sightings in the channel (Si1); (d) number of damage events to fishing gear (DAM) vs amount of evidence per cave in the channel (EVCA).

Fig. 6(b)). (2) The use of caves was significantly correlated with all three tested geographic levels of seal sightings (Ithaca channel; fishing area; study area). As might be expected, the best correlation was obtained with the sightings in the channel (Fig. 6(c)). (3) The damage/month was very strongly correlated with all levels of seal sightings. (4) To a lesser but still significant degree, damage was correlated with both indices of cave use (Fig. 6(d)).

These correlations support the contention that the variations in the data partly reflect real fluctuations in seal activities. Of special interest was a possible linkage between damage and cave use. Since all data were intercorrelated, Pearson's simple correlation coefficients do not tell if damage might have been directly linked to cave use or only indirectly via the association between cave use and sightings. Therefore, a partial correlation analysis was carried out with the three parameters DAM, Si2 and EVCA (Table 7). It revealed that the damage remained firmly related to sightings in the fishing area when the effect of the correlation with cave use was eliminated ($r_{\text{DAM Si2.EVCA}}$ = +0·62), whereas the correlation between damage and cave use vanished ($r_{\text{DAM EVCA.Si2}}$ = +0·14) when the effect of the correlation with sightings was eliminated. This is also shown by the multiple coefficient which demonstrates the correlation between damage and both sightings and cave use: $R_{\text{DAM.Si2 EVCA}}$ = 0·83, which is only slightly

Table 8. Reliable cases of dead seals in the study area, 1963–1987

Area	Age class	Causes of death					Total deaths
		Deliberate killing by		Accidental deaths by		Unknown causes	
		Fishermen	Others	Fishing gear	Other		
Ithaca, Ithaca channel and surroundings	Adults	—	—	2	—	1	12
	Juv/pups	2	1	4	—	—	
	Unknown	2	—	—	—	—	
Myrtos	Adults	3	—	—	—	1	13
	Juv/pups	6	—	—	—	1	
	Unknown	1	1	—	—	—	
SE Kefalonia	Adults	1	1	1	—	—	5
	Juv/pups	—	—	—	2	—	
	Unknown	—	—	—	—	—	
Argostoli bay and surround	Adults	2	1	—	—	—	4
	Juv/pups	—	—	—	—	—	
	Unknown	—	—	1	—	—	
Sum	Adults	6	2	3	—	2	13 (38%)
	Juv/pups	8	1	4	2	1	16 (47%)
	Unknown	3	1	1	—	—	5 (15%)
Total		17 (50%)	4 (12%)	8 (23%)	2 (6%)	3 (9%)	34

higher than the simple correlation coefficient relating damage to sightings. About 70% of the variation in damage can be predicted from measuring sightings in the fishing area and cave use in the Ithaca channel (R^2=0·69). If Si1 (or Si3) is used instead of Si2, the values are similar: $r_{DAM\ Si1.EVCA}$ = +0·72 ($r_{DAM\ Si3.EVCA}$ = +0·75), $r_{DAM\ EVCA.Si1}$ = +0·007 ($r_{DAM\ EVCA.Si3}$ = +0·16), and $R_{DAM.Si1\ EVCA}$ = 0·79 ($R_{DAM.Si3\ EVCA}$ = 0·83). We tentatively conclude that sightings of seals in the water were at least in part associated with predatory activity which results in damage to fishing gear. The percentage of caves used by seals was probably not casually linked to predation but reflected more generally the abundance of seals in the area.

Population decline and deaths

Historical reports relayed to us show that the population used to be larger than it is now: in a cave near Assos, which was destroyed in the 1953 earthquake, about 15 seals were regularly seen in 1940–50. In 1975–80 up to 13 seals were observed in another cave. Eight seals were reported in 1977 (Marchessaux & Duguy, 1977), and five in 1985–86 (Verriopoulos & Harwood, 1987). In S–SE Kefalonia in 1975–80, 10–15 seals were often seen on beaches north of Poros. Even if these reports are viewed with caution, a decline of population size is evident. Since birth rates seem to be normal, mortality and/or emigration must be crucial factors. This assumption is supported by simulation models which demonstrate that in this species adult mortality has the strongest influence on the chance of extinction (Harwood & Durant, 1987).

Table 8 summarizes reliable cases of death reported from local observers (mostly fishermen) covering a period of 25 years (1963–87). Altogether 34 cases were recorded. Adults and juveniles contributed similar proportions. More than half were deliberately killed while about a quarter died accidentally at fishing gear. Another 13 deaths were reported before 1963, including three adults, five pups or juveniles, and five animals of unknown size. Seven of these (54%) were killed by fishermen, three (23%) by other persons, and three (23%) died accidentally entangled in fishing gear. Naturally, information from this early period is scarce and less reliable.

Deliberate killing has been reported in several instances: Berkes *et al.* (1979) relate that of 25 seals reported dead from the Mediterranean coast of Turkey, 19 were shot by fishermen and six by hunters. Six seals got entangled in nets, and four died after capture. Avellá (1979) reports from the Baleares that of 50 dead seals 16 were shot, 10 killed by other methods (axe, sticks, thrown rocks), and 24 died entangled in fishing gear. Of 40 dead seals along the coast of Tunisia, Algeria and Morocco, 11 had been deliberately killed while six became entangled in nets (Avellá, 1987).

CONCLUSIONS

A viable population

Our findings allow some cautious conclusions. The population density of *M. monachus* in the study area in the Ionian Sea has declined during the past 20 years but there is still a viable group of about 18–25 animals. Reproduction appears to be normal. Some seals tend to stay in the same area for extended periods of time. Individuals show preferences for specific caves but changes in preference and possibly in the daily pattern of use do occur. The occasional arrival of individuals not seen before implies exchange with other populations.

The conclusions are tentative for the following reasons. First, we monitored only a small part of the study area in a continuous and regular manner. Numbers of caves,

exposure to storms, intensity of tourism, etc., vary from place to place. Therefore our results are probably not representative for the whole area. Second, temporal fluctuations were substantial: for instance, the increase of activities in the summer of 1987 was not repeated in 1988. Clearly the period of observation was insufficient to forecast future developments. Recent observations in May and June 1988, which have not been included in the present analysis (233 visits to the 11 caves in the channel), yielded only 10 cases (4%) of evidence, all in one cave. Seven sightings were reported and only one animal (a sick pup on a beach in S Kefalonia) was seen. In 350 interviews with fishermen only seven incidences (2%) of damage were registered. In comparison, during the same period in 1987 there were 39 cases of evidence in caves (9·5% of the visits), 36 sightings in the channel, and 37 cases of damage to fishing gear (12·7% of the fishing trips). Finally, due to the low number of animals, there is always a strong element of chance in all observations. For example, the resident male which faithfully visited the same cave for almost two years dominated much of the data from the Ithaca channel. This obviously constitutes a bias and casts doubt upon attempts to generalize. On the other hand, the good correlations between different parameters (Table 7), and the general congruence between our own observations and independent reports from local informants, tend to support the general validity of the findings.

The threat of death

In Greece, fishermen traditionally persecute seals as competitors and enemies. The decline of fish due to overfishing (partly a consequence of increased tourism) probably attracts seals to fishing nets more now than in the past. The increasing damage to fish catch and nets may have intensified the fishermen's negative attitude toward the animals. Records of deaths (Table 8) suggest that in the Ionian Sea deliberate killing and deaths in fishing gear are important components of seal mortality and thus perhaps one of the main causes of the population's decline. Assuming an average population size of about 20–30 animals during this period (Verriopoulos, 1985), a death rate of roughly 5% per year might have been inflicted by man. Normal birth rates may be insufficient to counterbalance these losses. The human contribution to overall mortality is likely to grow in the years to come because seals will concentrate more and more near fishing nets as coastal fish densities decline. Comments by older fishermen of Stavros support this view. These fishermen reported that 10–20 years ago the fish catch was about tenfold compared to the present, although fewer nets were used. At the same time the damage by seals was smaller although the animals were more abundant.

What needs to be done

More studies

Knowledge of the ecology of *M. monachus* is still poor. Data on rates of natality and mortality, age structure, home range and dispersal are missing. Long-term studies covering wider areas are needed to improve the design of conservation measures.

Stop the killing

In our opinion the key to any conservation success, at least in Greece, is an end to the animals' persecution, and a reduction of human-related mortality. Deliberate killing seems to be responsible for the animals' fear of man (Sergeant *et al.*, 1978). The Phocidae are well-known for their capacity for learning and memory. Already Pliny was impressed by the docility of monk seals (King, 1956). The resident male of cave 45 readily became conditioned to our presence. We believe that a long-term coexistence between seals and man is possible if the cause of the acquired fear is removed. The habitat available to the animals might even increase if they again accept open coastlines now avoided.

Compensate fishermen

A lessening of persecution will only be accomplished if fishermen receive adequate compensation for their losses. We have estimated the average reduction in the earnings of an Ithaca fisherman due to seals to be about 3–4%. This is roughly one day's income per month excluding the costs of replacing whole nets (Jacobs & Panou, 1988). Paralleling the support to fishermen, long-term efforts to reduce coastal fishing are needed. Fish farming, already well on its way in Kefalonia (Sweetman, 1990), might be another good alternative to coastal fishing.

Protection zones

Protection zones must be established and effectively controlled to counterbalance the widespread loss of habitat. All 'active' caves must be strictly off-limits in these areas. Tourism should be channelled in a way acceptable to both man and seals. Guided tours and other forms of ecotourism should be promoted. Tourism-related housing developments are to be forbidden in specifically protected core areas.

Public awareness

The necessary conservation measures should be propagated by educational campaigns at all levels. Governments will act only if public opinion is voiced strongly and repeatedly. In this study many fishermen have been persuaded to stop killing seals. If government measures follow, the change in the fishermen's attitude may stabilize.

If the three measures of public education, establishment of protection zones, and compensation are effectively implemented, the mediterranean monk seal may have a chance to survive or even increase in the Ionian Sea.

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