Haul-out behaviour, site fidelity and vigilance of common seals (Phoca vitulina) and grey seals (Halichoerus grypus) in the tees Estuary

Gaspari, Stefania

Haul-out behaviour, site fidelity and vigilance of common seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in the Tees Estuary

by

Stefania Gaspari

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Sciences in Advanced Ecology

Biological Sciences

The University of Durham
September 1994

CONTENTS

ABSTRACT

The project was carried out from the beginning of May to the beginning of July 1994, at Seal Sands, in the Tees estuary. The study aimed to examine (i) ecological and (ii) behavioural aspects of two species of seals, common seals (*Phoca vitulina)* and grey seals (*Halichoerus grypus*). The aims of the study were (i): (a) to document the seasonal fluctuation in number of seals using haul-out sites during May and June. (b) To compare activities between day and night time. (c) To examine possible factors influencing the proportion of the Tees population of common and grey seals hauling-out at Seal Sands, and factors conditioning haul-out site choice. (ii): (a) To examine distribution on haul-out sites and haul-out site fidelity, group and individual behaviour. (b) To determine vigilance behaviour in common and grey seals in relation to time of the day and group size.

The number of seals hauled-out at Seal Sands, varied from day to day and night to night, and between successive low tides. The common seal number hauling-out, varied from a minimum of 13 to a maximum of 39, at day time, and from 9 to 15 at night time. these number increased gradually during the study period. The number of grey seals varied from nil on two occasions to 27 at day time, and from 2 to 26 at night time. Both high and low number of common and grey seals tended to occur on the same days. The number of animals hauling out could be influenced by both environmental factors and population size at Teesmouth. Numbers of common seals at site C during day time was significantly and inversely related to the tide level at low water. The numbers of grey seals at site C at night time were inversely related to wind speed and positively related to maximum temperature. The changes in sites use are discussed in relation to physical characteristics of the sites and tide levels.

Common and grey seals were observed to haul-out in restricted areas, although space availability was not a limiting factor. Common seals showed site fidelity both as individuals and as a group. Grey seals, show site fidelity as a group.

Vigilance behaviour varied considerably within the two species of seals. In relation to the time of the day, the percentage of common seals alert, tended to decrease progressively after low tide. The percentage of grey seals alert was lower than in common seals with few peaks caused by sudden disturbance. Common seals show a strong negative correlation between the percentage of individuals alert and group size, whereas grey seals did not show any relation to the size of the group.

ACKNOWLEDGEMENTS

I would like to thank Professor P. R. Evans and Dr. N. Dunstone for their help and valuable criticism. I would like to express my particular gratitude to Dr. Sean Twiss for taking the trouble to help me with various aspects of my project. My thanks also go to Dr. P. Hulme for his advice. Thank you also to Eric and the photographers from the Department of Biological Sciences, to INCA, to Mike Leacky from English Nature and to John Laing Property Holding for giving me access to the study site. Thanks also to my M.Sc. colleagues for their friendship and support. And at last but certainly not least I wish to thank my friend Celia for her great help.

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER 1

INTRODUCTION

1.1 General biology of common and grey seals and their distribution

The common (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) belong to the order of Pinnipedia, family Phocidae. Common seals inhabit temperate, subarctic and some arctic waters of the North Atlantic and North Pacific, giving them one of the largest distributions of any pinnipeds. They occur on the coasts on either side of both the North Atlantic and North Pacific Oceans. Throughout the year *P. vitulina* is littoral in distribution. They are found principally, although not exclusively, in estuaries and in areas where sandbanks are uncovered at low tide. They are also found on shingle beaches and rocky shores that shelve gradually into the water and are easy of access. Generally they haul-out on protected tidal rocks, sandbanks and reefs. Large scale censusing is difficult as herds are scattered. The largest single group in Britain is in the Wash, where the estimated population is about 5-7000 seals, producing nearly 1500 pups a year. The total population of common seals in British waters is estimated to be about 20 000 (Bonner 1976, Anderson 1981, NERC 1981)

Grey seals occur in the temperate and sub-arctic waters of both western and eastern Atlantic coasts. The distribution of grey seals has been reviewed by Smith (1966) and Bonner (1972). There are three distinct populations centred on the Baltic sea, the eastern North Atlantic and western North Atlantic. These are separated both geographically and physiologically, by differences in breeding season. Outside the breeding seasons, grey seals are most often sighted off rocky or cliffy shores, or around small islands. However, sightings in estuaries, particularly when salmon are present, are also frequent. Grey seals spend much of the year at sea. Only during annual moult, and particularly during breeding season, do they spend appreciable amount of time on land.

Combining recent estimates of grey seals population, the total world population is approximately 170 000 to 196 000 (Zwanengurg and Bowen, 1990 for the western waters and Harwood *et al.* 1991 for Eastern Atlantic populations). Half of the world population, approximately 86 000, is to be found in the British Islands. One of the largest grey seal breeding colonies in the world is found in the outer Hebrides.

1.2 Description

In size adult male common seals are about 170 cm (nose to tail) length, female about 130 cm (nose to tail) length; they have a maximum weight of 113 kg. Pups at birth are about 85 cm (nose to tail) length and weigh about 12 kg. They are very variable in colour, the ground colour being any shade of grey or brownish grey, and the body covered with small black spots, which rarely fuse into patches. There is no obvious difference in colour between males and females. Common seals have a shorter and rounder head than grey seals.

Adult male grey seals are about 200 cm (nose to tail) length and their weight is about 230 kg. The females are about 180 cm (nose total) length and 150 kg. The pups at birth are about 95 cm and weigh 16 kg, once weaned their weight is about 40 kg. Among other phocids, only the elephant seals show a greater sexual dimorphism. Besides the size there are difference in shape between males and females. There are sexual differences in both colour and pattern (Hewer and Backhouse 1959). The male is generally darker on the back and shades into a lighter coloured belly this pattern is more noticeable in the females. In males the darker tone is more extensive, forming a continuous background with lighter patches; in females the lighter tone is continuous with the darker forming spots usually more densely distributed on the back. Immature males and females have a much less pronounced pattern than the adults and the yearling grey seals near the moult may be almost uniformly fawn in colour. Pups are born in a creamy white coat and rather silky fur. The white coat is shed after two or three weeks, the second coat nearly matches the adult patterns. The sexual differences in pattern are already distinguishable at this stage. The nostrils are almost parallel slits, separated below by conspicuous gap. In the common seals, *Phoca vitulina* , the nostrils are inclined and nearly joined at the base, and this characteristic can be used to distinguish the two species where both occur together and when only a front view of the head of the seal is to be seen out of the water (Wynne-Edwards 1954).

1.3 Breeding

Common seals appear not to have an obvious social organisation in the breeding season, and are thought to be promiscuous. Most births take place at the end of June or the beginning of July. The pups are usually born on the shore, between tide marks, or on sandbanks between one high tide and the next. Their embryonic coat of long white hair is normally shed *in utero*. The pups are born with a short adult-type coat and are ready to swim almost immediately. Lactation lasts from four to six weeks and might take place on land or in the water. From about the middle of August to the middle of September the adult seals moult. After moulting, the mating season starts. The fertilised egg develops into a blastocyst which remains unattached for two months; attachment to the uterine wall takes place at the end of November. Sexual maturity is reached by females at three/four years, and by males at six years. This seems to be the general pattern of life history for most common seals, though slight variations in timing occur (Bonner 1972, 1976).

Grey seals breed during the colder months of the year, but the precise time varies in different breeding colonies. In the UK the breeding season extends generally from the beginning of September to December, with colonies around the south-west coast tending to breed slightly earlier in the year while those on the northern and eastern coast are somewhat later. Despite these differences in the timing of the breeding season, the general sequence of events in the reproductive cycle is the same in all the colonies. Coulson (1981) suggested that the timing of the breeding was determined by factors which determined the period of delayed implantation and showed that both the mean date of birth of pups on the Farne Islands over a period of years, and geographical difference in the date of breeding, were correlated with the sea surface temperatures during the period just prior to the end of the suppressed embryonic development. Thus, a lower sea temperature correlated with a later mean pupping date. Further details on grey seal breeding biology and behaviour in eastern Atlantic can be found in Matthew (1950), Hewer and Bauckouse (1959, 1960), Coulson and Hickling (1964), Bonner (1972 and 1981), Boness (1984).

1.4 Migration and dispersal

The common seal is not a migratory species, and local movements are known to be associated with food and breeding.

Grey seals are not known to make definite and regular migratory movements. However, remarkable distances are covered by the pups. Probably most seals return to the rookery of birth. Major seasonal movements occur when seals congregate for the breeding season, and disperse when is over.

1.5 Feeding

Newly weaned common seal pups feed primarily on bottom-dwelling crustaceans for one and a half to three months. Older seals feed opportunistically on a wide variety of fish. Feeding occurs during the day but its occurrence also at night is uncertain.

There is a great deal of variability amongst individual grey seals in their pattern of distribution and movements. This presumably reflects similar variability in foraging habits and perhaps choice of prey. The Sea Mammal Research Unit has been studying the distribution, movements and behaviour of free-swimming seals off the coast of eastern England and south-eastern Scotland. It seems likely that there is a general dispersion from the breeding area. They are mostly coastal while feeding, principally on a wide variety of fish, but smaller quantities of crustaceans and molluscs are taken. The grey seals fast during the breeding season, the cows for about three weeks and the males for much longer. The available information on grey seal diet off the east coast of Britain has been presented in Prime and Hammond (1990), Hammond and Prime (1990). The diet is very varied but it is not known whether this is a result of each seal having a varied diet or of individual specialisation on different prey species. Examination of prey items in individual faecal samples provides evidences of both; some samples contain several species, but many contain only one (P. S. Hammond, B. J. McConnell and M. A. Fedak 1992).

1.6 Predators

There appear to be no major predator of grey and common seals. Sharks of various species and killer whales may take occasional seals, but is unlikely that either of these significantly affect the common and grey seal population in the north Atlantic. Man is, and has been, the principal predator, though human predation has lessened during this century.

1.7 Pollution

In common with other marine mammals, common and grey seals acquire a pollutant burden from their environment. Holden (1978) has reviewed the effects of pollutants on seals. The distribution of organochlorines in the tissue of the seals is related largely, but not exclusively, to their lipid content (Holden 1975). The organochlorine compounds, and also the industrial polychlorinated biphenils (PCBs) that are used in such things as paint and plastics, are soluble in fats, and are thus found in the fatty tissue of the seals. High concentrations are found in blubber, and low concentration in the brain. The physiological effects on seals are not yet known in details.

Studies on other animals suggest that there may be toxic effects on the central nervous system and decreased resistance to infection. Some correlation between the increased production of premature pups by sea-lions (*Zalophus californianus*) has been suggested. Pesticide concentrations was considerably higher in the cows and their dead pups (DeLong *et al.* 1973). The level of pollutants in seals appear to be correlated with the degree of industrial development of the shore of the sea where seals are found. A review of pollutants in seals (Holden, 1978), concluded that although the presence of PCBs may be implicated in the high abortion rate, there is still no conclusive evidence that pollutants, with the possible exception of mercury, are having an adverse effects on seals, though not enough is known about the subject yet.

1.8 History of the Common and grey seals at the Tees estuary

The seal population in the Tees estuary, north-east England is apparently the first in which seals have attempted to reestablish in an industrial environment. Common seals were numerous at the Tees estuary before they were displaced by man during the 19th century, when the tidal flats were reclaimed for industrial use. The actual intertidal area is now less than 10 % of the original size. After a century, a few seals returned to Seal Sands. Not much is known about the size of the original population. From Episcopal feasts dating back to the 14th century, it appear that common seals bred in great number at the mouth of the Tees. The grey seal probably also appeared in limited numbers along Cleveland coast but it is unlikely to have bred (Lofthouse, 1990).

The decrease in number of seals coincided with the start of land reclamation in the early 19th century and the rise of the Cleveland iron trade and Middlesbrough shipping industries around 1830. The decade 1830-40 was thought to have effected the final extinction of the seals as a permanent resident of Yorkshire, although small groups and transients were occasionally noted until the late 1860s (Wilson, S. C. 1989-93). For the next hundred years there were apparently no seals resident in the estuary, although there were few records of an individual transients. The seals were thought to have returned to the Seaton Channel area at the beginning of the 1960s. Species identification was not always certain. Until very recently, there were no reliable records of seals breeding at Seal Sands.

1.9 The aims of the study

This study aimed to investigate aspects of both the ecology and behaviour of the common and grey seals at Seal Sands, Teesmouth. The ecological study considered three aspects: temporal fluctuation in the number of common and grey seals that hauled-out during May and June, whether there was any difference in their activities during day time and night time and if so why, and an examination of possible factors influencing the relative proportions of common and grey seals hauling-out at Seal Sands.

The behavioural side of the study was concerned with the distribution of sites and haul-out site fidelity. This was considered at an individual and on a group level. Seals are assumed to haul-out for three main purposes: breeding, moulting and achieving economically energy balance Seals may haul-out at the same place for all three reasons at different time of the year or they may chose different places for each of these purposes. The haul-out used after feeding are rather more closely associated with the rookery in most colonies.

Common seals appear to use Seal Sands for all these three purposes. Although the majority of the common seals sighted at Seal Sands are known to moult and feed and some to breed in the Tees estuary, grey seals do not breed on sandy beaches. It is likely that the grey seals sighted at Seal Sands originally came from the Farne Islands colony, and that they return there during the breeding season (October- December). The different reasons for use of the Tees estuary will influence the seals' numbers depending on the time of the year. Very little is known about the differences between day and night time activities. It is assumed for example that common seals feed during day time, therefore at night time they would spend most of the time resting whilst hauled-out. On this subject, even less is known about grey seals Anderson (1978) concluded that there are no difference between day and night activities. In the Tees estuary there are several sites that could be used as haul-out sites. Both common and grey seals appear to have chosen sites according to physical characteristics, i.e. those that allow a rapid access to the water and keep the animals far as much as possible from human disturbance.

The study of homing behaviour in mammals is closely linked to the concept of home range i.e. the area over which an animal normally travels in pursuit of its routine activities (Jewell, 1966) during a stated period of time (e.g. a few weeks, a season, etc.). Mammals perform homing in two types of natural circumstances (i) when an individual makes a migration from one seasonal home range to another that it occupied the previous year, and (ii) when an animal returns home from a short-term foray "out of home range", thus completing an "excursion" (Bovet, 1992).

Many species of marine carnivores perform seasonal migrations, the length of one migratory movement, varies depending on the species. To qualify as homing behaviour, a migratory movement must bring the animal back to the previously occupied home range. Evidence for such site fidelity does not require that the total home range size and shape remain the same from year to year or are known with precision. For example, the return of a seal to a previously used breeding ground is considered as evidence of site fidelity, even if its non-breeding range changes, and hence homing in my study refers to the day to day return to the same haul-out site of a group of animals, and to the same post on the haul-out site of an individual. In many species of phocids, the capacity to store energy as blubber has led to a separation of feeding and breeding capacity. Recent marking and telemetric studies have shown that common seals may travel extensively and that their breeding activity may also constrain foraging behaviour. Two broad categories of movements are recognised. The first is between haul-out sites and the sea, these appear to occur within 50 km of haul-out sites. The second is movements which occur between different haul-out sites. Common seals are often seen in the same geographical areas throughout the year, and their more aquatic behaviour during the breeding season provides the opportunity for seals to feed during the pupping and mating periods. Until recently, this led to the belief that the species is rather sedentary, with little spatial and temporal separation of breeding and breeding activities (Scheffer and Slipp 1994).

The primary reason for an individual's movement is likely to be obtained food, but movement will also be influenced by the need to come ashore to breed or rest. Some species of seals and sea-lions are well known for their spectacular site fidelity to small and crowded breeding grounds (Riedmann, 1990) but it is usually assumed that outside the breeding season these animals do not hold ranges and have a rather nomadic way of life, driven by availability of food. When seals return regularly to offshore areas over periods of several weeks or months, it seems reasonably to assume that these movements are primarily for foraging (Thompson 1990). Data on-at sea locations of instrumented seals have been collected in only few areas but, common seals do not appear to forage more than 50 km from their haul-out sites (Stewert *et al.* 1989; P. M. Thompson and Miller 1990). Studies in the UK have shown that trips to the sea often last several days and are interspersed with periods of a day or two spent in the haul-out area (Thompson *et al.*1991) Common seals using intertidal sites must return to the water over high tide, even when they have returned inshore to rest.

In my study, vigilance behaviour was assumed to be important in group formation, and might thus be affected by the group size; therefore the proportion of seals alert was considered in relation to group size and to the time of the day.

Group life can have various beneficial consequences and there is now an enormous literature on this topic. Animals in groups may benefit as results of increased vigilance. Group living prey may also benefit by the dilution effect and by the confusion effect on predators. Terrestrial grouping by western Atlantic common seals *Phoca vitulina concolor* were investigated by De Silvia *et al.* (1988), in order to determine whether aggregation has a functional significance and if so what is that function. Their hypothesis were basically two: (i) that groups arise from shortage of haul-out sites or space on the sites, (ii) terrestrial groups extensions of groups formed in water for reasons not related to hauling-out. It appeared that the availability of space was not in short supply, rather one of the function of formation was to increase the probability to detect predators. I have investigated the same topic at Teesmouth.

CHAPTER 2

DESCRIPTION OF SITE

2.1 The study area

Seal Sands is the largest intertidal area in the Tees estuary, comprising 140 hectares of mud and sand, (see Plate 1). Plate 2 shows the location of the main seal haul-outs. In the west is Greenabella Bank (site B); it lies at a low tide level, is exposed for three or four hours in each tidal cycle and consists of rather soft mud. To the South of site B is Scalloped Mud (site A), most of which is at a higher level than site B and consists of medium soft mud.

2.2 Pollution in the Tees estuary.

The Tees estuary is in the north east of England (see Figure 1) and is highly industrialised. The river Tees has received waste discharges since the middle of the eighteenth century when an iron and steel industry was established locally. The wastes now include the discharges from a number of chemical and petrochemical works and the domestic sewage from adjacent towns. Since 1970 there have been considerable reductions in both the industrial and domestic sewage discharges to the estuary.

FIGURE 1 Location of Tees estuary in Britain

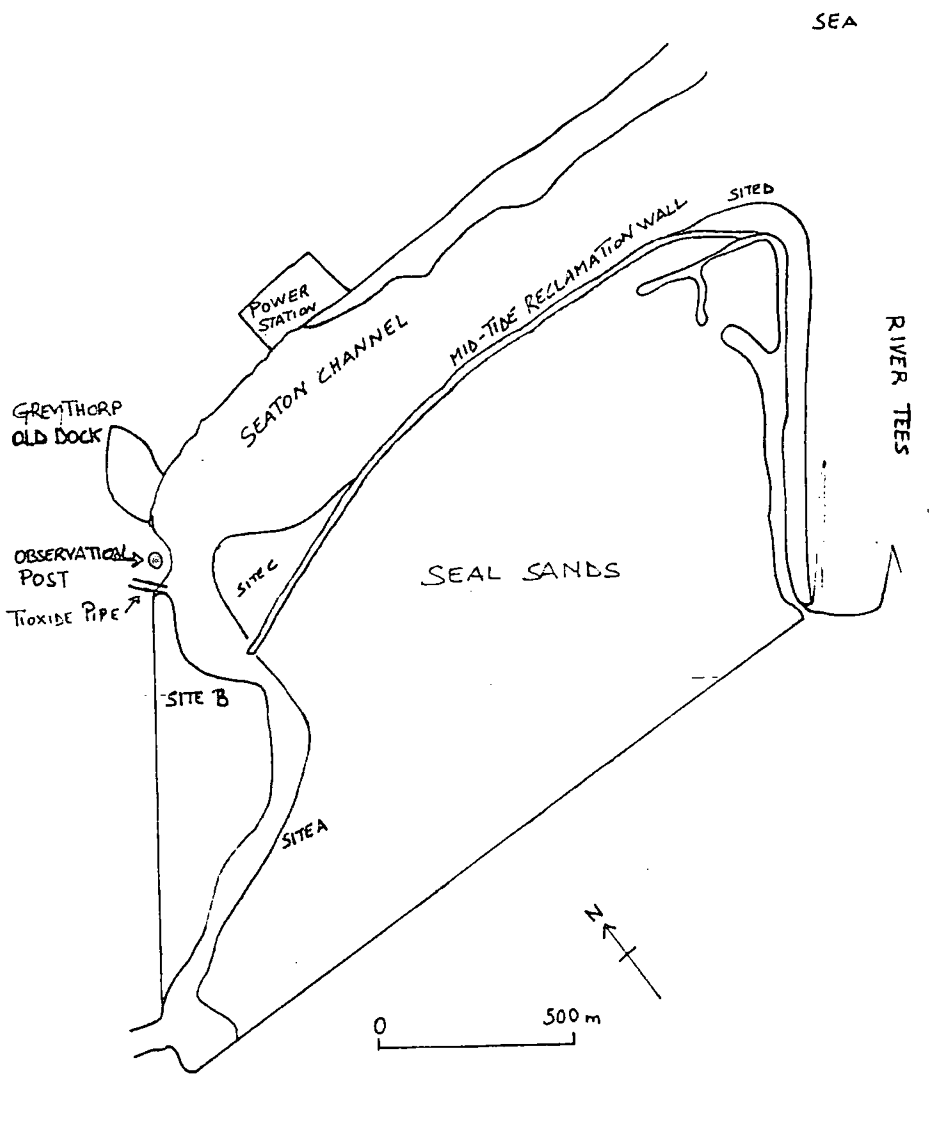

FIGURE 2 Location of the study site within the Tees estuary

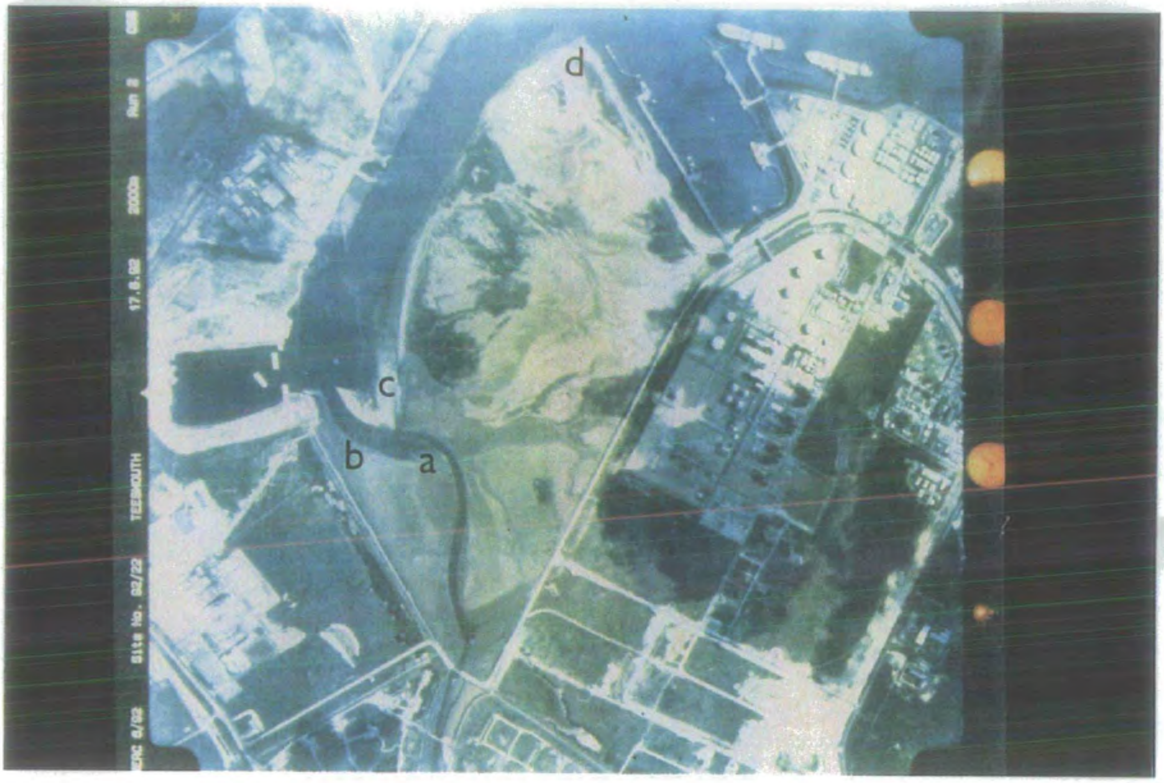

PLATE 1 Aerial photograph of Seal Sands showing the location of the four haul-out sites

2.3 Description and use of the sites by common and grey seals

Common and grey seals have selected four main haul-out sites along the sand and mudbanks of Seaton Channel, these allow them rapid access to the water (see Figure 2). Figure 3 shows the appearance of main haul-out sites at Seal Sands).

Site A

Site A was used for short periods, during the ebbing tide. Common seals hauled-out at A as soon as the mudflat was exposed but left site A and swam together to site B as soon as this became available. By the time site B was fully exposed, at site A quick access to the water was no longer possible. In 1990 an average of 38 % of the common seals that hauled-out on the ebb tide returned to site A on a rising tide, after being washed off sites B and C (Wilson, 1991). During my observations period seals returned to site A on the rising tide, after being washed off site B and C, only on a few occasions

Site B

Site B was the main haul-out site for common seals throughout the whole study period. Seals began to haul-out at B before the site was fully exposed, and moved when washed off again by the incoming tide. When the tide fell to approximately 1.1 m OD (above Ordnance Datum), site B became a 1 m high shelf above the water and an expanse of mud became exposed below the shelf. The group which hauled-out at B swam to site C before the ebbing tide fell below 1 m, and prevented quick access to water.

Site C

Site C is the main haul-out site for adult grey seals. It was also utilised by common seals, yearling and sub-adult grey seals when water level dropped below 1 m OD.

Occasionally a solitary common seal would occupy the site, regardless of the tide level. Solitary haul-out behaviour at site C was observed on four occasions by different individuals. Unless disturbed, seals at site C remained there until washed off by the incoming tide, i.e. about four hours. Often adult grey seals would bottle (cf. list of behaviours in the methods) around the site without hauling-out, or would rest on the submerged shelf with only the head emerged. At other times, especially before low tide, grey seals sometimes engaged in repeated short dives in the channel (between 30 and 60 seconds), especially off site C. Presumably they were feeding, although seals have never been seen actually catching their prey. They usually catch and swallow under water (Wilson 1993).

Site D

Site D, at the entrance of Seaton Channel, is exposed for most of the tidal cycle and seals have rapid access to the Channel even at low water. The site is used especially when the seals undergo the annual moult, from mid-January to the beginning of April, for the grey seals and between August and October for the common seals when apparently they prefer prolonged haul-outs. Common seals seldom used site D at other times of the year (Wilson 1989- 93).

PLATE 2 Location of the three main haul-out sites at Seal Sands


a
b

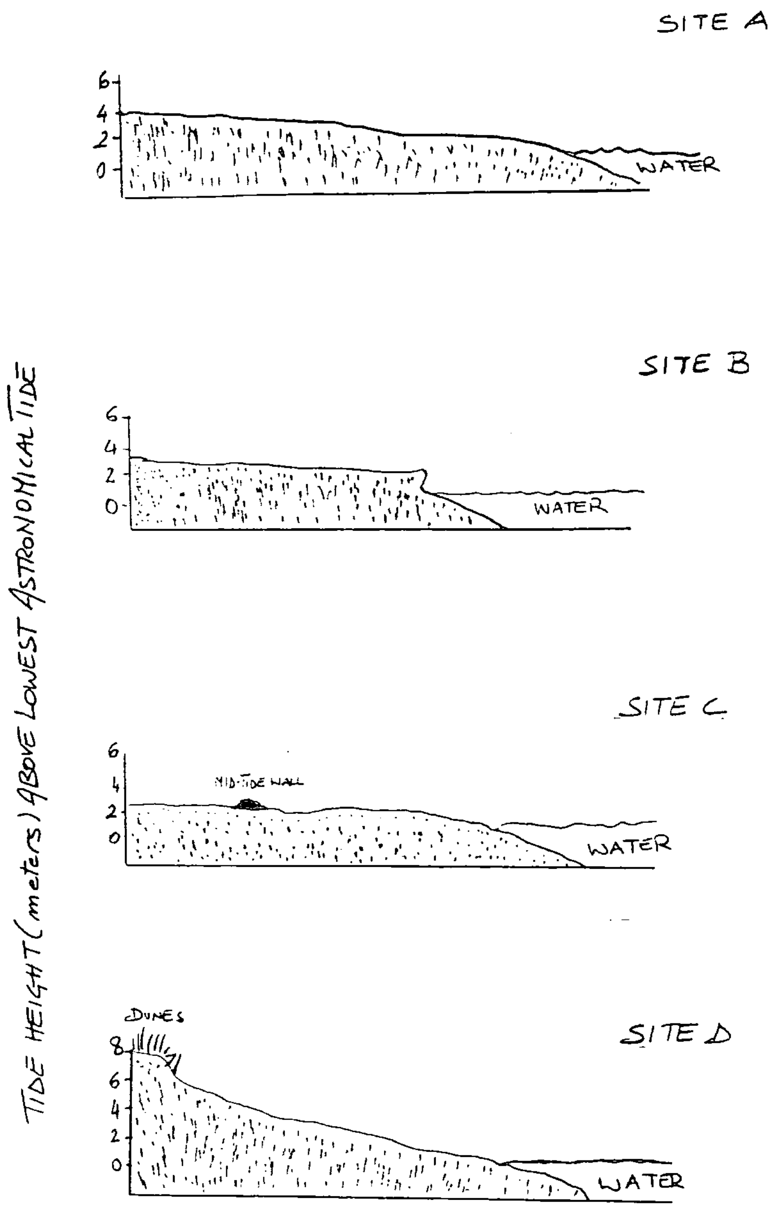

FIGURE 3 Apperance of main haul-out sites at Seal Sands (based on Wilson, 1993)

CHAPTER 3

METHODS

3.1 Observations

The study began on 7th May and ended on 8th July: a total of 21 days (71.5 hrs), and 8 nights (27.5 hrs) of observation were carried out during this period.

On the first four days, seals were observed from site D, from behind a green hut, in order not to disturb the animals, but it was decided that the green hut was not a suitable observation post for several reasons: (a) site C was not visible (the mid-tide wall covered the view), (b) the distance from site B was too far for detailed studies (1,350 m), (c) during May and June, site D was not used as a haul-out site by common seals, and the number of grey seals there was very low. For three successive days at the beginning of the observation period (7th to 10th May), only one adult male and one yearling grey seal hauled-out on site D and on the following eight days no grey seals were observed there. From the 14th May onwards, it was decided to carry out all observations of sites A, B and C from the Graythorp Dock, which was a more suitable observation post. The distance from Graythorp old dock to sites B and C were respectively 500 m and 300 m. From this place site D was not completely observable, so thereafter only sites A, B and C were considered in the study, and the data collected from the green hut early in May, were not included in the analyses. Since so few seals used site D, this will not have affected the conclusions.

3.2 Seal identification

During day time observations, photographs of groups of both common and grey seals were taken from the same observation point, at different times of the day. Hand drawn maps and, when possible seal sketches were made. The combination of photographs and hand drawn maps, allowed reliable recognition of 15 individuals throughout the study period. Only those seals which were always recognisable were included in the results related to individual behaviour. Grey seals were more easy to identify because of their distinctive coat patterns. However some circumstances made grey seal identification difficult and uncertain: (a) rarely the same individual was observed to haul-out with frequently, (b) unless grey seals hauled-out in big groups, they spent most of the time bottling without hauling-out, with just the head or part of the head emerged, (c) when they did haul-out in big groups (between 10 to 25) they changed their position very frequently so that it was difficult to make quick skatches from all the sites while also scanning seals behaviour.

In addition, the seals were filmed for a few minutes with a Canon vision EXI HI, 8 mm Videocamera and recorder with a lens: Cl 8-120 mm, whenever they changed their distribution on the site or moved to another site, and when interactions were visible. The filming was a useful tool to double check the number of seals and compare their distribution with the hand drawn maps, but could not be used for individual identification because the images were not sufficently clear.

3.3 Data collection

At day time, the seals were observed through a Optolyth TBG80 22-60 X 80 telescope from the same observation point (Graythorp Dock). Observation duration varied, but a minimum period of two hours before and two hours after low tide were undertaken every time. Data from these four observation hours on each day are those considered in the analysis of the results.

The total number of seals present simultaneously at the three sites, and the number of seals performing certain types of behaviour, were recorded on a scan sheet (table 1, appendix 1) every five minutes. The seals' behaviours were divided into six categories: Rest (or Bottling); Alert (or Floating alert); Agression; Play (or Porpoising); Walk (or Swim); Grooming. Common and grey seals were distinguished in all the records; age categories and sex were identified whenever possible. The positions of the animals were allocated to three categories, (i) on land, when they were hauled-out on the beach or sandbank, (ii) half on land and half in the water, (iii) in the water, when they were more than four or five meters from the haul-out site. During the night time observations, the seals were observed through a Omega III Image Intensifier. Only the number and position of the seals could be recorded.

Records of tide level at low tide, wind speed, wind direction, mean and maximum temperature (°C) were considered for every day of observation. The mean of these environmental variables for the four hours considered was used in the analysis. The day to day variation in seal numberswere correlated to these environmental factors.

3.4 Haul-out site fidelity

In order to test the degree of haul-out site fidelity in common and grey seals, two (imaginary) spatial grids were constructed, one for site B and one for site C. The shore line utilised by the seals to haul-out was about 200 m long. It was divided into, approximately, equal distance, 15 at B and 20 cells at C. The measurements of the distances and the division of the sites were not wholly accurate due to problems of perspective. The grids were drawn on two photographs, one of site B and one of C. For individually recognisable common seals, the daily position of the animal was transferred to the corresponding grid cell so that the number of times the same seal was observed in the same cell could be calculated. On a group level, for both common and grey seals, the position of the animals was assigned to the grid cell, i.e. the 14th May one common seal was observed in cell number 1, three seals were observed in cell number 7, etc. The first half of the grid's cell number, e.g. 1 to 15 at site B, and 1 to 20 at site C, correspond to the upper part of the beach, further away from the water, the second half of the grid, from cell 16 to 30 at B, and from cell 21 to 40 at C, corresponds to the lower part of the beach, closer to the water edge. The maximum number of seals fitting lengthways in one cell was foue or five. Distribution of seals was considered at only one time of the day, namely low tide, because at this time the number of seals hauled-out was a maximum. The seals' distribution on the haul-out sites appeared to be non-random. Therefore the variance in number of seals per cell was compared to the mean number of seals to find whether their distribution was clumped on every day of observation. A variance greater than the mean suggested a clumped distribution; if this was found a $\chi 2$ test was then applied to determine whether the sample variance was significantly greater then the mean.

3.5 Vigilance behaviour

The percentage of animals alert was analysed in relation to time of the day and to group size. Before carrying out correlations with data expressed as percentages, angular transformations were applied.

3.6 List of behaviours

Rest: lying in a relaxed position with head on the ground and eyes usually closed. This category includes comfort movements such as adjusting the body position and short scratching.

Alert: lying with eyes open, head raised, often looking around.

Agression: this involved waving flippers at each other, sometimes making contact with the opponent.

Play (splash): leaping, running in and out of the water.

Swim: in water, actively moving.

Walk: moving across a solid surface.

Bottling: in the water, not actively moving, near the surface.

Porpoise: jumping out of the water during fast swimming.

Grooming: scratching, rubbing.

Float alert: in the water, not actively moving but head up.

CHAPTER 4

RESULTS

4. 1 Numbers of common and grey seals in the Tees Estuary

The observations on common and grey seal population were carried out from 7th May to the 8th July. Table 4.1 summarises the dates and the time of observations. Animals which hauled-out on a particular day were counted at the three most important sites (A, B and C). Figure 1a summarises the maximum number of common and grey seals visible simultaneously at site A, B and C during day time, and Figure 16 during night time observations. The number hauling-out varied from day to day and night to night, and between successive low tides. The average number of common seals present during the day was 23 and of grey seals was 10, whereas during the night the average number of common seals was 12, and of grey seals six. In general the number of common seals present at Seal Sand was about double that of grey seals during both, day and night time. Table I in appendix A displays the total number of common and grey seals counted during the day and night observations.

Table 4.1
Summary of the observation periods, including the date, time of observations, and the time at which low tides occurred.

Date	Obs. Time	Low Tide	Date	Obs. Time	Low Tide
07-May	7:45-13:00	08:33	04-Jun	17:25-21:00	19:23
08-May	18:00-21:10	08:15	07-Jun	18:15-22:30	21:36
09-May	20:45-24:00	22:10	09-Jun	21:10-23:15	22:51
10-May	21:15-00:45	22:42	12-Jun	10:50-14:50	12:40
14-May	11:15-15:15	12:51	16-Jun	14:00-17:30	15:44
16-May	12:00-16:00	14:15	18-Jun	17:00-19:00	17:51
17-May	12:00-17:00	15:05	20-Jun	18:20-21:00	20:02
19-May	14:50-18:00	17:14	22-Jun	19:00-23:00	21:57
24-May	7:30-12:05	09:45	24-Jun	8:45-12:25	11:14
25-May	21:00-23:35	23:00	24-Jun	21:15-00:00	23:33
26-May	9:00-14:00	11:24	25-Jun	9:00-13:00	12:01
27-May	21:50-01:15	00:33	08-Jul	8:220-11:30	10:23
30-May	12:20-17:00	14:42			
31-May	12:45-17:00	15:36			

4. 2. Seasonal fluctuation in seal numbers

Day to day variation in haul-out number was greater in grey seals than in common seals. Maximum numbers of common seals during day time occurred the 8th of July, when two common seal females were nursing two pups. Pupping is a possible reason for the high number of common seals recorded towards the end of my study; grey seals do not breed at Seal Sands. Excluding the last observation day, high number of common and grey seals tended to occur together, but the maximum did not occur on the same day.

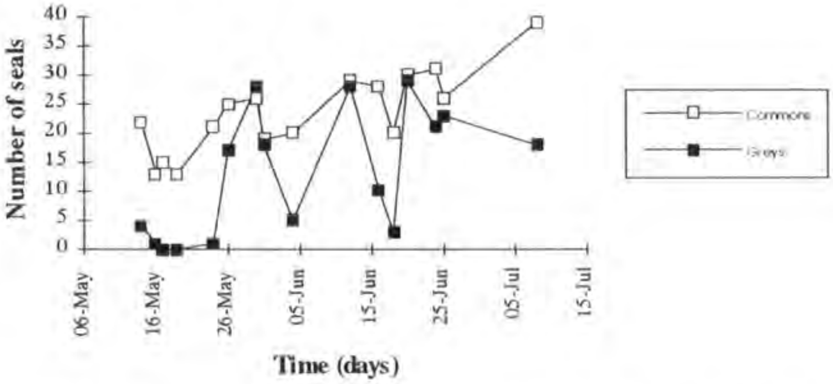

FIGURE 4 a. Total number of seals counted during day time observation.

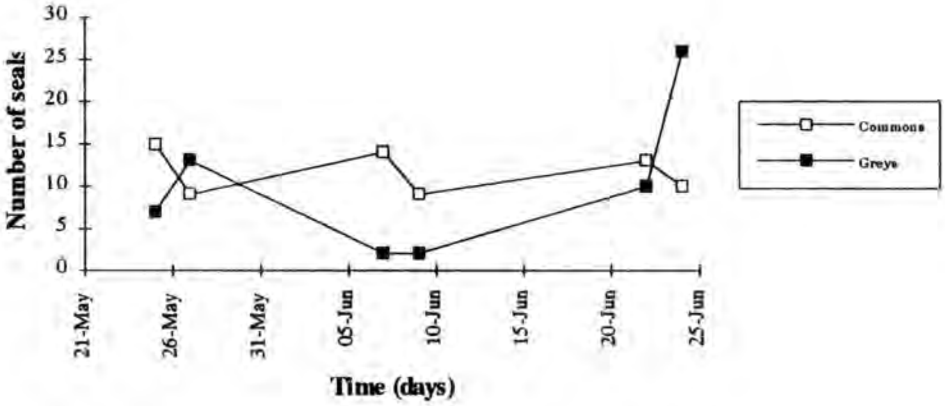

FIGURE 4 b. Total number of seals counted during night time observations.

There is a significant difference in the night time haul-out seasonal pattern of common and grey seals. On average the number of common seals counted during the night is much lower than that counted during the day. For Grey seals the night time pattern is very different from the day time pattern and also differs from that of common seals. There were two peaks, one of 13 animals and the second of 26 animals. The fluctuation in number is larger than that found for common seals. On the 24th of June observations were carried out both during day and night time, and more seals were counted during the night (26) than during the day (21). This was the opposite to all other observations, where the number of seals was always considerably higher during day time.

4.3 Use of site A, B and C by common and grey seals during day and night time

Figures 5 a-j in appendix 4 are descriptive figures to show the proportion of common and grey seals hauled-out at the three different sites, both during day and night time. The bars represent the total number of seals at Seal Sands, the squares represent the number of seals present at the site considered.

Figures 5 a, b, c, d show the seals' different pattern of use of the three different sites during the day and night time.

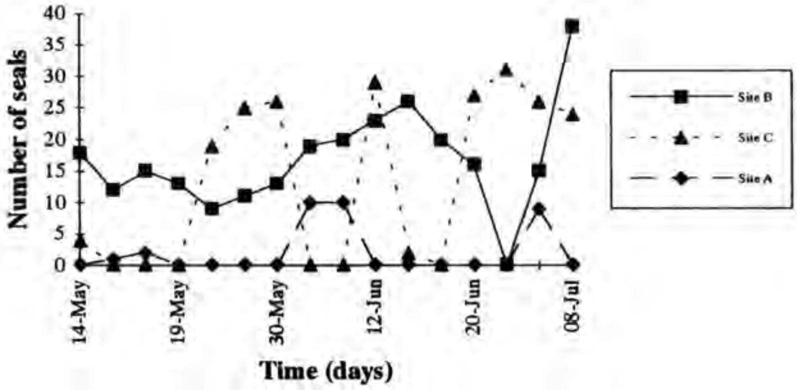

FIGURE 5 a. Maximum number of common seals at the three different sites during day time.

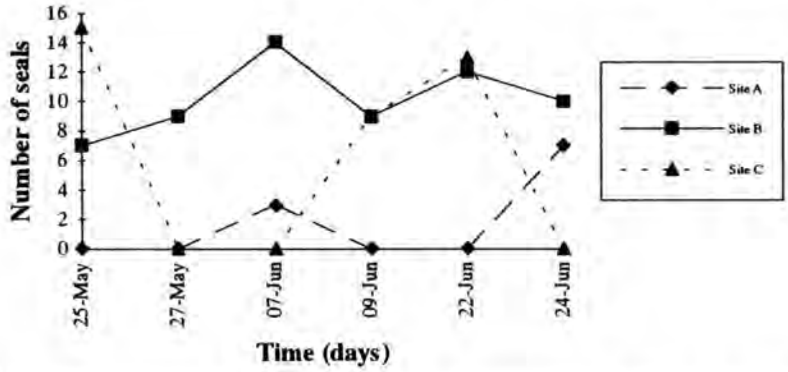

FIGURE 5 b. Maximum number of common seals at the three different sites during night time

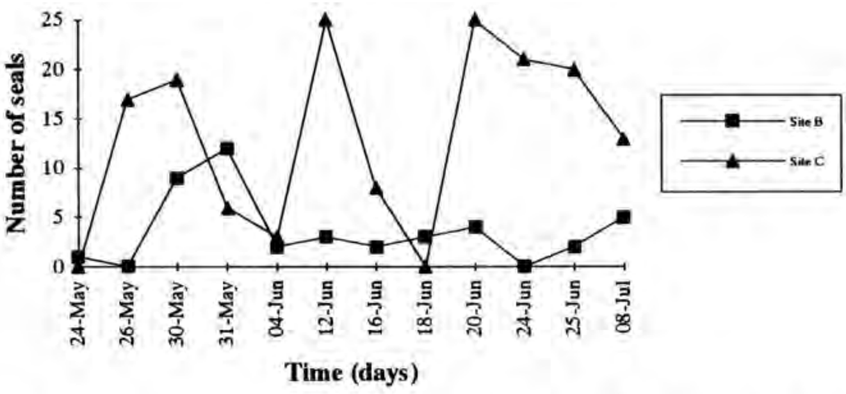

FIGURE 5 c. Maximum number of grey seals at sites B and C during day time

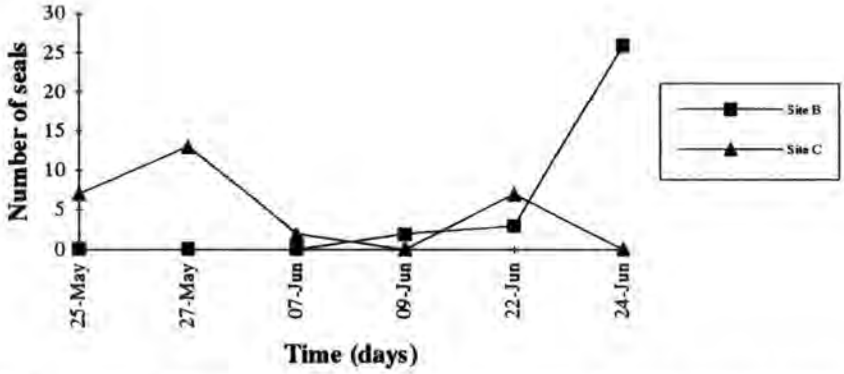

FIGURE 5 d. Maximum number of grey seals at sites B and C during night time

The presence of common seals at site A by day (Fig. 5a) was observed only occasionally and involved a very low proportion of the Tees population. Site A was the least favoured site of the three studied during the observation period. The presence of grey seals at site A was very infrequent: only on one occasion, the 25th June, a yearling was observed at the site, therefore grey seals were not consider in the analyses of site A. The number of common seals present at site B during day time (Fig. 5a) was high and varied much less than the total number of common seals hauled-out in the estuary. In fact site B was the main haul-out site for common seals both during day and night time. The proportion of common seals present at site C was either very high or very low. On the 8th July two females of the group were nursing two pups, this might have influenced the usual movement pattern of the group. The absence or low number of common seals using site C coincided with high tidal levels at low water, between 1.2 m and 1.7 m. On the other hand, high use of site C coincided with at low water at low tide levels of between 0.5 m and 1.1 m. There are similarities in the use of sites A and B, except on the last day of observation. In fact the same group of common seals hauled-out at site A before moving to B, where they were then joined by other individuals coming from the outer estuary. When the number was high at B, it was low at C and vice-versa; when tides fell to below 1 m, seals swam from B to C (see Fig. 5a).

A small proportion of the total number of grey seals utilised site B as a haul-out site (see Fig. 5c). No adults were ever observed to haul-out at B. Individuals at this site were either yearlings or male sub-adults. The number of grey seals at site C during the day time represents almost the entire population of grey seals at Seal Sands, i.e. the number of grey seals at site C usually coincides with the total number hauling-out.

Use of sites A and B by common seals at night (see Fig. 5b) was very similar to the day time pattern. The proportion of grey seals occupying site C at night was considerably higher than at B (seen Fig. 5d), with the exception of the 24th of June, the only occasion when the number of seals was higher during the night than during the day.

A t-test was carried out to find out whether there was any significant difference in the use of the sites, both during the day and night time. The t-test revealed a significant difference in the use of site A and B, ($t=6.44$, $P<0.01$), and site A and C ($t=3.81$, $P<0.01$), by common seals during day time. There was a significant difference in the use of site A and B by common seals during night time ($t=5.48$, $P<0.01$). There was a significant difference in grey seals between site B and site C during the day time ($t=-2.90$, $P<0.01$).

4. 4 Factors influencing the number of common and grey seals using haul-outs

Numbers of common and grey seals hauling-out could be influenced by both environmental factors and total population size within the whole Tees esuary. A variety of environmental factors were measured to examine whether they had an effect on the day to day variation in numbers hauling-out. In order to eliminate the effect of any seasonal changes in population size on the numbers hauling-out from day to day effects determined by weather, the actual number of animals observed each day are presented only in the more descriptive part of the results, whereas the statistical analyses were carried out using the difference between the number observed and the seasonally adjusted expected values on each day. The expected values were calculated from the following formula: (Nos. = C + S × D), where C is the constant of the regression line fitted to the figures representing any seasonal population trend in Figures 3 a-d, S is the slope of the regression line and D is the date of observation but measured as number of days from the first day of observation (i.e. 14th May = day 1, 16th May = day 3 etc.).

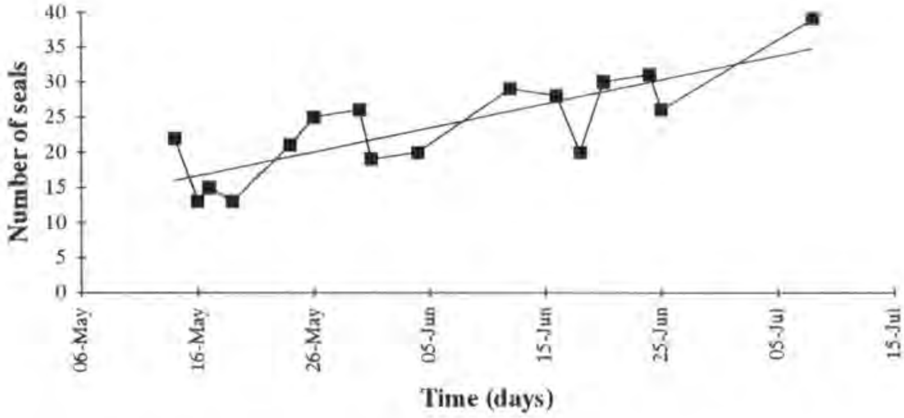

FIGURE 6 a Total number of common seals during day time of observations. (R^2=.66, $R_{adj.}^2$=.63, n = 16, P<0.01, SE=4.25, y=.341 x + 15.7).

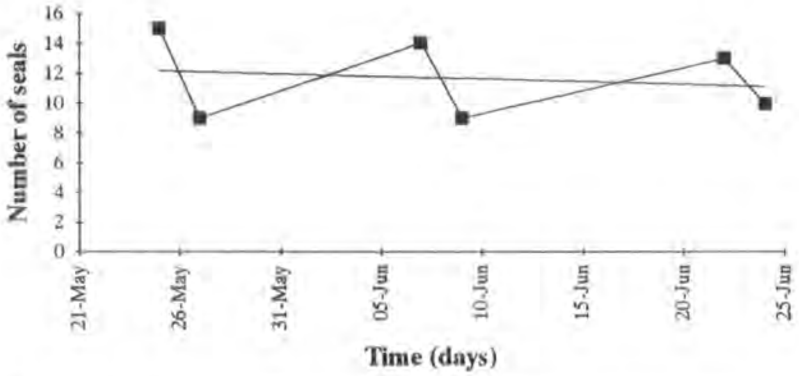

FIGURE 6 b Total number of common seals during night time observations. (R^2=.027, $R_{adj.}^2$=-.21, n=6, P=.75, SE=2.93, y=-.034 x+12.59).

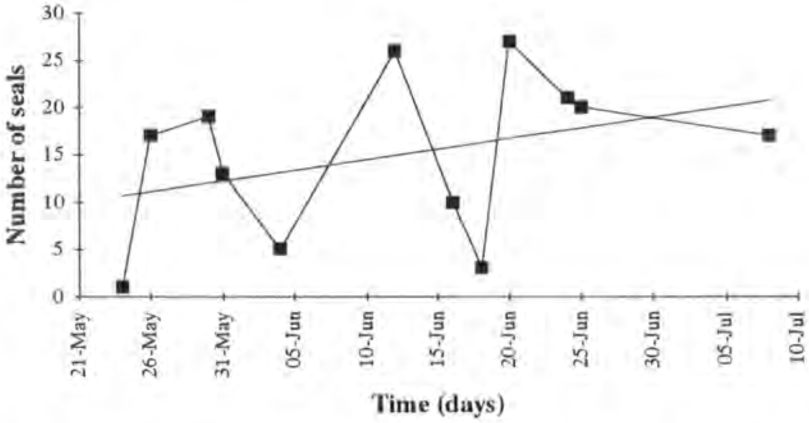

FIGURE 6 c Total number of grey seals during day time observations. (R^2=.13, $R_{adj.}^2$=.043, n=12, P=.24, SE=8.43, y=.22 x+8.20).

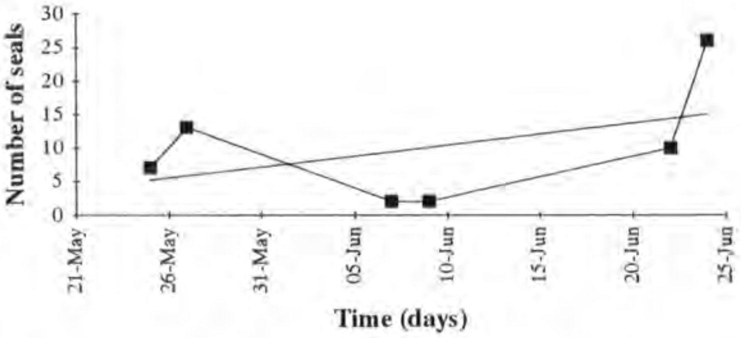

FIGURE 6 d Total number of grey seal during night time observations. (R^2=.21, $R_{adj.}^2$=.019, n=6, P=.34, SE=8.87, y=.33 x+1.17).

Figures 6 a, b, c, and d, show the common and grey seal populations patterns throughout the study period. A regression line was fitted through the general trend to calculate the slope and the constant, from which the expected values were derived (formula above). Fig. 6 a indicates a small but steady and statistically significant rise in common seal numbers hauling out between mid May and beginning of July. Fig. 6 c utilizes observations from 24 May because of an almost complete absence of grey seals from Teesmouth until late May. Thereafter, numbers varied erratically, without evidence of a significant increasing trend.

4.5. Number of seals and environmental variables

In order to determine whether environmental changes, such as tide level, air temperature and wind speed had an influence on the day to day changes in the proportion of animals hauled-out, correlations with these environmental variables were carried out. All variables were tested for normality. Figures 7 a-f show the environmental variables throughout the study period, which were considered in the analysis.

It is generally assumed that pinnipeds haul-out to save energy by resting and for thermoregulation. Hence number of seals hauling-out could depend on air temperature and wind speed. Moreover, the number of animals hauling-out may also depend on space availability and physical characteristics of haul-out sites.

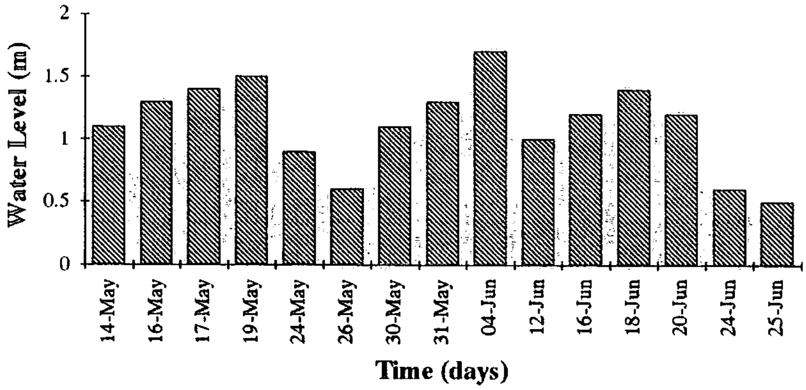

FIGURE 7 a. Water level (m) during day time observation.

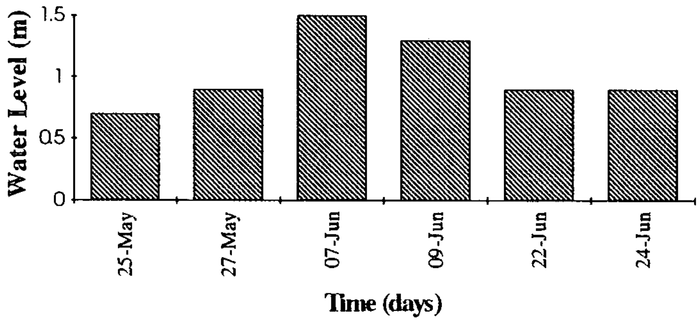

FIGURE 7 b. Water level (m) during night time observations.

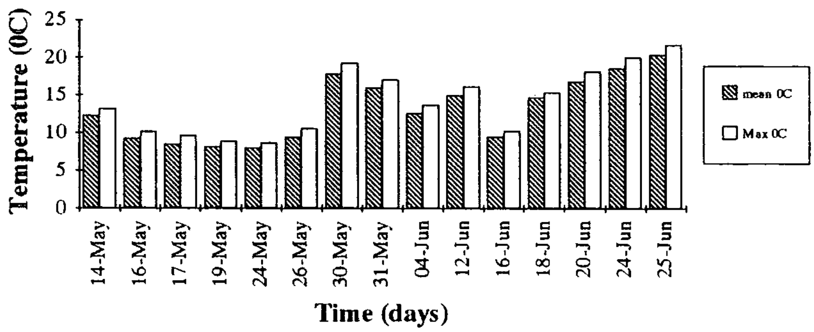

FIGURE 7 c. Mean and maximum air temperature (°C) during day time observations.

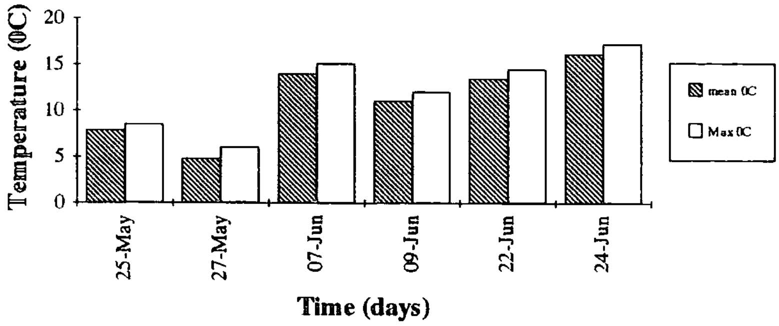

FIGURE 7 d. Mean and maximum air temperature (^{0}C) during night time observations.

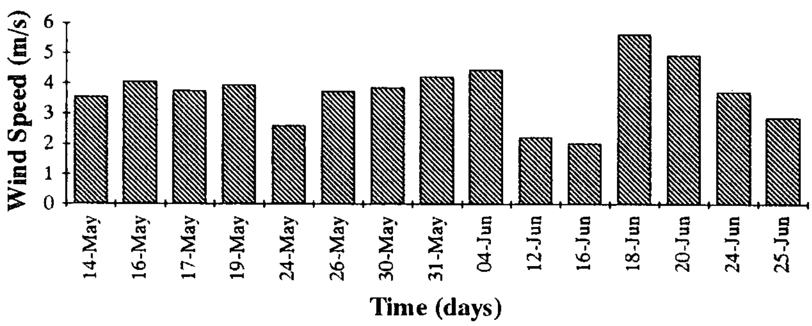

FIGURE 7 e. Wind speed (m/s) during day time observations.

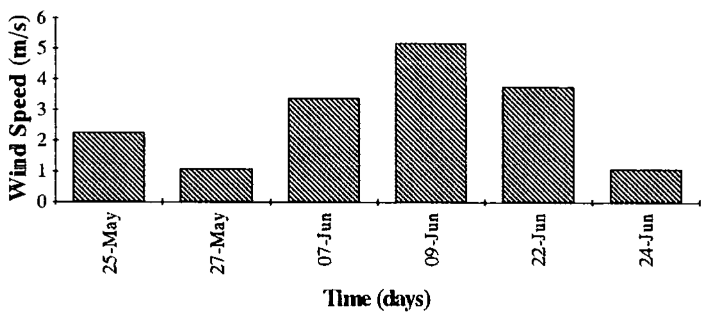

FIGURE 7 f. Wind speed (m/s) during night time observations.

The environmental variables and the total number of common and grey seals hauled out at the three sites are give in table 4.2.

TABLE 4.2

Summary table of the maximum number of common and grey seals present simultaneously at the three sites, and environmental variables.

Mean Temp. (°C)	Max. Temp. (°C)	Water Level (m O.D.)	Wind Speed (m/s)	Common	Grey
Day time					
7.92	8.62	0.9	2.61	21	1
8.15	8.9	1.5	3.95	13	0
8.5	9.65	1.4	3.75	15	0
9.2	10.18	1.3	4.04	13	1
9.4	10.6	0.6	3.73	25	17
9.48	10.2	1.2	2.04	28	10
12.28	13.2	1.1	3.56	22	4
12.62	13.7	1.7	4.44	20	5
14.72	15.37	1.4	5.62	20	3
14.96	16.6	1	2.23	29	26
15.98	17.05	1.3	4.21	19	13
16.82	18.12	1.2	4.92	30	27
17.8	19.28	1.1	3.85	26	19
18.6	20	0.6	3.73	31	21
20.3	21.72	0.5	2.88	39	20
Night time					
4.76	6.04	0.9	1.08	9	13
7.87	8.52	0.7	2.25	15	7
11.05	12.02	1.3	5.17	9	2
13.52	14.56	0.9	3.76	13	10
13.96	15.05	1.5	3.38	14	2
16.2	17.3	0.9	1.07	10	26

The highest number of common seals (39) at Seal Sands during day time, occurred when mean and maximum temperature were highest, respectively 20.3 °C and 21.72 ° C, water level at low tide was lowest (0.5 m), and wind speed was very low (2.88 m/s). The minimum number of common seals (13) occurred at a low temperature range (8.15 °C - 9.2 °C), high water level at low tide (1.5 m) and high wind speed (4.04 m/s). The maximum number of grey seals (26) at Seal Sands during day time, occurred at high, but not maximum temperature (16.82 °C), low water level at low tide (1 m) and low wind speed (2.23 m/s). The minimum number of grey seals (0 - 2), occurred at low temperature (8 °C), high water level at low tide (1.4 m, 1.5 m) and high wind speed (4 m/s).

In general the conditions under which the the highest number of seals hauled-out were: high temperature, low water level at low tide (below 1 m) and low wind speed. The highest number of common seals (15) during night time, occurred at low temperature (7.87 °C), lowest water level (0.7 m) and lowest wind speed (2.25 m/s). The lowest number of common seals (9) occurred twice under very different environmental conditions, temperature was either lowest (4.76 °C) or medium (11.05 °C), water level was either low (0.9 m) or high (1.3 m), and wind speed was either lowest (2.25 m/s) or higher (5.17 m/s).

Correlation tests were applied to the difference between the observed and the expected numbers, and the meteorological variables. For the common seal population both during day time and night time observation, there were no significant correlations with any of the variables. (If the total number of common seals present during day time was considered, instead of the difference between the observed and the expected number, there was a significant positive correlation ($r=0.612$, $P=.015$, $n=15$) between the total number of common seals hauled-out during day time and maximum temperature. This parallels the increase in numbers of common seals as the season progressed; more were present later in the season, when temperatures were higher. Causation cannot be established).

Figure 8 shows that there was no significant correlation between the grey seal numbers hauled-out and environmental variables during day time observations, whereas there were a significant negative correlations between grey seal numbers and wind speed ($r=-.830$, $P<0.05$, $n=6$), Figure 9 shows a significant positive correlation with maximum temperature time ($r=.922$, $P<.01$, $n=6$) during night. The values used for the correlation between number of common and grey seals and environmental variables are shown in Table III and IV in Appendix 3.

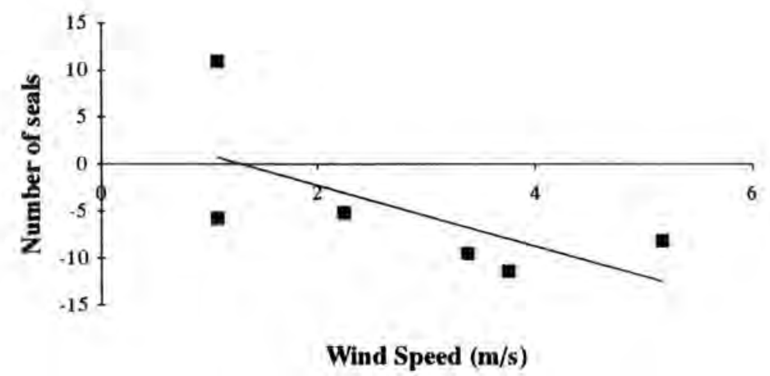

FIGURE 8 Negative correlation between wind speed and expected number of grey sealsduring night time. (R^2=.68, $R_{adj.}^2$=.61, n=6, P<0.05 , SE=5.22, y=-4.29 x+8.7).

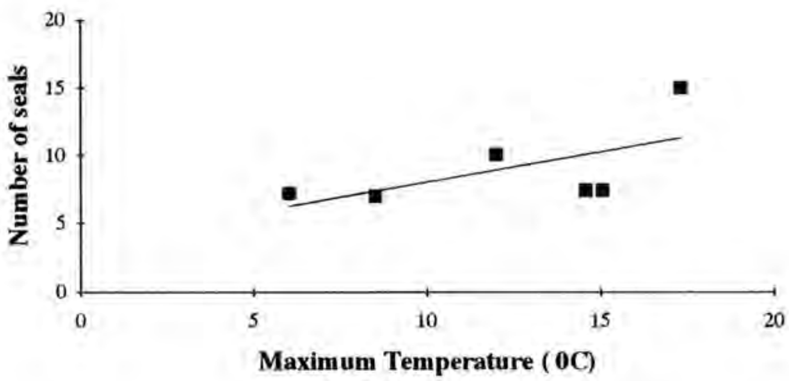

FIGURE 9. Difference between the observed and the expected number of grey seals at site C in relation to maximum temperature (°C) during night time. (R^2=.85, $R_{adj.}^2$=.81, n=6, P<0.01 , SE=3.98, y=-1.99 x+20.2).

In contrast to the results for the metereological variables, there was a significant inverse correlation of the difference between observed and expected number of common seals at site C during the day with water level at low tide (r=-.736, P<0.01, *n*=16). A significant presence of seals at C occured only when the tide was below 1.1 m.

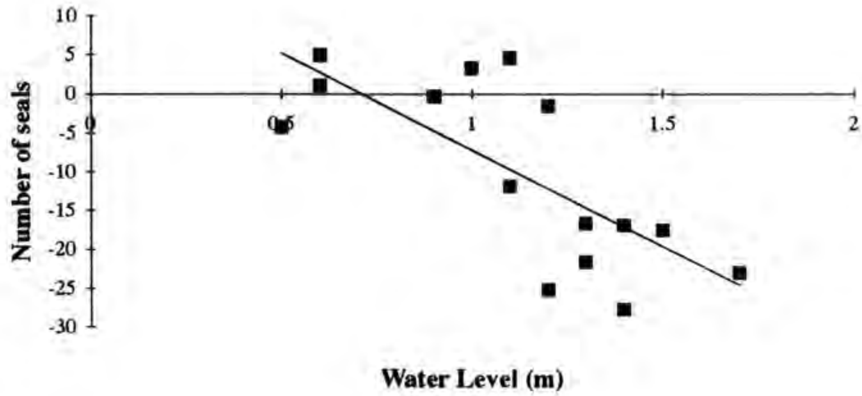

FIGURE 10 Difference number (observed - expected) of common seals at site C correlated with water level. (R^2=.54, $R_{adj.}^2$=.50, n=6, P<0.01 , SE=8.27, y=-24.86 x+17.64).

For common seals there was no significant correlation with any of the environmental variables during the night.

4.6 Distribution on haul-out sites

At both sites B and C, seals were observed to haul-out in restricted areas, i.e. they used only a proportion of the sandbank that was exposed. At site B, although space available was not a limiting factor, the group tended to aggregate in a particular area, of about 200 m in length. This was the portion of sand from which access to the water was easy (see Figure 3). At site C, common seals also occupied a portion of the beach of about 200 m. They tended to form small aggregations. The flank to flank distances between common seals inside these aggregations varied from one to two seal body lengths, whereas the distances between seals in different aggregations varied from about two to five seal body lengths. Common seals always hauled-out further inland than grey seals which used a much smaller proportion of the available space; they tended to congregate at the edge of the water in the central part of the beach. The flank to flank distances between grey seals ranged from body contact to 20 cm, when they were semi hauled-out in the water next to the beach. If they were hauled-out on the sand, distances varied from half to one seal body length. There was an evident segregation between the common and the grey seal groups at site C. Yearlings and sub-adult grey seals that hauled-out at site B did so together with the common seals group, and the same behaviour was seen at C.

4. 7 Individual behaviour

At an individual level, the identified animals were observed to prefer some areas within a haul-out site rather than others. In fact they tended to haul-out on most of the days at the same spot. It was possible to follow ten common seals throughout the whole study period at site B. They were named with the last ten letters of the alphabet. Seven of the ten individuals showed a significant clumped distribution (Q, R, S, T, U, V and W).

Figures 11-14 show distribution of common seals at site B and C, and of grey seals at site C during the study period. The spatial separation between the two species of seals is evident. Common seals occupy the portion of beach further inland, with the larger spacing between animals. As there were a similar number of common and grey seals hauled-out at site C common seals therefore occupied a larger area. Grey seals were confined to the lower portion of the beach, along the water edge, or just above it. Young and sub adults occupied the lower part of the site, very close to their conspecifics adult group, and tended to mix more with common seals. Yearlings and sub-adult grey seals that used to haul-out at site B together with the common seals group, and did the same at site C, (see Figure 14), where on two occasions grey seals were observed in cell 9 and 16. The space between them was very little and most of the time they were in body contact, especially if in the water next to the beach. They tended to increase the distance between themselves as they climbed up on land (between half and one seal body length), but it was still much smaller than the distance between common seals. Adult grey seals were always observed in the splash zone, they would move further inland only during incoming tide, but still did not mixed with the common seals, instead occupied a buffer zone that existed between the two species. Once the tide reached this buffer zone grey seals would swim away instead of moving further inland. While common seals remained at the site until they were washed by the tide, grey seals would leave the site earlier.

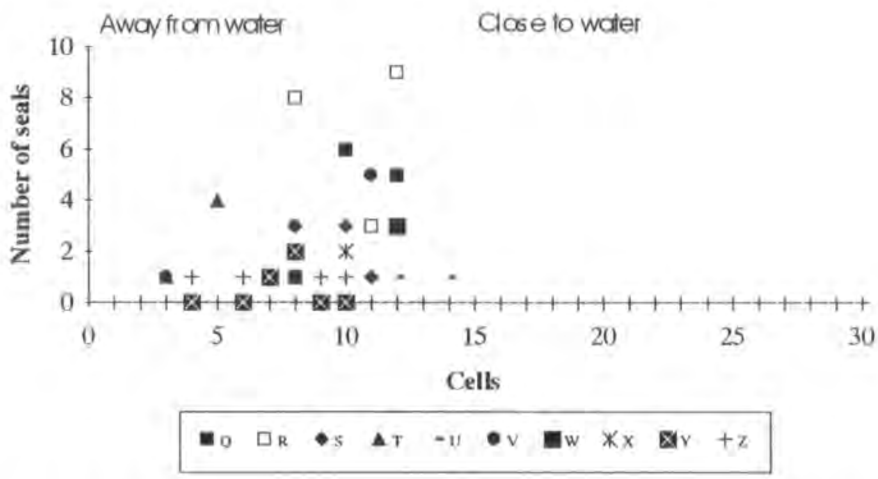

FIGURE 11. Distribution of ten common seal individuals at site B throughout the study period .

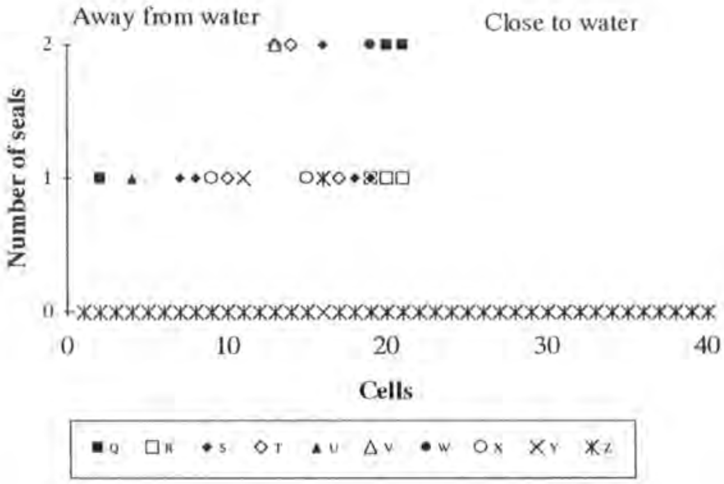

FIGURE 12. Distribution of eight common seal individuals at site C throughout the study period

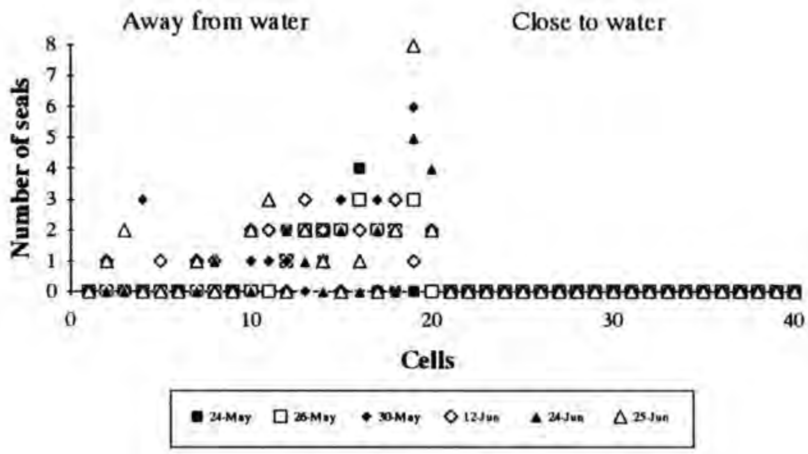

FIGURE 13 Common seals at site C throughout the study period.

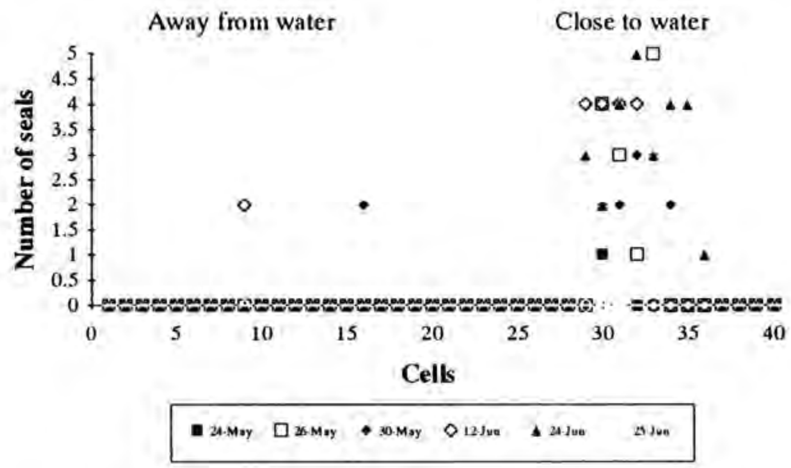

FIGURE 14 Grey seals at site C throughout the study period.

4. 8 Intra-haul-out site fidelity

The distribution of common seals at site B, revealed a significant clumped distribution throughout the study period, animals occurred more often in some grid cells than expected by chance

(χ^2=438.65, P<0.01, df=29). On a daily level, the variances in number of animals are significatively greater than the means, for every day of observation except for the 7th

May and the 12th June. The distribution of common seals at site C throughout the study period was also significatively clumped (χ^2=323.56, P<0.01, df=39). On a daily level, the variances in number of animals are significantly greater than the means for every observation. The distribution of grey seals group at site C revealed a significant clumped distribution throughout the study period (χ^2=376, P<0.01, df=39). On a daily level all variances were significantly greater than the means, indicating a significant clumped distribution for every haul-out considered.

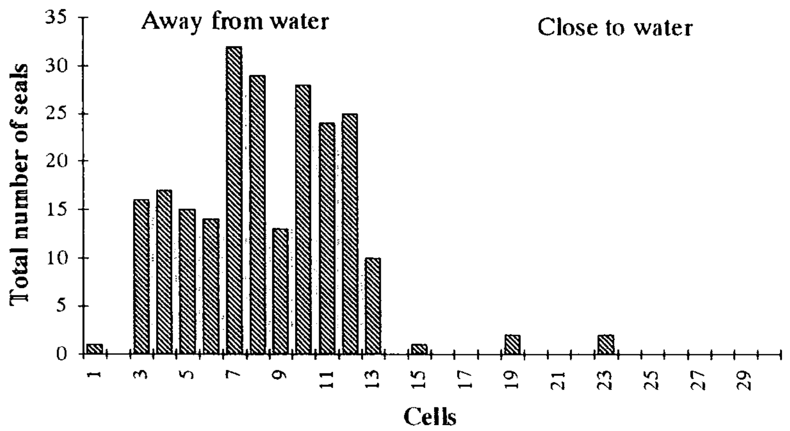

FIGURE 15. Total number of common seals hauling-out at site B throughout the whole study period.

Common seals used site B as the main haul-out site. Fig. 15 shows that common seals occupy the upper part of the beach throughout the whole study period. Only a few of them were observed to haul-out on the lower part of the beach. The greatest proportion of the seals occupy cell number 7, 8, 10, 11 and 12, which corresponds to the centre right of the haul-out site. The portion of sand closer to the water was rarely occupied. At very low tide levels, common seals moved from site B to site C before low tide. They used to move to the lower part of the beach (cells 15 to 30), and stay there for about twenty minutes before swimming to site C. The lower part of site B was also occupied when a sudden disturbance occurred. Common seals were observed to move very quickly to the portion of sand closer to the water. Once they had moved they rarely returned to the previous positions. Figure 16 shows where and how many seals haul-out every day at site B. Common seals tended not to overcrowd the cells at the same day. An average of two seals occupy the same cell, the seals usually dispose themselves in adjacent cells during the same day. Only on a few occasions, more than four seals were observed in the same cell.

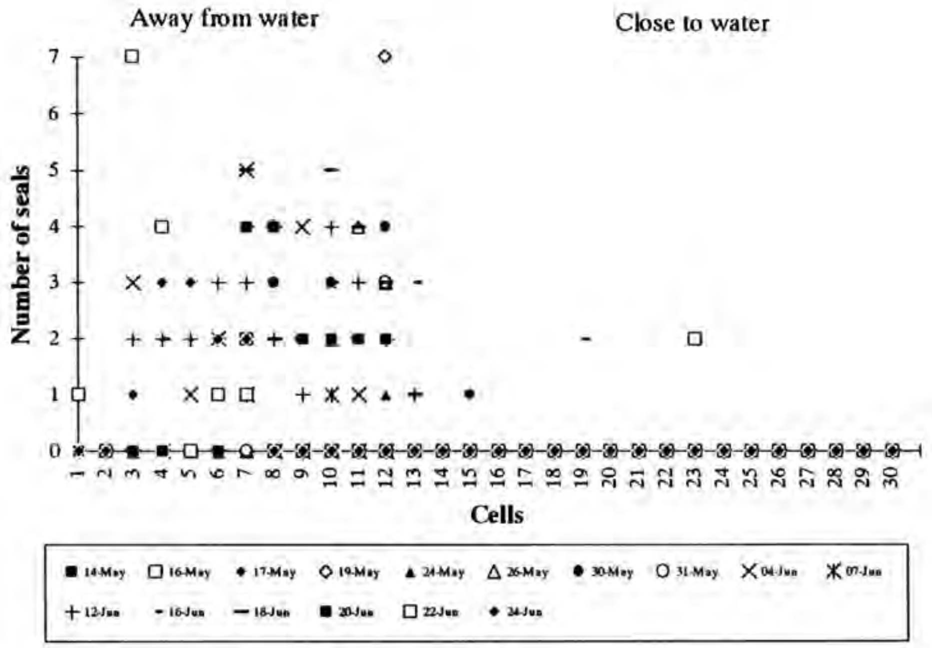

FIGURE 16. Daily distribution of common seals at site B. The number of seals is recorded on the corresponding cell.

4. 9 Inter- haul-out site fidelity

Common seals occupied site C less frequently than site B, therefore less observations were recorded. From Figure 12, it appears that the common seals group at site C spread themselves more over the available haul-out space. No more than two individuals were observed in the same cell. At site C as well as at site B, common seals showed a certain degree of intra-haul-out site fidelity. Seals Q and R occupy the same portion of the beach, as at site B, i.e. the upper right side.

4.10 Vigilance behaviour in common seals.

Seals were observed for a period from two hours before low tide to two hours after low tide, their behaviour was recorded every five minutes on a scan sheet. The mean of the percentage of animals alert at each observation time i.e. every five minutes was plotted against time. Figures 17-22 show the vigilance behaviour during the four hours observation, throughout the whole study period. The total of the means of the percentage of seal alert everyday of observation at 5 minutes interval was plotted against time. The mean of data of different days of seals alert at a particular time of observation was plotted against time. The seals spent about 90% of their haul-out time by resting. Usually a small proportion of the group was involved in vigilance behaviour. Different individuals would take vigilance in turn. The percentage of common and grey seals alert was investigated in relation to the group size. It was expected that a high percentage of animals would be alert when the group size was low, and would gradually decrease as the group size increased. The common seals at site B formed on average a group of fifteen animals. The percentage of animals performing vigilance varied depending on the time of the day. Fig. 17 shows the peak of alertness at about one hour before low tide and then gradually decreases towards the end of the four hours of observation. During the first hour an a half of observation, the degree of variation was greater than during the last hour an a half of observation. This was possibly due to various degrees of disturbance. Disturbance factors were not constant, and they were mainly caused by bait diggers. Presence of bait diggers was maximum one hour before low tide. Human disturbance would usually cease just before low tide. Fig. 18 shows the vigilance behaviour trend excluding one hour before low tide on those days when disturbance due to bait diggers was maximum and altered the alertness of the seals. The inverse correlation of the percentage of seals alert, was significant (r=-.81, P<0.01, n=48). Furthermore, most seals hauled-out well before low tide time, but a few individuals, mainly juveniles, would occasionally join the group around low tide. When this happened, the group would respond with an increase of alertness that might have contributed to the high degree of variation recorded in the data before low tide. Common seals appear to be more settled during the last hour of observation, the degree of alertness does not exceeds 5%.

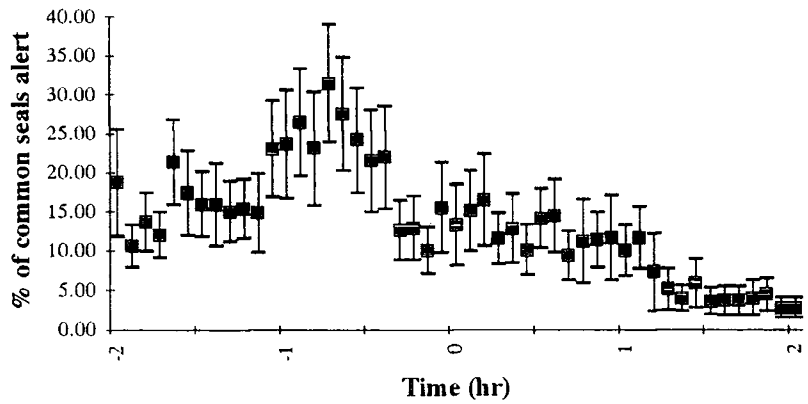

FIGURE 17 Percentage of common seals alert at site B (0=low tide).

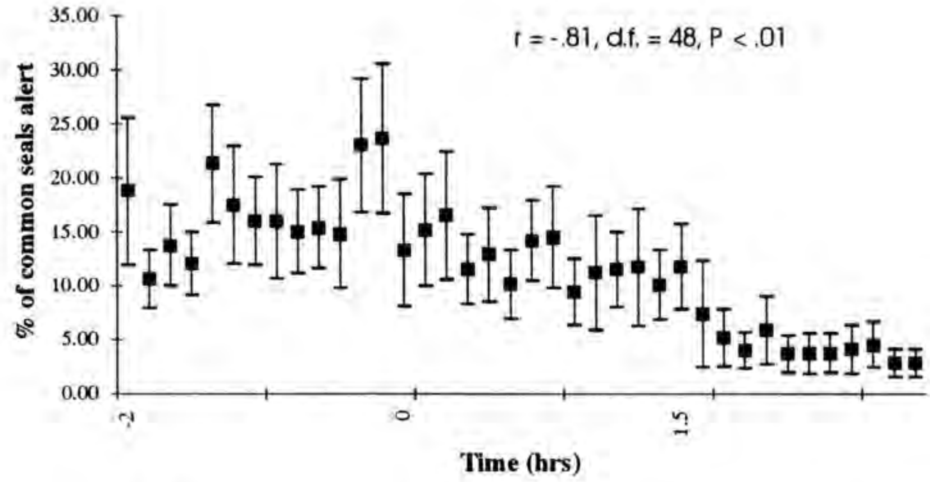

FIGURE 18. Percentage of common seal alert at site B without the influence of human disturbance (0=low tide).

The common seals group at site C (Fig. 19), shows a vigilance trend similar to that of site B (Fig. 18) The percentage of common seals vigilant at site C is inversely correlated with time. However, the peak of alertness was not as evident as at site B, and the degree of variation was much higher at site C, especially during the first two hours of observation. At site C seals are disturbed by bait diggers, and are also more exposed to boat passage.

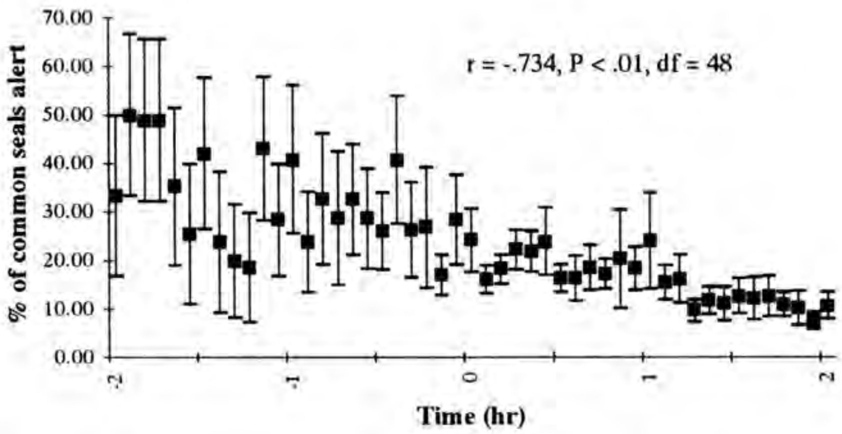

FIGURE 19. Percentage of common seals alert at site C (0=low tide).

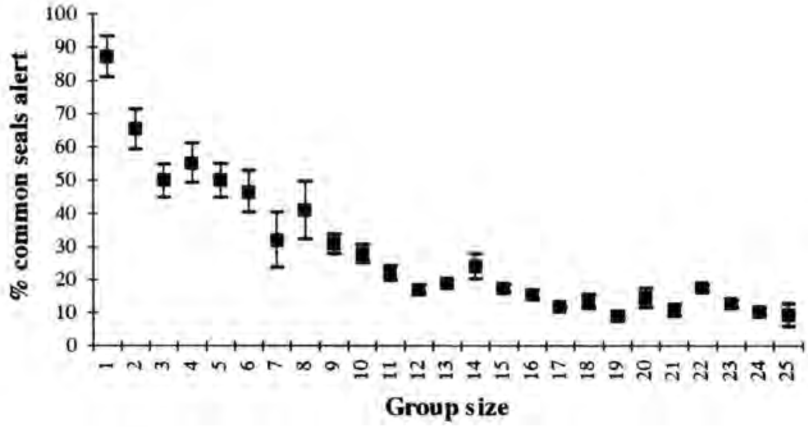

FIGURE 20 Percentage of common seals alert at site B in relation to group size.

Common seals group size is inversely correlated to the percentage of animals vigilant, and is significant (r= 884, P<0.01, n=25). With little degree of variation, common seals at site B (see Fig. 20) follow the expectation of having a high percentage of animals performing vigilance when group size is small. They stabilise a more or less constant degree of vigilance when the group reaches about ten individuals.

The percentage of common seals alert at site C in relation to group size, (Fig. 21) is very similar to that of site B (Fig. 20). The percentage of animals alert decreases as the group size increases. At site C when the common seals group ranges from one to four seals the percentage of animals performing vigilance is very high, ranging from 100 % to 65 %. It drops to about 30 % and 20 % when the seal group ranging from five to 21 individuals, and decreases further to about 15 % when there are between 23 and 30 seals present. Overall the average percentage of alertness behaviour in common seals at C is higher that at site B.

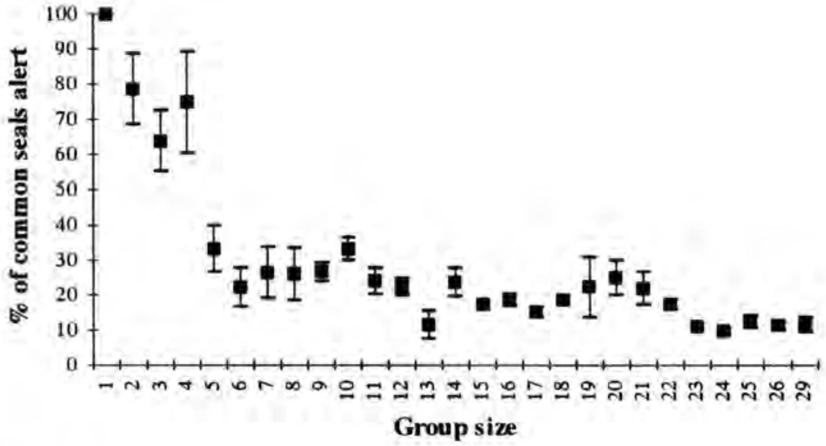

FIGURE 21 Percentage of common seals alert in relation to group size at site C.

4.11 Vigilance behaviour in grey seals.

The vigilance behaviour in grey seals group was very different from the common seals group. There is no evident pattern and no correlation between the percentage of animals alert and the time. On many occasions, regardless of the time, grey seals were not vigilant. Grey seals were usually vigilant during disturbance, but not much in undisturbed conditions. Their position at site C, on the water edge, possibly make them less vulnerable. Since they would need less time to escape from danger coming from land or from a boat, grey seals would not invest the same amount of time and energy in vigilance as the common seals did. Possibly grey seals were using common seals for vigilance, and their alertness behaviour would have been possible different in the absence of common seals group. But the group of grey seals was always observed together with the common seals group. when a small group of grey seals was observed bottling around site C, one of the seals was always more alert than the others.

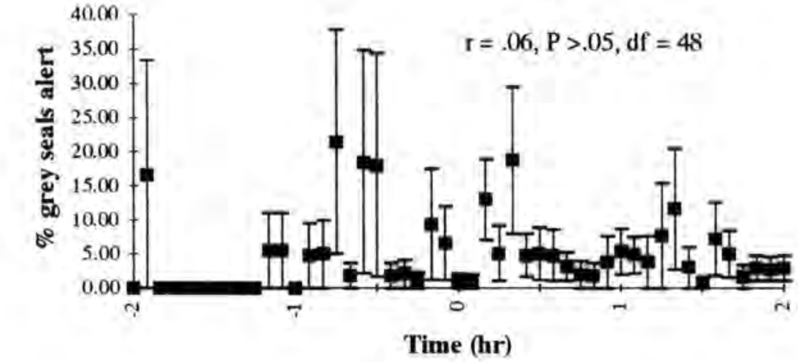

FIGURE 22 Percentage of grey seal alert at site C (0=low tide).

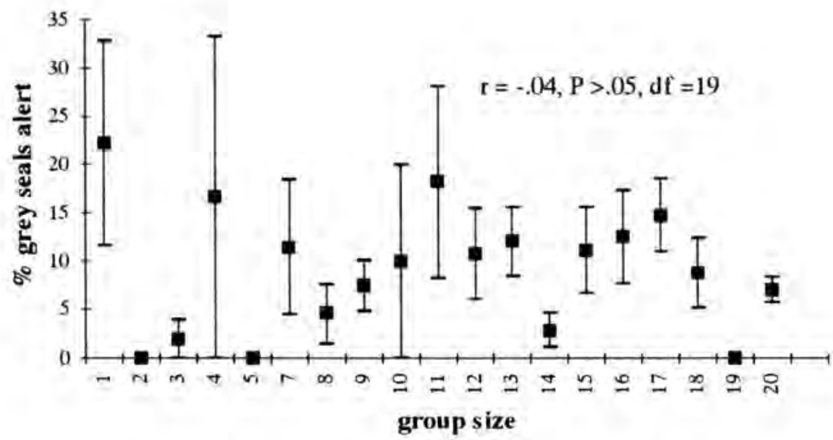

FIGURE 23. Percentage of grey seal alert in relation to group size at site C.

Vigilance behaviour in grey seals, in relation to group size show no evident pattern (Fig. 23). Even when the number of grey seals is very low, between two and five vigilance is performed by few individuals and in some occasion is absent. The degree of variance is very high, regardless the group size.

CHAPTER 5

DISCUSSION

5.1 Hauling-out behaviour and fluctuation in number of common and grey seals

There is still no conclusive explanation of why seals haul-out. A pinnipeds' life is still strongly linked to the terrestrial environment for some vital aspects, such as mating, giving birth and moulting, but it is generally accepted, that seals haul-out also for thermoregulation and resting (Gentry, 1973).

Because sea water is always colder than blood temperature (37 °C) and heat is much more rapidly lost to the water than to air, seals need adaptation to avoid excessive loss of heat from their body surface. One way of doing this is for an animal to reduce the surface area in relation to volume (i.e. to become more nearly spherical). Another way to control heat loss is to insulate what surface there is exposed. The layer of air trapped in the coat of a mammals is an effective insulator when on land. Fur is an effective insulator in air but has the disadvantage that if the seal dives the air layer in the fur is compressed, by half its thickness for each 10 meters depth, reducing its efficiency accordingly. Because of this, seals have developed another mode of insulation. This is the layer of fatty tissue beneath the skin, which also provides energy during fasting and lactation. Fat is a poor conductor of heat, and blubber insulation is about half as effective an insulator on land as an equal thickness of hair. When in water, however, the insulation property of blubber is reduced to about a quarter of its value in air, but this is unaffected by the depth to which the seal dives. However, pinnipeds cannot emphasise only one side of the heat balance equation. Anatomical adaptations, such as the insulative layer of blubber and counter-current heat exchange, function to conserve heat in the water; out of the water, these same adaptations inhibit heat dissipation.

Pinnipeds employ behaviour as well as physiological means for thermoregulation (Riedman 1990). When air temperatures are cool during the haul-out, seals lie on their bellies with their flippers tucked under their bodies. To conserve heat when resting on the water surface, fur seals and sea-lions for example, extended both hindflippers. When sea water covered about half of the body surface of grey seals at Teesmouth they assumed the so called gondola position, i.e. the body formed an arch and the surface in contact with the water was kept as small as possible.

Most studies of activities budgets of pinnipeds on shore have shown that the majority of their time is spent resting, thereby saving energy. Hauled-out individuals spend most of their time frequently alerting between scanning and resting. Scanning and resting by common seals have been considered analogous to feeding in flocking birds (Krieber and Barrette 1984). Grey seals, and possibly all other phocids, can achieve slow-wave sleep while submerged, but can achieve rapid-eye movement sleep only when at the surface or hauled-out (Ridgeway, *et al.* 1975). Phochid seals may thus have to haul-out in order to sleep.

Common seals tend to be solitary in the water but form small groups when hauled-out (Ridgeway, 1981). Since no individual identification of seals had been attempted at Teesmouth before my two months' study, it is not known whether the common seals form a resident group and whether the same grey seals come back to the estuary every year. My observations suggest that it is quite possible that the small group of common seals is resident in the Tees estuary. However, monitoring between 1998-93 has established that few individuals of the small colony of common seals were seen regularly at the haul-out since the study began (Wilson 1994). During my study period, most of the individually recognisable common seals were seen on every date, suggesting that at least most of them formed a stable group during these two months of observation. The group consisted of mixed sex and ages. Because the sex of animals was possible to determine, only when the seals showed their bellies, it is difficult to give a proportion. Young comprised about 20 % of the population. Within the common seals group, grey seal yearlings, one or two at the beginning of the observation period, and three to four at the end, and one or two male sub-adults, they usually hauled-out in the centre of the common seals group without any apparent rejection from the latter. Those young individuals were possibly rejected from their conspecifics, in fact they did not mingle with the grey seals group even when the two species hauled-out together at the same site.

Grey seals did not form a stable group at the Tees estuary. Components of the group were of both sexes, but the great majority were adult females, about 90 %. Just one or two adult males were occasionally seen with the rest of the group, few yearlings joined the adults, which were more regular in hauling-out. Three adult females were observed regularly at Seal Sands; they hauled-out with the other grey seals on site C when low tide was below 1 m. Otherwise they bottled around the sites or swam along the channel, but were never seen hauling-out on other sites within the Estuary.

There was a greater variation in the number of grey seals attending the haul-out sites in Seal Sands throughout the two months of observation, when compared the variation in the number of common seals (see Fig. 4a). Several reasons may contribute to this seasonal variation in numbers. Common seals used Seal Sands for breeding, moulting and feeding, whereas grey seals feed, moult, but do not breed on the sandy beaches of the Tees estuary. The grey seals group at Seal Sands is possibly part of the Farne Islands colony, thus during the autumn months they are expected to leave the Tees estuary and congregate at the Farne Island or on other breeding grounds.

From previous studies it has been observed that common seal numbers increased during the June/July pupping season and peak in the August/September moulting season and grey seals number declined sharply during October/December 1989-93 breeding season

(Wilson 1993). Thus the seasonal variation in number of seals, and the difference in timing of fluctuations in numbers between common and grey seals might be a consequence of a different stage of their life cycle i.e. common seals uses Seal Sands as a breeding ground but grey seals do not. For common seals the increase in number towards the end of the study period (see Fig. 6a) coincide with the increase in temperature but the increase in number was more likely to be due to the approaching pupping season. Despite the assembly of common seals during the summer breeding seasons, there has been not successful breeding. During the last five breeding seasons, three pups were born, and all have died within few days. During the last breeding season (1994), two pups have been born and survived. Another five were detected in the Tees estuary in 1994 but they all died from different causes. Their birth places were uncertain.

Diverse factors might account for the day to day variation in the number of seals of the two species hauling-out. Beside population size in the whole Tees estuary, the variation in numbers appeared to be associated with environmental changes, both during the day and night time, this was more evident in grey seals than in common seals. The total number of common seals hauled-out at the three sites appeared not to be influenced by meteorological factors, either during the day or night. Air temperature and wind speed by day also seemed to have no effect on the number of grey seals hauled-out; on the other hand the number was inversely correlated with the wind speed (see Fig. 8) but positively correlated with the maximum temperature during the night (see Fig. 9).

Water level at low tide, did influence the choice of sites, since physical characteristics of the sites were modified. The choice of sites was based on quick access to the water. This changed, depending on the state of the tides. Common seals hauled-out regardless of the water level on site B, but they occupied sites C according to this level (see Fig. 10). Whereas grey seals hauled-out only at site C when water level was below 1 meter at low tide, when the water was above it, a small number of grey seals, ranging from nil to five, bottled close to site C.

5.2 Day and night activities

Recent studies in Monterey Bay, California, show that juvenile common seals feed overnight along the continental shelf, and return to haul-out sites each day (P. M. Thompson 1994). Not much is known about nocturnal activities in seals. Anderson (1978), suggested that there was no difference in the diurnal and nocturnal activity patterns in grey seal bulls. In both common and grey seals at Seal Sands, the average number of animals hauling-out at night was about half of the number hauling-out during the day. Number of common seals hauled-out during the night did not correlate with environmental factors, the variation was not as big as in grey seals. This suggests that common seals also haul-out for reasons other than thermoregulation, such as saving energy by resting. Number of grey seals hauled-out during the night was positively correlated to maximum temperature and negatively correlated with wind speed, as it would be expected in animals trying to conserve heat. This suggests that for grey seals, environmental changes affect the choice of whether to haul-out or not (see Table 4.2).

5.3 Haul-out site fidelity and distribution on the sites

Common seals travel between haul-out sites for a variety of reasons. Some movements result from animals dispersing to new social groups, while others may occur because the physical characteristics of the site make it suitable for particular activities such as pupping. In general one would aspect dispersal movements to predominate at one or few stages of the life cycle, while movements based on site characteristics should occur on a seasonal basis in line with the annual cycle. If seasonal changes in food availability are predictable, movements to sites near feeding areas may also be similar from year to year, but between year-year difference in site-use could also occur (Thompson 1989). Groups of seals at different sites within a local haul-out area may also show consistent differences in sex or age structure (Kundtson 1977; Salter and Markoviwitz 1993; Allen, Ribic and Kjelmye 1988; P. M. Thompson 1989; Kovacs, Jonas and Welke 1990), indicating that the individual's status will affect its choice of site, or at least its success in gaining access to the site. In other studies, changes in haul-out distribution apparently result from changes in foraging grounds. In several estuaries along the Pacific coast of North America there are seasonal increases in abundance at haul-out sites during major runs of prey species (Brown and Mate 1983; Roffe and Mate 1984; Jeffries 1986).

Of the four haul-out sites utilised by the seals at Seal Sands, two were given special attention (B and C) because they were used more frequently. Haul-out sites and space on the haul-outs were not in short supply, but common and grey seals grouped only in specific areas, to which they returned every time they hauled-out. Sites were chosen in relation to physical characteristics, i.e. easy access to the water and as far as possible from human disturbance. On site B common seals spread along a length of about 200 meters; there was no evident segregation between sexes and/or age categories. At site C they spread along about the same length as at site B, but they occupied the upper part of the beach with respect to the grey seals.

When the grey seal group hauled-out at site C, spatial segregation between sexes and ages was evident. The younger seals positioned themselves further inland, just below the common seals group, and spent the whole hauling-out time on the beach. Adult females, however, hauled-out at the edge of the water, and adult males mixed with them. As opposed to common seals, adult grey seals did not maintain a fixed position during the haul-out, and often left the haul-out site and then returned. This behaviour was less frequent in young individuals.

Passive body contact varies greatly among species of pinnipeds in the extent to which it is tolerated or sought. Incidental contact is tolerated by resting common seals. Common seals defended their space from intrusion by other seals by displaying aggressive gestures such as biting and fore-flipper waving. These were the only occasions when aggression was observed. Common seals spaced themselves one or two meters apart, and maintained more or less this distance for the whole hauling-out time. At site B they positioned themselves on the haul-out site before it was exposed; body contact occurred occasionally when they were partially covered in water. More elaborate physical communication occurs in special circumstances, as when young common seals ride on the backs of their swimming mothers or when the mother hold them between the foreflippers while swimming, and during rearing and nursing. Nuzzling, which has tactual and olfactory components and employs the strongly developed mystacial vibrissae, occurs between females and pups of all pinniped species.

Grey seals appear to be less concerned about maintaining a distance between themselves. The adults which hauled-out at the waters edge were almost in body contact. Distances between them increased to about half a meter if they moved further inland.

Ten individuals of the common seal group were identified during every haul-out and they showed an high degree of site fidelity at site B and C (see Fig. 11 and 12). They tended to occupy the same spot, haul-out after haul-out. The lower part of the beach (cells 16-30) was occupied occasionally by the common seal group during the first hours of haul-out, or as a consequence of disturbance, when the seals approached the waters' edge. The common seals group had a clumped distribution at both haul-out sites. At site C the common seals group never occupied the lower part of the beach (cells 21-40). The segregation between the two species was evident (see Figures 13 and 14). The adults of the two species never mixed during the observation period; however they tolerate each other, for aggression between common and grey seals was never observed, possibly because the two species groups were always separated by a "buffer zone".

5.4 Vigilance behaviour

Social life involves a number of disadvantages, and advantages. What advantages animals gain by living in groups has been the subject of much discussion. The benefit which individuals derive from grouping together can be of various kinds. Among these, the defence against predation is one and animals living in groups may benefit as a result of increased vigilance. Terrestrial grouping of common seals might have this functional significance. Shortage of haul-out sites or space on the sites was not a limiting factor, therefore the grouping was not forced by haul-out space availability.

Pinnipeds have failed to make the complete transition from land to water. Those adaptations that fit them extremely well for life in the sea, render them clumsy and vulnerable to terrestrial predators. When ashore they have to adopt various strategies. to ensure their safety. This relates to the selection of secure sites and the social structure. Alexander (1974) considered predation pressure to be the primary factor in promoting group living. The percentage of common seals that were vigilant decreased about one hour after low tide at both sites, B and C (see Figures 18 and 19). There was also an evident peak about one hour before low tide (see Fig. 17), when 25% of the animals were scanning, although with a great degree of variation. At this time of the tide, disturbance was highest, bait diggers collected crabs and worms close to site B, causing noise, sometimes as close to the haul-out site as about 150 meters. Seals responded with an increase in alertness, and on few occasions they swam away. Human disturbance on seals at Seals Sands has been reviewed by Wilson (1994).

Most of the common seals hauled-out within half an hour, from three to four hours before low tide. However few animals hauled-out at intervals within the two hours before low tide, causing a brief increase in scanning behaviour.

The grey seals group did not show any relation between degree of alertness and time during the low water period (see Fig. 22). On some occasions, grey seals were not alert, whereas the common seal group always maintained some degree of vigilance throughout the hauling-out time.

Scanning can be regarded as an expression of social vigilance with respect to predators. Two commonly cited benefits to animals that gather in groups is the increase in probability of detecting predators and the decrease in time spent by an individual in predator detection. The relation between group size and scanning has also been found for birds (Bertram, 1980; Barnard, 1980) and other mammals. Over fifty studies of birds and mammals show a negative relationship between group size and vigilance rates and most authors conclude that the relationship at least partly explains why individuals forage in groups (Elgar,1989).

There are differences in time budgets between groups for the scanning behaviour. Members of a smaller group scan more. It can be easily understood that they do so in order to reach the same probability of detecting a predator. If a single animal hauled-out, it spent its whole time being vigilant. In a small group of common seals, about five animals, the percentage of animals alert was still high, about 50 % at site B (see Fig. 20) and ten at 70% at site C (see Fig. 21). Once the group size stabilised, common seals became vigilated in turn. When the seals were not disturbed by bait diggers or boats, usually two of the members of the group which occupied different positions on the haul-out, were vigilant for about 30 seconds and then went back to rest, and another two took over vigilance.

Sometimes they were scanning for longer intervals, for about two minutes. Young appeared to be more alert than adults and some adults were scanning more then others. The two adults females, named Q and R, which used the side of the haul-out site B closer to the bait diggers, were vigilant for more of the time than the rest of the seals of the group. The two grey seal sub-adults hauled-out with the common seals did not share any vigilance at any time.

The percentage of grey seals' alert was related neither to the time of haul-out (see Fig. 22) nor to group size (see Fig. 23), there was a high degree of variation regardless of the group size. Two reasons may account for it. The first regards the position on the haul-out site, close to the water edge, and frequently, partially in the water. Therefore in case of disturbance grey seals would escape more rapidly and easily than common seals. Thus a grey seal group might not need to detect a potential danger with much anticipation. Secondly, it is possible that grey seals group relay on the common seals' vigilance. This assumption is difficult to test because grey seals hauled-out in a group at C only when common seals were there too, therefore it is not know whether grey seals vigilance behaviour would have been affected by the common seals' absence.

CHAPTER 6

REFERENCES

Allen, S.G., Ribic, C.A.and Kjelmyr, J.E. (1988). Herd segregation in harbor seals at Point Reyes, California. *Calif. Fish Game* 74: 55-59.

Anderson, S. S. (1978) Day and night activity of grey seal bulls.*Mammal Rev .8* :43-46.

Anderson, S. C. (1981). Seals in Scotland waters. Proc. Roy. Soc. Ediburgh. **80**B: 181-188.

Barnard, C.J. (1980) Flock feeding and time budgets in the house sparrow (*Passer domesticus* L.) *Anim. Behav.* **28**: 295-309.

Bertram, B.C.R. (1980) Vigilance and group size in ostriches. *Anim. Behav.* **28**: 278-286.

Bonnner, W. V. (1976). The stock of grey *Halichoerus grypus,* and common seals *Phoca vitulina* in Great Britain. 16 pp Nat. env. Res. Council Pub. Ser. C. No. 16.

Bonner, W. N. (1972). The Grey Seal and the Common Seal in European waters. Oceanography and Marine Biology Annual Review. 10:461-507.

Bonner, W. N. (1981). Grey Seal, *Halichoerus grypus,* (Fab.). Chapter 5 in; "Handbook of Marine Mammals, vol.2: seals", Ed. Ridgeway, S.H. and Harrison, R. J., Academic Press Lond. pp 111-144.

Boness, D. J.(1984) Activity budget of male grey seals, *Halichoerus grypus. J. Mammal.* **65**: 291-297.

Bovet, J. (1992) Mammals. In: Animal homing. ed. Papi, F. Chapman and Hall.

Brown, R.F. and Mate, B.R. (1983) Abundance, movements, and feeding habits of harbor seals, Phoca vitulina, at Netarts and Tillamook Bays, Oregon. *Fish. Bull. U.S. Fish. Wildl Ser.* **81**: 291-301.

Coulson, J. C. and Hickling (1964). The breeding biology of the Grey seal, *Halichoerus grypus.* (Fab.), on the Farne Islands, Northumberland. J. *Anim. Ecol.*, 33: 485-512.

Coulson, J. C. (1981). A study of the factores influencing the timing of breeding in grey seals, *Halichoerus grypus.* J. Zool., Lond., 194, 553-571.

da Silvia, J. and Terhune, J. M. (1988) Harbour seal grouping as antipredator strategy. *Anim. Behav.* **36**: 1309-1316.

DeLong, R. L., Gilmartin, W. G. and Simpson, J. G. (1973). Premature birth in California Sea Lions: association with high organochlorine pollutant residue levels. Science. 18: 1168-1170.

Elgar, M.A. and Catterall, C.P. (1989). Flock size and feeding efficiency in house sparrows. Emu. in press

Gentry, R. L. (1973) Thermoregulatory behavior of eared seals. *Behavior* **46**: 73-93.

Hammond, P. S., McConell, B.J., Fedak, M. A. and Nicholas, K. S. (1992) Grey seals activity patterns around the Farne Islands. In Wildlife telemetry: remote monitoring and tracking of animals: 677-686 (Eds Priede, I.G. and Swift, S.M.). Ellis Horwood, Chichester.

Hammond, P. S. and Prime, J.H. (1990) The diet of British grey seals (*Halichoerus grypus*). In population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate hosts (Ed. Bowen, W. D.). Can. Bull. Fish aquat Sci **222**: 243-254.

Harwood, J., Hiby, L., Thompson, D. and Ward, A. (1991). Seal stocks in Great Britain: Survay conduced between 1986 and 1989. NERC News, Jan 1991, p 11-15.

Hewer, H. R. (1957). A Hebrieadn colony of grey selas with comparative notes on the grey seals of Ramsy Island. *Proc. Zool. Soc. Lond.*: **128**, 23-656.

Hewer, H. R. and Backhouse, K. M. (1959). Field identification of bulls and cows of the Grey seal, *Halichoerus grypus* Fab., Proc. Zool. Soc. Lond., 132:641-645.

Hewer, H. R. and Backhouse, K. M. (1960). A preliminary account of the colony of Grey seals, *Halichoerus grypus*. (Fab.), in the Southern Inner Hebrids. Proc. Zool. Soc. Lond., 134: 157-195.

Holden,m A. V. (1975). The accumulation of oceanic commitments in the marine mammals. Rapp. P. -v. Reun. Cons. Int. Explor. Mer. 169: 353-361.

Holden,m A. V. (1978). Pollutants and seals a review. Mammal review. 8: 53-66.

Jeffries, S.J. (1986) Seasonal movements and population trends of harbor seals (*Phoca vitulina* richardsi) in the Columbia River and adjacent waters of Washington and Oregon: 1976-1982. Report to the US Marine Mammal Commission, Contract MM207937-5.

Jewell, P. A. (1966). The concept of home range in mammals, in: play exploration and territory in mammals. Eds. P. A. Jewell and C. Loizos. Symp. Zool. Soc. Lond., **18**: 85-109.

Knudtson, P. M. (1977) Observations on the breeding behaviour of the harbor seals in Humbolt Bay, California. *Cal. Fish Game* **63**:66-70.

Kovacs, K.M., Jonas, K.M. and Welke, S.E. (1990) Sex and age segregation by *Phoca vitulina concolor* at haul-out sites during the breeding season in the Passamaquoddy Bay region, New Brunswick. *Mar. Mamm. Sci.* **6**:204-214.

Krieber, M & Barrette, C. (1984). Aggregation behaviour of harbour seals at Forillion National Park, Canada. *Journal of Animal Ecology:* **53**, 913-928.

Matthew, L. H. (1950). The natural nistory of the Grey seal, including location. Proc. Zool. Soc. Lond., 120: 763.

Prime, J.H. and Hammond, P.S. (1990) The diet of grey seals from the south-western North Sea assessed from analyses of hard parts found in faeces. J. appl. Ecol. **27**: 435-447.

Rheingold, H. L. (1963). Maternal Behaviour in Mammals. National Institute of Menthal Health. John Wiley & sons. London.

Ridgeway, S. and Joyce, P. (1975) Studies on seal brain by radio telemetry. Rapp P-V Reun. Cons. Int. Explor. Mer. 169: 81-91.

Ridgeway, S. and Harrison, R. (1981) Handbook of Marine Mammals. Vol II. New York Academic Press.

Riedmann, M. (1990). The pinnipeds: seals, sea-lions and walruses. University of California Press. Barkley.

Roffe, T.J. and Mate, B.R. (1984) Abundances and feeding habits of pinnipeds in the Rogue river, Oregon. J. Wildl. Mgmt **48**: 1262-1274.

Smith, E.A. (1966) A review of the world's grey seal population. *J. Zool.* (London) **150**: 463-489.

Salter, L.M. and Markowitz, H. (1983) Spring population trends in *Phoca vitulina richardsi* in two central California coastal areas. *Cal. Fish Game* **69**: 217-226.

Scheffer, V.B. and Slipp, J.W. (1944) The harbour seal in Washington State. *Am. Midl. Nat.* **32**: 373-216.

Stewart, B.S., Leatherwood, S., Yochem, P.K. and Heide-Jorgensen, M.P. (1989) Harbor seal tracking and telemetry by satellite. *Mar. Mamm. Sci.* **5**: 361-375.

Thompson, P. M, (1989) Seasoanl changes in the distribution and composition of common seals *(Phoca vitulina)* haul-out groups. *J. Zool.* **217**: 281-294.

Thompson, P.M. and Miller, D. (1990) Summer foraging activity and movements of radio-tagged common seals (*Phoca vitulina* L.) in the Moray Firth, Scotland. *J. Appl. Ecol.* **27**:492-501.

Thompson, P. M. (1993) Harbour seals movement patterns. In: Symp. Zool. Soc. London No. 66: 225-239.

Wilson, S. C.(1994) The tees seals programme. Monitoring report No. 5 (1989-1993). Report prepared for Teeside Deveolopment corporation/Cleveland INCA.

Wynne-Edwards, V. C. (1954). Field identification of the Common and Grey seals. Scottish Nat. 66:192.

Zwanenburg, K. C. T. and Bowen W. D (1990). Population trends of the grey seal *Halichoerus grypus* in Eastern Canada In "Population biology of seal worm *Pseudoterranova decipiens* in relation to intermadiate seal hosts", ed. W. D. Bowen. Can Bull. Fish. Aquat. Sci. 222: 185-197

Appendix 1

Data sheet

Date \ \94					Time			L. t			H. t				Site						
LAND								LeW							WATER						
	Re	**Al**	**W**	**Gr**	**Pl**	**Ag**	**tot**	**R**	**Al**	**W**	**Gr**	**Pl**	**Ag**	**tot**	**Bo**	**Al**	**swi**	**Pla**	**Ag**	**tot**	**To**
0																					
5																					
10																					
15																					
20																					
25																					
30																					
35																					
40																					
45																					
50																					
55																					
60																					
0																					
5																					
10																					
15																					
20																					
25																					
30																					
35																					
40																					
45																					
50																					
55																					
60																					

APPENDIX 2

Total number of common and grey seals counted simultaneously at the three sites A, B and C during the day and night at seal sands

Table I

Day Date	Commons	Greys
14-May	22	(4)
16-May	13	(1)
17-May	15	(0)
19-May	13	(0)
24-May	21	1
26-May	25	17
30-May	26	19
31-May	19	13
04-Jun	20	5
12-Jun	29	26
16-Jun	28	10
18-Jun	20	3
20-Jun	30	27
24-Jun	31	21
25-Jun	26	20
08-Jul	39	17
Night		
Date	Commons	Greys
25-May	15	7
27-May	9	13
07-Jun	14	2
09-Jun	9	2
22-Jun	13	10
24-Jun	10	26

* The Values in parenthesis are not included in the statistical analysis, to avoid spurious results.

APPENDIX 3

TABLE I

Values used for the correlation between number of common and grey seals and environmental variables. The values are the difference between the observed and the expected values.

Day DATE	D	Commons (O-E)	Greys (O-E)
14-May	1	6.08	*
16-May	3	3.59	*
17-May	4	1.93	*
19-May	6	4.61	*
24-May	11	1.67	-9.65
26-May	13	4.99	5.90
30-May	17	4.63	7.00
31-May	18	2.70	0.78
04-Jun	22	3.07	-8.10
12-Jun	30	3.2	11.11
16-Jun	34	0.83	-5.78
18-Jun	36	7.84	-13.22
20-Jun	38	1.47	16.32
24-Jun	42	1.10	3.43
25-Jun	43	4.23	2.21
Night			
25-May	12	2.80	-4.0
27-May	14	3.12	0.61
07-Jun	25	2.25	-11.05
09-Jun	27	2.682	-11.71
22-Jun	40	1.76	-4.37
24-Jun	42	1.172	10.97

TABLE II

Summary table of total number of common and grey seals and evironmental variables. Mean and Maximum temperature are ranked.

Day DATE	Day time Mean T.(°C)	Max T.	Water Level	Wind Speed	Comm.	Grey
14-May	7.92	8.62	0.9	2.61	21	1
16-May	8.15	8.9	1.5	3.95	13	0
17-May	8.5	9.65	1.4	3.75	15	0
19-May	9.2	10.18	1.3	4.04	13	1
24-May	9.4	10.6	0.6	3.73	25	17
26-May	9.48	10.2	1.2	2.04	28	10
30-May	12.28	13.2	1.1	3.56	22	4
31-May	12.62	13.7	1.7	4.44	20	5
04-Jun	14.72	15.37	1.4	5.62	20	3
12-Jun	14.96	16.6	1	2.23	29	26
16-Jun	15.98	17.05	1.3	4.21	19	13
18-Jun	16.82	18.12	1.2	4.92	30	27
20-Jun	17.8	19.28	1.1	3.85	26	19
24-Jun	18.6	20	0.6	3.73	31	21
25-Jun	20.3	21.72	0.5	2.88	39	20
Night	Night time					
25-May	4.76	6.04	0.9	1.08	9	13
27-May	7.87	8.52	0.7	2.25	15	7
07-Jun	11.05	12.02	1.3	5.17	9	2
09-Jun	13.52	14.56	0.9	3.76	13	10
22-Jun	13.96	15.05	1.5	3.38	14	2
24-Jun	16.2	17.3	0.9	1.07	10	26

TABLE III

Summery table of the observed and expected values and the difference between observed and expected values for common seals.

Day					Night				
Date	D	Observed value	Expected value	Difference (O-E)	Date	D	Observed value	Expected value	Difference (O-E)
14-May	1	22	15.911	6.089	25-May	12	15	12.192	2.808
16-May	3	13	16.593	-3.593	27-May	14	9	12.124	-3.124
17-May	4	15	16.934	-1.934	07-Jun	25	14	11.75	2.25
19-May	6	13	17.616	-4.616	09-Jun	27	9	11.682	-2.682
24-May	11	21	19.321	1.679	22-Jun	40	13	11.24	1.76
26-May	13	25	20.003	4.997	24-Jun	42	10	11.172	-1.172
30-May	17	26	21.367	4.633					
31-May	18	19	21.708	-2.708					
04-Jun	22	20	23.072	-3.072					
12-Jun	30	29	25.8	3.2					
16-Jun	34	28	27.164	0.836					
18-Jun	36	20	27.846	-7.846					
20-Jun	38	30	28.528	1.472					
24-Jun	42	31	29.892	1.108					
25-Jun	43	26	30.233	-4.233					
08-Jul	56	39	34.666	4.334					

TABLE IV

Summery table of the observed and expected values and the difference between observed and expected values for gey seals.

Day					Night				
Date	D	Observed value	Expected value	Difference (O-E)	Date	D	Observed value	Expected value	Difference (O-E)
24-May	11	1	10.653	-9.653	25-May	12	7	11.07	0.61
26-May	13	17	11.099	5.901	27-May	14	13	12.39	-11.05
30-May	17	19	11.991	7.009	07-Jun	25	2	13.05	-11.71
31-May	18	13	12.214	0.786	09-Jun	27	2	13.71	-4.37
04-Jun	22	5	13.106	-8.106	22-Jun	40	10	14.37	10.97
12-Jun	30	26	14.89	11.11	24-Jun	42	26	15.03	-15.03
16-Jun	34	10	15.782	-5.782					
18-Jun	36	3	16.228	-13.228					
20-Jun	38	27	16.674	10.326					
24-Jun	42	21	17.566	3.434					
25-Jun	43	20	17.789	2.211					
08-Jul	56	17	20.688	-3.688					

Appendix 4

Maximum number of seals hauled-out at the three sites, A, B and C

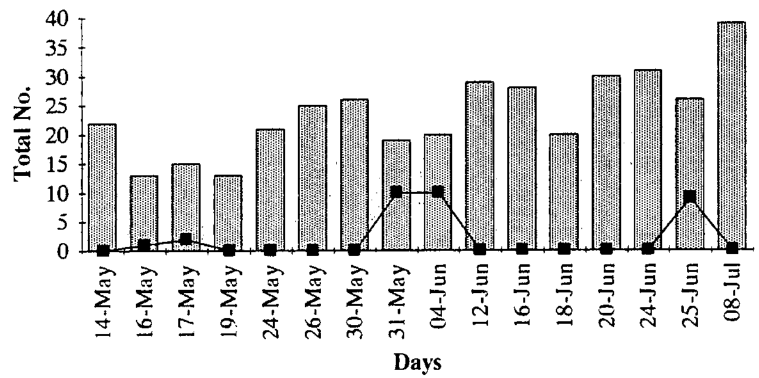

Fig. 5 a Maximum number of commonseals at site A during day time.

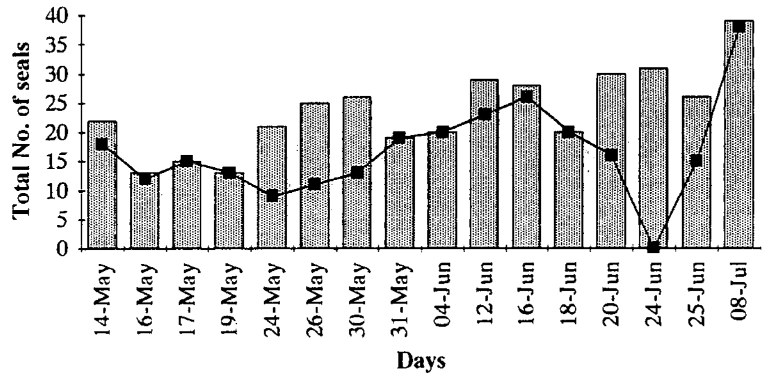

FIG. 5 b Maximum number of common seals at site B during day time.

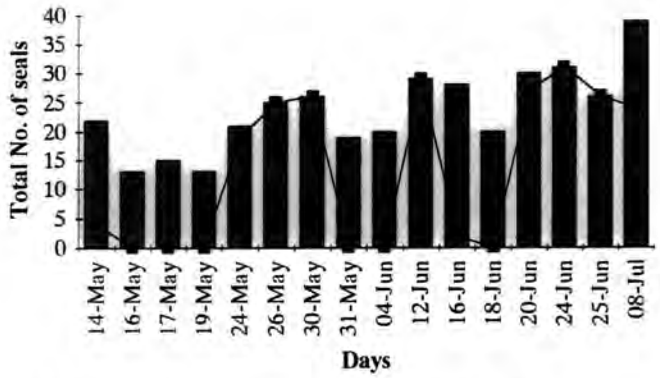

FIG. 5 c Maximum number of common seals at site C during day time.

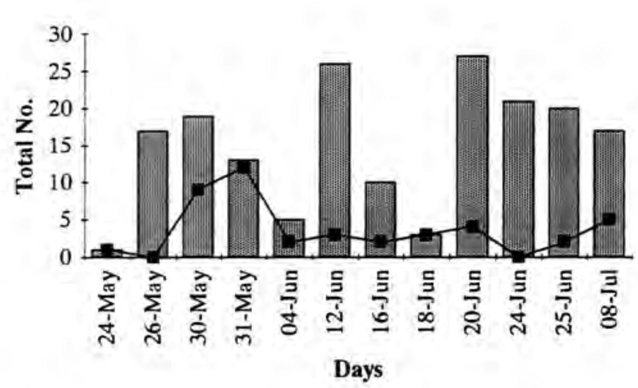

FIG 5 d Maximum number of grey seals at site B during day time.

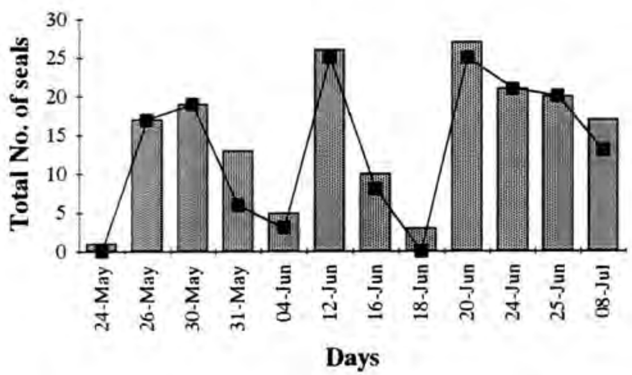

FIG. 5 e Maximumnumber of grey seals at site C during day time

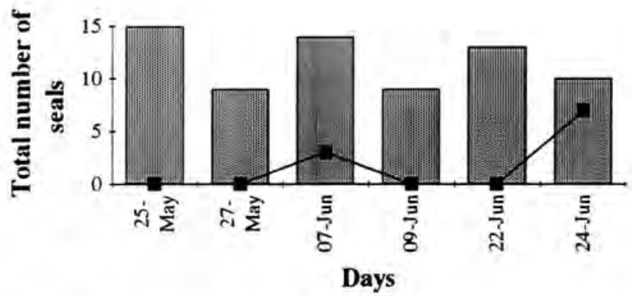

FIG. 5f Maximum number of common seals at site A during night time

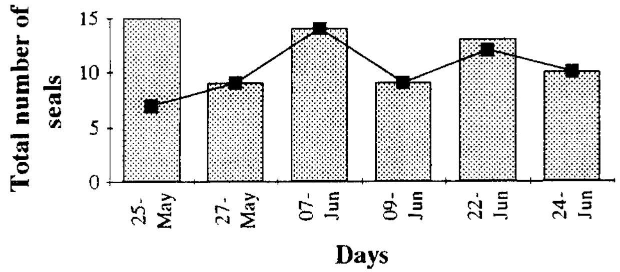

FIG. 5g Maximum number of common seals at site B during night time.

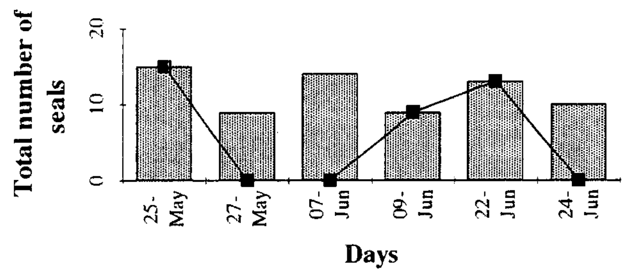

FIG. 5h Maximum number of common seals at site C during night time.

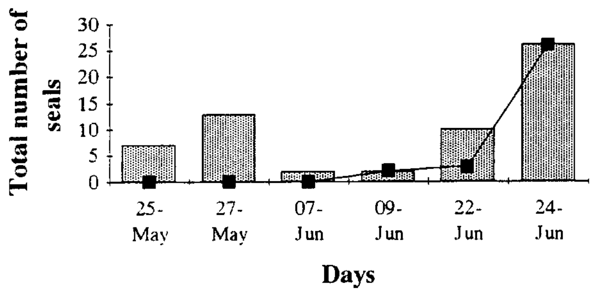

FIG. 5i Maximum number of grey seals at site B during night time.

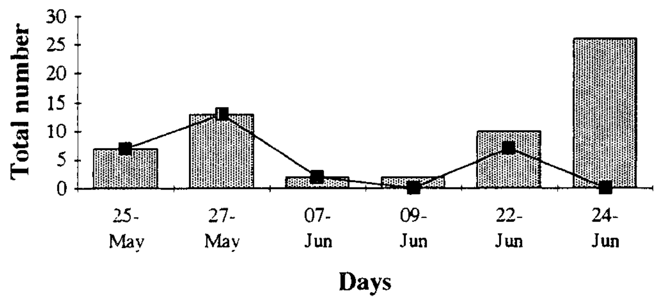

FIG. 5j Maximum number of grey seals at site C during night time.