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Arenaria interpres and purple sandpipers Calidris
maritima, in the pre-migratory period*

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THE ROOSTING AND FORAGING ECOLOGY OF TURNSTONES
Arenaria interpres AND PURPLE SANDPIPERS *Calidris*
maritima, IN THE PRE-MIGRATORY PERIOD.

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CONTENTS.

ABSTRACT.	1
LIST OF FIGURES.	2
LIST OF TABLES.	3
CHAPTER ONE : INTRODUCTION.	4
1.1 Questions to be investigated.	
1.2 Study aims.	
1.3 Study species.	
1.4 The study area.	
1.5 Literature review.	
CHAPTER TWO : METHODOLOGY.	18
2.1 Determination of feeding day length.	
2.2 Determination of feeding and vigilance rates.	
2.3 Analysis.	
CHAPTER THREE : RESULTS.	20
3.0 Utilization of West Harbour roost site.	
3.1 Roost site arrival and departure directions.	
3.2 Determination of feeding day length.	
3.3 Determination of feeding and vigilance rates	
CHAPTER FOUR : DISCUSSION.	51
BIBLIOGRAPHY.	59
APPENDICES.	62
1.1 Feeding site; foraging duration data.	
1.2 Numbers feeding through the tidal cycle.	
1.3 Median arrival/departure times at the feeding site.	
1.4 Roost site arrival/departure data.	
1.5 Roost site cumulative arrival/departure curves.	
1.6 Median arrival/departure times at the roost.	
1.7 Estimation of peck rates.	
1.8 Peck and vigilance data.	

ABSTRACT.

Many bird species need to accumulate fat deposits prior to long distance migration. The surplus energy required to achieve this can be obtained by increasing food intake. There are two main ways of attaining an increased food intake; by increasing feeding day length or by an increase in the rate of feeding.

The foraging and roosting behaviour of Turnstones, Arenaria interpres, and Purple Sandpipers, Calidris maritima, was studied in the spring pre-migratory period at Hartlepool, N.E. England. Adult Turnstone increase both their feeding day length and feeding rate. First year Turnstones show no lengthening of their feeding day and only a small increase in feeding rate, they do not undergo long distance migration so do not need to deposit fat. Purple Sandpipers do not exhibit an increase in their feeding day length, due to the availability of their feeding areas being strictly tidally controlled, and rely on an increased feeding rate alone to achieve fat deposition. Associated with the increased feeding rates is a reduction in time spent vigilant, suggesting a trade off occurs as increased time spent foraging becomes more beneficial.

The possible consequences of redevelopment of the West Harbour roost site are discussed and suggestions made for future study.

LIST OF FIGURES.

- FIG. 1. LOCATION MAP. 11
- FIG. 2. WEST HARBOUR ROOST COUNTS SPRING 1991. 21
- FIG. 3. DIRECTION OF ARRIVAL AND DEPARTURE AT WEST HARBOUR ROOST. 23
- FIG. 4. MEDIAN ARRIVAL TIMES AT THE FEEDING SITE AGAINST DATE: ADULT TURNSTONE. 25
- FIG. 5. MEDIAN ARRIVAL TIMES AT THE FEEDING SITE AGAINST DATE: FIRST YEAR TURNSTONE. 26
- FIG. 6. MEDIAN ARRIVAL TIMES AT THE FEEDING SITE AGAINST DATE: PURPLE SANDPIPER. 27
- FIG. 7. MEDIAN DEPARTURE TIMES FROM THE FEEDING SITE AGAINST DATE: ADULT TURNSTONE. 28
- FIG. 8. MEDIAN DEPARTURE TIMES FROM THE FEEDING SITE AGAINST DATE: FIRST YEAR TURNSTONE. 29
- FIG. 9. MEDIAN DEPARTURE TIMES FROM THE FEEDING SITE AGAINST DATE: PURPLE SANDPIPER. 30
- FIG. 10. MEDIAN ARRIVAL TIMES AT THE ROOST SITE AGAINST DATE: TURNSTONE. 33
- FIG. 11. MEDIAN ARRIVAL TIMES AT THE ROOST SITE AGAINST DATE: PURPLE SANDPIPER. 34
- FIG. 12. MEDIAN DEPARTURE TIMES FROM THE ROOST SITE AGAINST DATE: TURNSTONE. 35
- FIG. 13. MEDIAN DEPARTURE TIMES FROM THE ROOST SITE AGAINST DATE: PURPLE SANDPIPER. 36
- FIG. 14. FEEDING RATE REGRESSION PLOT ADULT TURNSTONE. 39
- FIG. 15. FEEDING RATE REGRESSION PLOT FIRST YEAR TURNSTONE. 40
- FIG. 16. FEEDING RATE REGRESSION PLOT PURPLE SANDPIPER. 41
- FIG. 17. VIGILANCE RATE REGRESSION PLOT ADULT TURNSTONE. 44
- FIG. 18. VIGILANCE RATE REGRESSION PLOT FIRST YEAR TURNSTONE. 45
- FIG. 19. VIGILANCE RATE REGRESSION PLOT PURPLE SANDPIPER. 46
- FIG. 20. PERCENTAGE OF OBSERVED TIME SPENT VIGILANT. 50

LIST OF TABLES.

- TABLE 1. ROOST SITE COUNTS SPRING 1991. 22
- TABLE 2. SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE FEEDING SITES WITH DATE.24
- TABLE 3. SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE PARTON ROCKS FEEDING SITE.24
- TABLE 4. SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE FEEDING SITES ON NEAP AND SPRING TIDES.31
- TABLE 5. KRUSKAL-WALLIS ANALYSIS OF VARIANCE FOR MEDIAN FEEDING TIMES.32
- TABLE 6. SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE ROOST SITE WITH DATE.32
- TABLE 7. SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE ROOST SITE ON NEAP AND SPRING TIDES.37
- TABLE 8. MANN WHITNEY U-TEST MEDIAN ROOST TIMES.37
- TABLE 9. FEEDING RATES CORRELATED WITH DATE.38
- TABLE 10. FEEDING RATES ON SPRING AND NEAP TIDES CORRELATED WITH DATE.42
- TABLE 11. ONEWAY ANALYSIS OF VARIANCE BETWEEN FEEDING RATE AND SPECIES/AGE CATEGORIES.43
- TABLE 12. VIGILANCE RATES CORRELATED WITH DATE.47
- TABLE 13. VIGILANCE RATES ON SPRING AND NEAP TIDES CORRELATED WITH DATE.47
- TABLE 14. ONEWAY ANALYSIS OF VARIANCE BETWEEN VIGILANCE RATE AND SPECIES/AGE CATEGORIES.48

CHAPTER ONE : INTRODUCTION.

Long distance migration in birds requires navigational abilities and physiological adaptations in relation to the storage and utilization of energy reserves. Costs are imposed by migration, the foremost being high metabolic rate during flight. These must however be outweighed by the benefits, ie abundant and easily available resources, to make migration worthwhile.

Arctic breeding birds have only a limited period in which to complete their breeding cycle. This places a premium upon early arrival at the breeding grounds and the rapid establishment of pairs on territories. Any late arriving individuals may be at a competitive disadvantage. Birds need to store enough fuel reserves for migration to their breeding areas. These reserves need to be accumulated at the correct time to enable individuals to synchronise their arrival with conspecifics. This means birds can compete fully for the available breeding resources and so maximise their possible breeding success. The possibility of bad weather upon arrival for Arctic migrants means that enough reserves need to be left over to enable birds to survive until feeding is possible. These facts place a premium upon accumulating fat reserves (ie sufficient fuel resources) prior to migration in anticipation of future needs.

In the non-breeding season a shorebird requires enough daily energy to serve three major purposes:-

- i) To maintain body temperature and normal metabolic rate.
- ii) To fly and move between roosting and feeding sites whilst avoiding potential predators.
- iii) To cover energy costs expended during foraging.

In the pre-migratory period fat deposition requires the acquisition of energy in surplus to the normal daily maintenance energy. The most likely way that surplus energy is gained is by increasing food intake, though it is possible that some energy could be "spared" for fat deposition by

reducing activity.

1.1 QUESTIONS TO BE INVESTIGATED.

The study reported in this dissertation examined how the surplus energy needed for fat deposition prior to long distance migration is obtained by two species of shorebirds. The two major means of increasing food intake and thereby acquiring surplus energy are:-

- 1) Feeding time: increasing food acquisition by lengthening the feeding day.
- 2) Feeding rates: acquiring more food by increasing the rate of food intake.

Shorebirds' feeding time is limited by a various factors. Feeding efficiency, i.e. rate of food acquisition, may be compromised if birds try to lengthen their feeding period. At either side of the low tide cycle, only relatively small feeding areas are exposed. Feeding bird densities will be high increasing competition for food and associated aggressive encounters. Prey densities tend to be lowest in the littoral zone nearest to the high tide line. This is the area in which the increase in feeding time would have to occur. The long exposure length of these areas means organisms tend to burrow deeper to avoid possible desiccation. These limitations would not apply if birds switched their feeding habitats and/or concentrated on different prey types. Feeding time is ultimately controlled by the tidal cycle but superimposed upon this is day length. For birds using visual hunting techniques feeding time is limited to periods on either side of low tide in daylight hours.

Feeding rates can vary depending on several factors (Evans 1976). The substrate type and condition (ie wet or dry) will determine the feeding technique employed, which prey species are present and how they are distributed. All these factors will affect the time it takes to find and eat an individual prey item. Weather, particularly wind and temperature, also influences prey availability. High winds will desiccate the

substrate (affecting prey depth and therefore availability), buffet the bird and disturb the water surface thus compromising prey searching techniques. Low and high temperatures can affect the activity and depth of prey. The motivational condition of the bird also affects its feeding rate: shorebirds tend to show higher peck rates on the ebb tide since this is when they are most hungry (ie after the high tide roost), and lower peck rates approaching high tide since they may be nearing satiation (Krebs 1980). However it may be that prey is more readily available on the ebb tide, i.e. density of available prey is higher, and so feeding rate is higher.

Optimum foraging strategy (Krebs 1987) predicts that an animal will maximise its rate of net energy gain by trading off search time (energy expended) against prey size profitability (energy gained per unit handling time). This means that as the search time for the optimum prey size increases a point is reached where it becomes more profitable to take prey of a non-optimum size, reducing and replacing energy expended in searching. However other selection pressures affect foraging producing a compromised optimal foraging strategy. This is less efficient in terms of net energy gain but is ultimately of greatest benefit by maximising overall fitness and survival. One of the most important factors producing the modified foraging strategy is predator avoidance (Krebs 1980). This results in an investment in vigilance time at the cost of time spent foraging, the two activities being mutually exclusive in many circumstances.

Optimum behaviour is a dynamic process. The relative costs and benefits are continually changing due to variations in the importance of the controlling selection pressures (McCleery in Krebs 1987). The increased importance of feeding prior to migration produces an alteration in the cost/benefit balance between foraging and predator avoidance. In theory foraging will be more beneficial and an increase in the foraging rate should occur at the expense of vigilance. This was found to

occur by Metcalfe (1984) in Turnstones *Arenaria interpres*, see 1.5 Literature Review.

1.2 STUDY AIMS.

This study investigated the roosting and foraging ecology of Turnstone *Arenaria interpres* and Purple Sandpipers *Calidris maritima* in the spring pre-migratory period. Observations were made on the times of arrival and departure of birds at their roosting and feeding sites; and peck and vigilance rates were measured while the birds were foraging (see Chapter Two Methodology). Using these data the study sought to show how both species obtained the increased food intake needed to lay down fat deposits prior to migration. I examined whether the two species used an increased feeding rate, a lengthened feeding day, or a combination of both these techniques to obtain the necessary surplus energy. I aimed to check if Turnstones in north eastern England employ the same technique to lay down fat for migration as those in western Scotland (Metcalfe & Furness 1984). No similar research has been carried out on *C.maritima*.

1.3 STUDY SPECIES.

Turnstone *Arenaria interpres*.

This species of migratory shorebird has a breeding range encircling the holarctic but divisible into five populations. Prater (1981) estimated that c.25 thousand Turnstones winter in Britain. These are mainly birds of the north western Palaearctic population, breeding in Greenland and north east Canada and wintering from the Irish and North Sea coasts southwards to Iberia.

Turnstones are present on their breeding grounds from late May and early June to early August (adults) or early September (juveniles). Birds start to arrive on their winter quarters from late July (adults) or August (juveniles), with the main influx occurring in August-September. British birds tend to return to the same wintering sites in subsequent years and within one winter are relatively sedentary (Branson et al.

1978; Clapham 1979). The available evidence suggest that Turnstones are not stressed in British winters and survival rates are high even under severe conditions. In contrast to most wintering shorebirds no marked fat deposition occurs in winter. Therefore it is in the period prior to migration that fat deposition becomes paramount.

Return passage occurs mostly in April to May. Evidence exists of a northwards movement of birds prior to the period of major fat deposition and departure for breeding grounds (Branson et al. 1978). Migration departure is preceded by excited calling and high flying by flocks of birds. The majority of first year birds remain in or near the wintering areas dispersing northwards, some do deposit fat and migrate to the vicinity of the breeding areas. The apparent synchronised arrival of birds back at their breeding areas may be explained by the migration of coherent wintering groups/flocks (Metcalf & Furness 1984).

Turnstone distribution is almost entirely coastal. They usually come inland only during the breeding season when they inhabit a thin coastal and insular band. In winter Turnstones are gregarious and sociable, forming close groups within flocks. Pre-roost are not usual but can occur. They roost communally, usually at well established sites. Individuals or groups of commonly 2-5 (up to 50) birds arrive 2.5 to 3 hours before high tide (Brearey 1982). Birds keep close together, sitting or standing, often in the open. Strong wind may disrupt the roost, forcing birds to seek the shelter of vegetation and hollows. Turnstones depart from the roost in small groups often feeding in the immediate vicinity. The most usual roost association is with Purple sandpiper, Dunlin *C.alpina* and Knot *C.canutus* (Cramp & Simmons 1983).

Turnstones are active feeders, using a multitude of methods. These include stone and object overturning, rolling seaweed mats, probing cracks, probe-jabs and surface pecking. They forage on a variety of substrates and catch a wide spectrum of prey types. In the breeding season the principal food types are insects, marine invertebrates and plants. Outside of the

breeding season they prey almost exclusively on marine invertebrates particularly Molluscs, Crustaceans and Annelids (Cramp & Simmons 1983).

Purple Sandpiper *Calidris maritima*.

Perhaps the most northerly distributed wader species, its breeding areas comprise Arctic Canada, Greenland and the Arctic islands of Russia. Birds winter as far north as possible provided that coasts remain ice free, i.e. south west Greenland and Norway. The southern limits of winter distribution extend only as far as Brittany and rarely Iberia. It is unknown whether lower latitude breeding birds move southwards and are replaced by those from higher latitudes. Alternatively leap-frog migration of high Arctic sub-populations might occur (Cramp and Simmons 1983). European wintering flocks include some birds originating from the northernmost breeding populations.

The majority of birds return to the North Sea wintering areas between October and November. In Scotland the appearance of early returning birds (from July onwards) represents the return of unmoulted adults. Juveniles start to appear from mid-September onwards (Atkinson 1981). Individuals frequently return to the same wintering area in successive years. Spring departure to the breeding areas occurs in April-May with northwards movement continuing through Scotland and Scandinavia during May. Female birds are capable of breeding in their first year. A high incidence of non-breeding pairs, and flocks comprising of non-breeding first year birds have been noted at the breeding grounds (Cramp and Simmons 1983).

The British wintering population is thought to be around fifteen thousand birds (Prater 1981), seventy five percent of which are to be found in Scotland. In England they exhibit a predominantly north eastern distribution, with all suitable habitat areas along the coast being occupied. The British summering population (non-breeding first years) maybe larger than thought since their distribution is concentrated on the remote northern coasts and islands of Scotland, and is

therefore difficult to measure (Prater 1981).

Purple sandpipers are gregarious outside the breeding season. Wintering flocks in Britain usually number less than twelve, but occasionally may comprise of 20-30 birds. Flocks aggregate to form large roosts. They are limited to sites with secure, disturbance free areas which remain uncovered by the highest spring tides. Roost sites are traditional and favour the seaward side of rocks, harbours and pier structures (Cramp & Simmons 1983). Roosting is tidally influenced and also nocturnal, since they are exclusively diurnal feeders. Departure from the feeding area to roost is often sudden and synchronised but departure from roost to feeding areas maybe gradual in groups of 10-15 birds. Feare (1966a) established that birds in north east England arrived at roost around one and a half hours before high water and departed approximately one and three quarters hours after it.

Food is predominantly invertebrates with some plant material being taken in the breeding season, outside of which they feed almost exclusively on invertebrates in the marine littoral zone. Molluscs are particularly important especially *Littorina*, *Lacuna*, *Nucella*, *Mytilus* and *Hydrobia* species (Cramp & Simmons 1983).

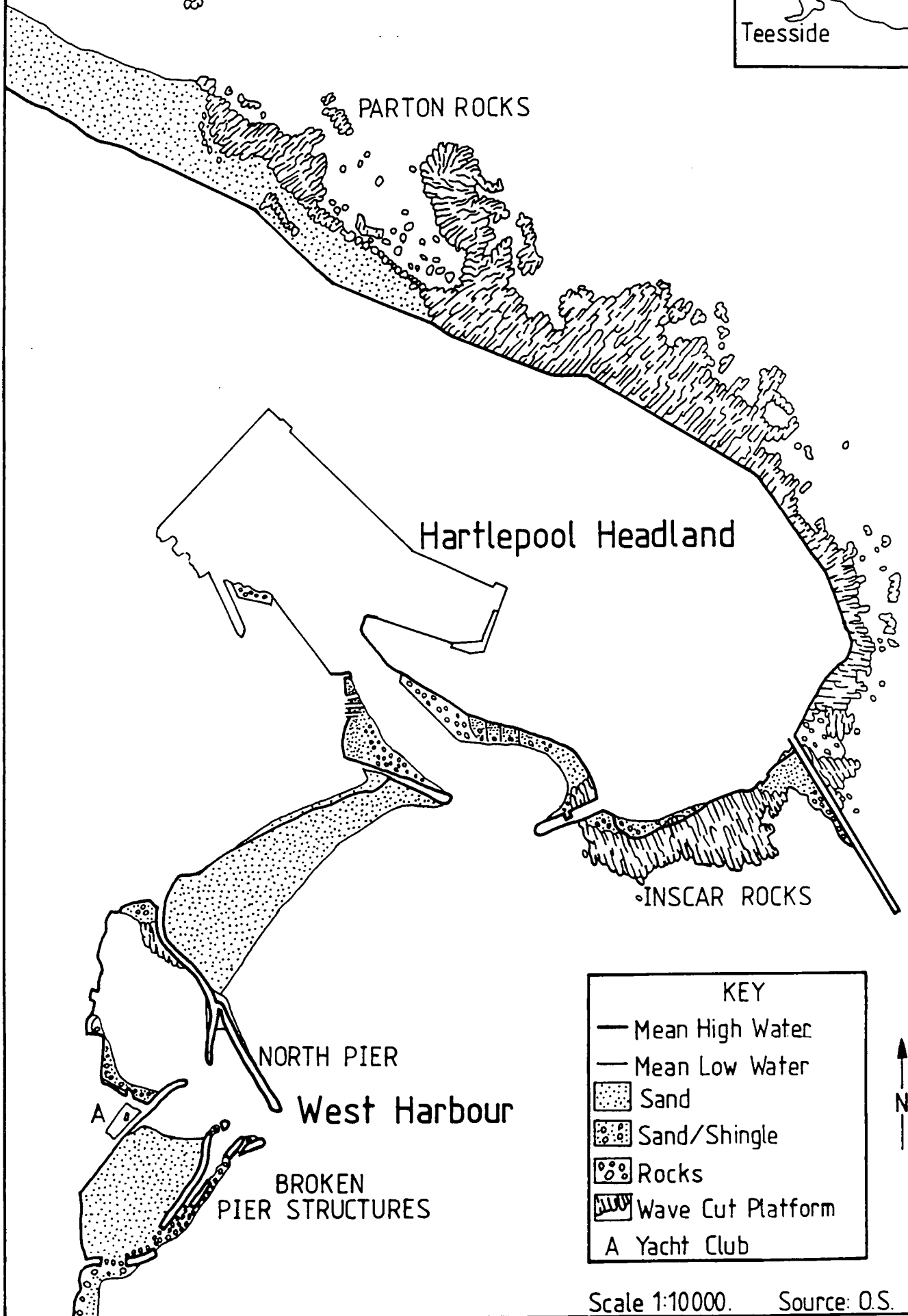
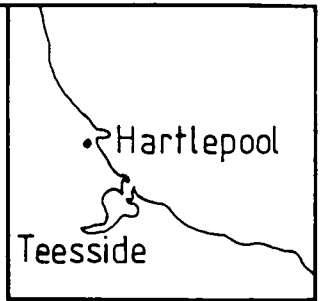
1.4 THE STUDY AREA.

The study took place at Hartlepool in north east England. Field research concentrated upon the main feeding and roosting locations in the Hartlepool area (Figure 1).

Hartlepool Headland (Grid Ref: NZ5334).

The headland consists of an outlying mass of Upper Permian magnesian limestone, joined to the mainland by a sand spit from the north west (Steers 1964). Sea wall defenses, backed by residential properties, protect the exposed headland from erosion and are fronted by magnesian limestone scars and wave cut platforms. Inside the bay area (Grid Ref: NZ532336) a small area of sand/shingle beach has developed in places, helped by a beach rejuvenation scheme. A similar situation

FIG. 1. LOCATION MAP.



KEY	
—	Mean High Water
—	Mean Low Water
[Stippled pattern]	Sand
[Stippled pattern with dots]	Sand/Shingle
[Pattern of circles]	Rocks
[Wavy line pattern]	Wave Cut Platform
A	Yacht Club



Scale 1:10000. Source: O.S.

exits on the north eastern side of the headland with a variable amount of sand covering the wave cut platform below the sea wall.

The headland forms the main feeding area for this study, being rich in marine rocky shore invertebrates. Field observations were focused in the bay area (Grid Ref: NZ532336) and on the north east side of the headland at Parton rocks (Grid Ref: NZ524345).

West Harbour (Grid Ref: NZ5233).

The broken stone and wooden pier structures at West Harbour made an ideal high tide roost site for a variety of wader species. Their importance lay in the fact that they offered a safe, disturbance free roost (being cut off from the mainland through the high tide cycle) well above the level of the highest spring tides. The structures were a long standing roost site for Turnstones and Purple sandpipers (County of Cleveland Bird Report 1974).

Recent redevelopment (summer-autumn 1991) of the area into a joint marina and housing scheme meant the demolition of the old pier structures (Grid Ref: NZ519328). They were replaced by an artificial island, comprising of interlocking stone blocks, which offers an equivalent safe high tide roost site, and a new outer southern pier which is linked to the shore and therefore liable to disturbance over the high tide period. The possible effects of this development on the quality of the area as a roost site remain to be seen.

In Cleveland the only other regularly used, sizeable, Turnstone roosts are situated at South Gare (in a small harbour Grid Ref: NZ 556280) or on nearby Bran Sands (Breary 1982 see 1.5 Literature review). Low numbers of both species roost on the outflow pipes at Steetly Magnestite (Grid Ref: NZ508352) but usage appears to be limited to neap tides when enough of the structures remain uncovered to provide a viable roost site.

1.5 LITERATURE REVIEW.

The papers summarised concentrate on aspects of vigilance/feeding rates and roost behaviour of the study species. Groves (1978) studied age related differences in the foraging and aggressive behaviour of Turnstones in autumn on the Massachusetts coast. The observed differences between adult and juvenile foraging rates (number of pecks) and success level (number of prey items eaten) on different substrates was found to be statistically significant. Overall, juveniles were not as adept as adults at procuring food. Their inefficiency was attributed to their lack of experience in searching, extracting, and handling prey items. Juveniles did not compensate for the lower quantity of prey obtained by increasing their foraging time. Foraging inefficiency of juveniles may play a major role in their higher level of mortality in comparison to adult birds. The observed disparities between adults and juveniles diminished over time as they gained experience, juveniles developed better foraging proficiency.

Metcalf (1984a) studied the effects of habitat visibility on vigilance behaviour of Turnstones and Purple Sandpipers in the Firth of Clyde (western Scotland). In habitats which reduced visibility, ie structurally complex ones, both species were found to increase their rate of vigilance.

Increased vigilance was achieved in each species by different means. Turnstones lengthened the duration of each scan while Purple Sandpipers scanned more often. This would seem to be the more effective method since it reduces the interscan interval and lowers the probability that a predator can move from a hidden to an attack position undetected. This is based on the assumption that brief scans are as effective as long scans in assimilating information, irrespective of the degree of visibility. This might apply for Purple Sandpipers but not for Turnstones. An alternative explanation for the difference in methods employed is that the short interscan intervals result in foraging being frequently interrupted. Therefore feeding efficiency may be compromised for prey with

long handling times. Turnstones often feed on prey which requires protracted manipulation time, eg. *Balanus* and *Carcinus* spp. Increasing their scanning rate as a means of heightening overall vigilance would therefore compromise efficient foraging. Purple sandpipers specialise on prey requiring shorter handling times, eg. *Littorina* spp., enabling a frequent scanning rate to be used since it does not effect foraging efficiency.

In mixed species flocks Metcalfe (1984b) found that both *A.interpres* and *C.maritima* shared vigilance with other wader species. The extent to which vigilance is shared depended upon two factors:-

i) Relative size of the other species. Sharing occurred commonly with species of a similar size since they possess similar predators.

ii) Extent of habitat overlap with the other species. Vigilance was shared the most with species they most frequently associate with.

The extent to which vigilance was reduced in mixed species aggregations depended more on visible rather than on actual density. Vigilance in Turnstones was reduced most, as would be expected, in the presence of conspecifics, to a lesser extent by Purple Sandpipers and less still by Redshank *Tringa totanus* and Oystercatcher *Haematopus ostralegus*. Vigilance reduction in Purple Sandpipers was most in the presence of conspecifics and to a lesser extent in the presence of Turnstones; the effect of other species being negligible. They increase their vigilance in the presence of gulls *Larus* spp. which represent moving obstructions and to avoid being trodden on.

The level of vigilance was reduced by altering both the scan duration and the rate of scanning. In both Turnstones and Purple Sandpipers scanning rate increases as density drops. This increase is not maintained below a density of five birds within 10m. Vigilance is increased by increasing scan duration. Scan duration remains relatively constant at

densities over five but increase sharply below it until a constant of approximately 0.37 seconds is reached. This time period presumably represents the minimum time needed to take in all the relevant information from a scan.

Mecalfe and Furness (1984) studied the change in priority between foraging and vigilance, in Turnstone, prior to migration. They found that vigilance decreased in direct proportion to increasing adult bird density in both winter and in the period prior to migration. However the overall vigilance level between the two periods was significantly different ($P > 0.001$) with vigilance lower prior to migration. In juveniles vigilance rates remained constant, at the winter level, in the pre-migratory period of adults.

This difference they explained as a shift in optimal behaviour. Resource accumulation acquires an increased priority, due to the future benefit that it brings breeding adults. The majority of juveniles (first years) do not undergo long distance migration and so do not benefit from such a trade off. Therefore their feeding and vigilance rates remain unchanged. They represent a control against which the pre-migratory behaviour of adults can be assessed. The fact that a constant level of vigilance is maintained by juveniles confirms that it is the migratory urge which promotes the change in adults.

The trade off of vigilance for the accumulation of fat produces an increase in the proportion of the time spent foraging at the expense of time spent vigilant. This trade off produces an increased risk of predation which must be outweighed by the future benefits it accrues migrating adults. Metcalfe and Furness (1984) suggested that to compensate for their need to reduce vigilance adult birds might be expected to form denser flocks, since vigilance decreases with increasing density. However an increase in aggression levels, feeding interference and alteration of home ranges to encompass such flocks would inhibit their formation. A second strategy might be for adults to seek out the juveniles since their vigilance remains unaltered. However they form only

around fifteen percent of the population and should avoid association with adults who contribute less to flock vigilance.

Brearey (1982) studied the feeding ecology and foraging behaviour of Sanderling *Calidris alba* and Turnstone at Teesmouth. The study focused primarily upon the south side of the river. Turnstones confined their feeding activities to an area between South Gare and Saltburn and used two roost sites. The main roost site was at a small harbour on South Gare and a subroost on Bran Sands. The main roost site was sheltered, especially from cold/strong onshore winds, and had easy, rapid, access to the first feeding areas exposed. The roost may have served as a place where information transfer could occur, with individuals radiating out from the roost following birds with knowledge of good feeding sites.

Juvenile birds were seen roosting with adults along Coatham Sands but were rarely seen at the main roost. Two possible explanations Brearey suggested were:-

i) That juveniles may continue to feed elsewhere over high water. Due to their inefficient feeding techniques juveniles may need to increase time spent foraging to meet daily energy requirements.

ii) Juveniles are not tolerated by adults at the main roost.

Turnstones left the roost, watched by Brearey, approximately two hours after high tide, as soon as adjoining rocks became exposed. Successive waves of 2-20 birds, usually ten or less, departed. This pattern reversed after low water with birds arriving to roost 2.5 to 3 hours before high water. The time of return to roost was dependant upon a variety of factors. Birds arrived earlier on spring tides. When strong wind and wave action ripped-up species of Phaeophyceae (Brown seaweeds ie. Kelp and Wracks) and Mussels (*Mytilus* spp.) depositing them on the shore. These provide rich sources of food. When wracks occurred, and in particular when Kelp flies (Coelopidae) were emerging, Turnstones, even those utilising

regular feeding rocks, moved to the beach to exploit them. During these episodes it was not uncommon for the majority of birds to start to roost 2-3 hours before midday high water. During fly-emergence periods birds would sometimes remain feeding or roosting on the beach over the high tide period. In gales birds concentrated their feeding to areas near to the roost site. Interestingly, when wind retarded tidal movement back up the beach birds still left on schedule for the roost site.

CHAPTER TWO : METHODOLOGY.

The study period lasted from the 10th of April to the 1st of June 1991. Observations were made using 10x40 binoculars and a 15-60x60 telescope which was replaced by a better quality 15-45x60 model towards the end of the study. Most observations at the start of the study were made from the open but later observations, where practical, were made from a car.

2.1 Determination of feeding day length.

Two methods were used to determine the length of feeding day, one concentrated on the feeding area and the other on the roost site.

1) Feeding site observations.

To determine the duration of foraging, scans of the feeding area were made every fifteen minutes and the total number of birds present and numbers feeding recorded. Observations were made on both Turnstones, separating adults from first years, and Purple Sandpipers (Appendix 1.1). Graphs were plotted of numbers feeding at different stages of the tidal cycle, with low tide used as time zero (Appendix 1.2). The times at which fifty percent of the maximum number present had arrived at or departed from the feeding area were identified (Appendix 1.3). These median times of arrival and departure were then graphed against date.

2) Roost site observations.

Turnstones and Purple Sandpipers were counted, and the time and roost position noted, as they arrived at and departed from the West Harbour roost site (Appendix 1.4). Observations were made from either the end of the north pier or from near the yacht club head quarters (Fig. 1). The separation of adult and first year Turnstone proved impracticable due to the speed, paths of approach and the considerable distances sometimes involved, which when combined gave observations of limited time and low quality. The data were used to plot cumulative percentage arrival and departure curves with zero representing high water (Appendix 1.5). The median arrival and departure times (Appendix 1.6) were then graphed against date.

2.2 Determination of feeding and vigilance rates.

A focal bird was chosen and watched for a period of five minutes, the minimum time required to produce a reliable estimation of peck rate. (This was established by plotting the running mean of the peck rate against the duration of observation (Appendix 1.7), with birds watched for up to 10 minutes. A reliable minimum observation time is one after which no large fluctuations in the mean peck rate occur (Townsend 1982)). During the five minute periods the number of pecks made were counted using a tally counter and the amount of time spent vigilant cumulatively recorded on a stop watch to the nearest half second (Appendix 1.8).

The five minute period was timed using an LCD parking meter alarm. On a few occasions a personal dictophone was used to record observations, the tape later being transcribed. Also recorded for each five minute period were the time of observation and the substrate type on which the bird was feeding. Observations were made on Turnstones and Purple Sandpipers. Feeding, vigilance rates (seconds per minute) and percentage of time spent vigilant were plotted against date. Records were discounted from focal birds disturbed during the observation period since this produces a strong bias in the levels of vigilance and peck rate recorded.

2.3 Analysis.

The data sets were analysed using the Statistical Package for the Social Sciences (SPSS PC version) computer program (Nie et al 1975). Data for adult and first year Turnstones was analysed both seperately and jointly, producing an overall species result and adult to juvenile comparisons. Data which fulfilled the criteria were analysed using parametric statistics, namely regression analysis and one way analysis of variance of feeding and vigilance rates. The median arrival and departure times for both feeding and roosting sites were analysed using Spearman's rank correlation, Mann-Whitny U tests and Kruskal-Wallis analysis of variance (ie. non-parametric tests), because of the small number of data points and uncertainty over whether or not they were normally distributed.

CHAPTER THREE : RESULTS.

3.0 Utilization of West Harbour roost site.

The roost counts of Turnstones and Purple Sandpipers are shown in Fig. 2 and Table 1 Turnstone numbers increased from 252 on April 1st reaching a maximum of 449 by April 29th. Numbers roosting at West Harbour dropped to only 43 on May 1st due to bad weather conditions but rose again, fluctuating at between c.120-200 until May 16th, after which numbers declined until only nine birds were present on May 29th. An influx of birds occurred at Seal Sands in late May.

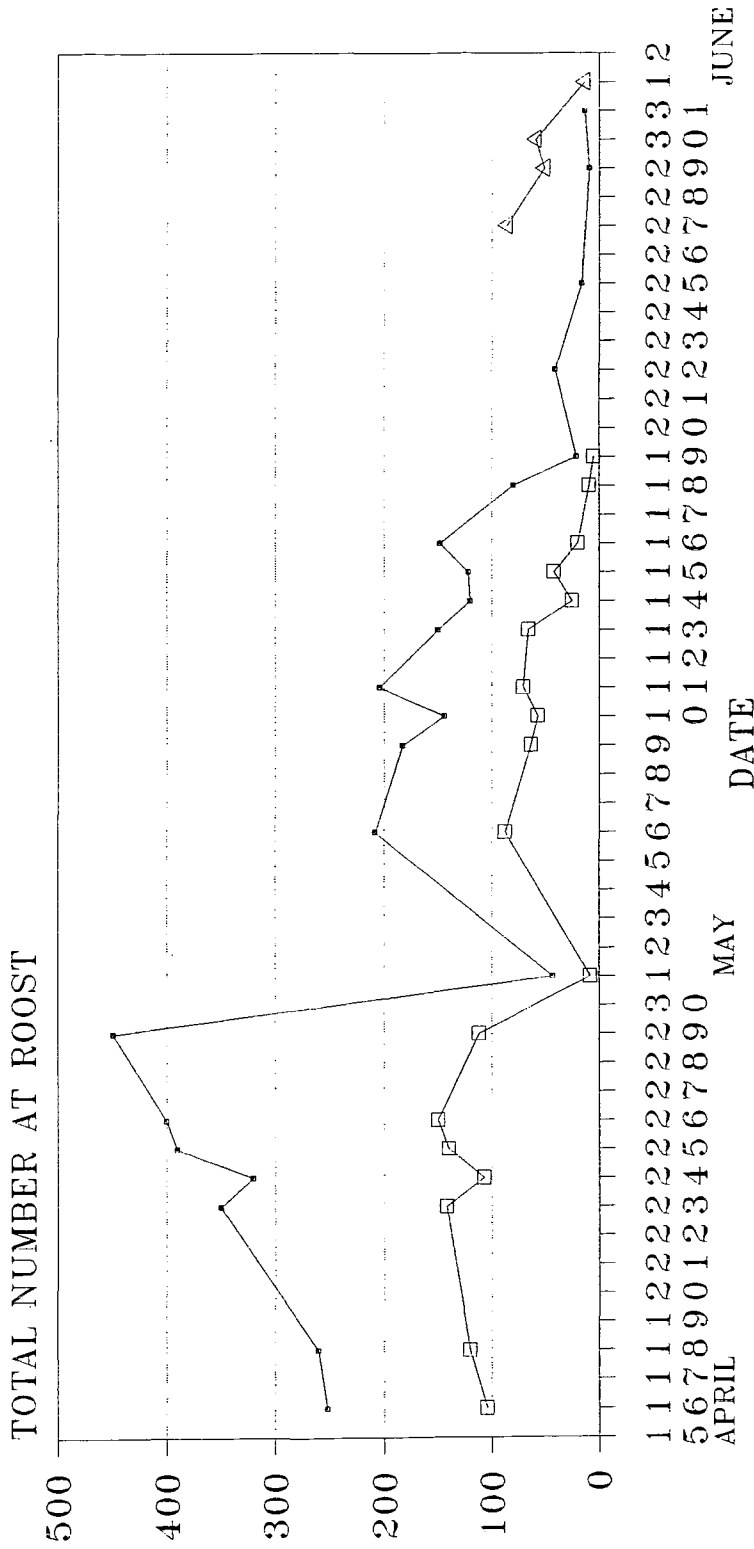
Purple Sandpiper numbers fluctuated at between c100-150 birds throughout April with a sharp fall, as with Turnstones, on May 1st. After this the number of birds varied from 55-88 individuals until May 14th when numbers roosting dropped to 25 birds, increasing to 42 the next day. Numbers then declined rapidly to only five birds on the May 19th after which no more were seen at the roost site.

3.1 Roost arrival and departure directions.

Most of the Turnstones using the West Harbour roost arrived from and departed to the Hartlepool Headland feeding area to the north (Fig 3). On the 16th April and 11th May, however approximately 50% of birds arrived from each direction and the majority of birds arrived from the south on the 1st, 15th and 16th May. Approximately 50% of turnstones departed in each direction on the 25th of April, but on other dates the majority of birds were observed departing to the north. On the 16th May, although 60% of roosting Turnstones arrived from the south, on departure the majority of birds (88%) left to the north, but this included migratory flocks of approximately 43, 28 and 26 birds which departed northwards at height.

The majority of Purple Sandpipers arrived and departed to the north of the roost site. Usually, at most, 30% (often less than 10%) of birds arrived or departed southwards. The only exceptions to this were on the 11th and 15th May when approximately 50% of birds arrived from each direction. The first date coincided with equal numbers of Turnstones arriving from each direction.

FIG. 2. WEST HARBOUR ROOST SITE COUNTS
TURNSTONE AND PURPLE SANDPIPERS.



SPECIES & LOCATION
 T. STONE — P. SAND — T. STONE G. CREEK
 DATE AND NUMBERS OF OBSERVED TURNSTONE MIGRATION
 8 May - @40 16 May - @63 18 May - 8+
 1 May = Bad Weather

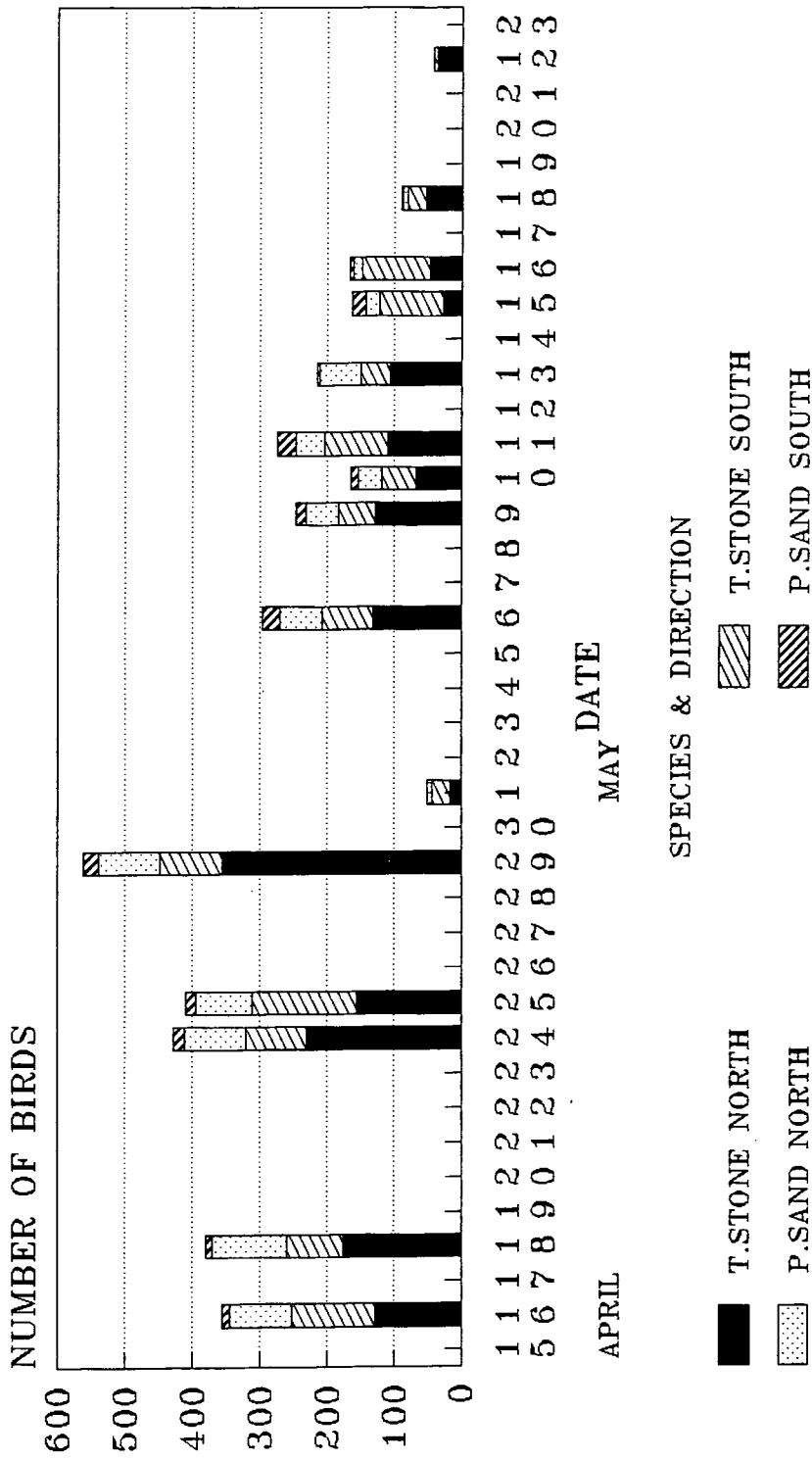
TABLE 1. WEST HARBOUR ROOST COUNTS SPRING 1991.

DATE	P.SAND	T.STONE	OCATCH	KNOT	SDLING	BTGOD
16APRIL	104	252	164	40		
18APRIL	120	260	207	15		
23APRIL	142	350	200	2		
24APRIL	107	320	193	3	2	
25APRIL	140	390	216	6		
26APRIL	150	400	-			
29APRIL	112	449	212			
1MAY	8	43	115			
6MAY	88	208	-			
9MAY	64	183	160			2
10MAY	57	144	200		2	2
11MAY	71	204	154		1	
13MAY	66	150	142			
14MAY	25	120	-			
15MAY	42	122	117		4	
16MAY	20	165	73	1		
18MAY	9	80	71	3	2	
19MAY	5	21	89			
22MAY		41	102			
25MAY		16	77			
29MAY		9	48			
*29MAY		51				
*30MAY		59				
*1JUNE		13				

* Denotes Greatham Creek high tide counts.

P.SAND = Purple sandpiper, T.STONE = Turnstone, OCATCH = Oystercatcher, SDLING = Sanderling, BTGOD = Bar-tailed Godwit.

FIG. 3. DIRECTION OF ARRIVAL & DEPARTURE
 AT WEST HARBOUR ROOST
 TURNSTONES AND PURPLE SANDPIPERS



ROOST DEPARTURE DATES
 25 APRIL 6, 9 & 10 MAY

3.2 Determination of feeding day length.

i) Feeding site data.

The median arrival and departure times at the feeding sites were analysed in relation to date using Spearman rank correlation for adult and first year Turnstone separately, for Turnstone as a whole and for Purple sandpiper. The null hypothesis was that no change occurs in the median time of arrival/departure at feeding site with date. Data plots are shown in Figs. 4-9.

TABLE 2
SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE FEEDING SITES WITH DATE.

SPECIES/AGE	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	16	-.1183	.331	18	.1701	.500
T.STONE ADULT	8	-.4762	.116	9	.1667	.334
T.STONE 1YR	8	.2143	.610	9	.1333	.732
P.SAND	5*	-.3000	.312	5*	.6000	.285

n = Number of observations.

r = Spearman rank correlation coefficient.

s = significance level.

* = less than the minimum required sample size.

The null hypothesis has to be accepted, no species or age shows a significant difference in the median time of arrival/departure with increasing date. In the case of Purple sandpipers less than the acceptable minimum number of seven sampling days could be tested invalidating the result.

Spearman rank correlations were then carried out on the same data set but utilizing only the data from the Parton Rocks feeding area, upon which feeding studies concentrated.

TABLE 3
SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE PARTON ROCKS FEEDING SITE.

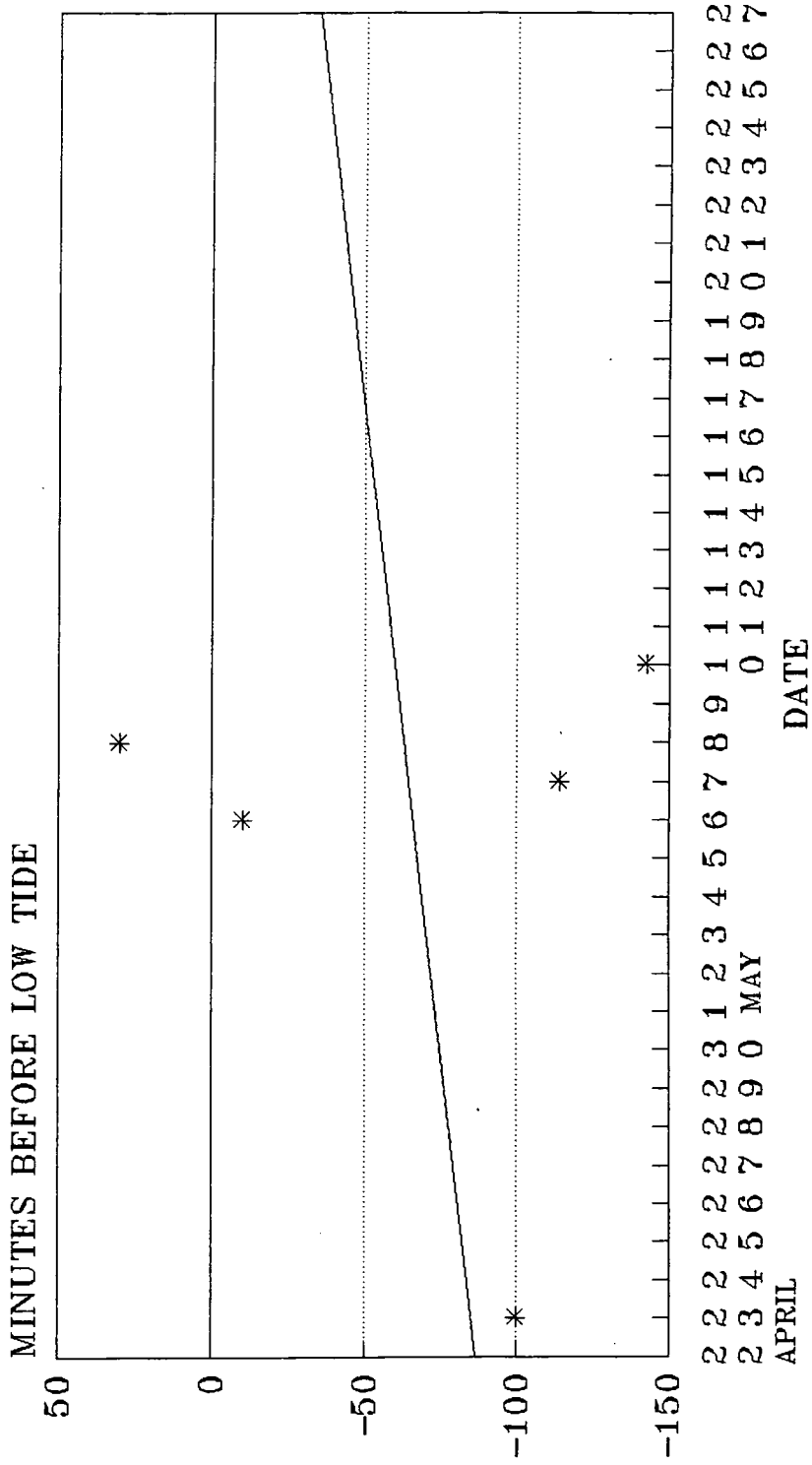
SPECIES/AGE	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	14	-.3278	.126	14	.6120	.010
T.STONE AD	7	-.4643	.147	7	.7500	.026
T.STONE 1YR	7	-.1786	.702	7	.4286	.186
P.SAND	4*	-.4000	.300	4*	.2000	.400

r = Spearman rank correlation coefficient.

s = significance level.

* = less than the minimum required sample size .

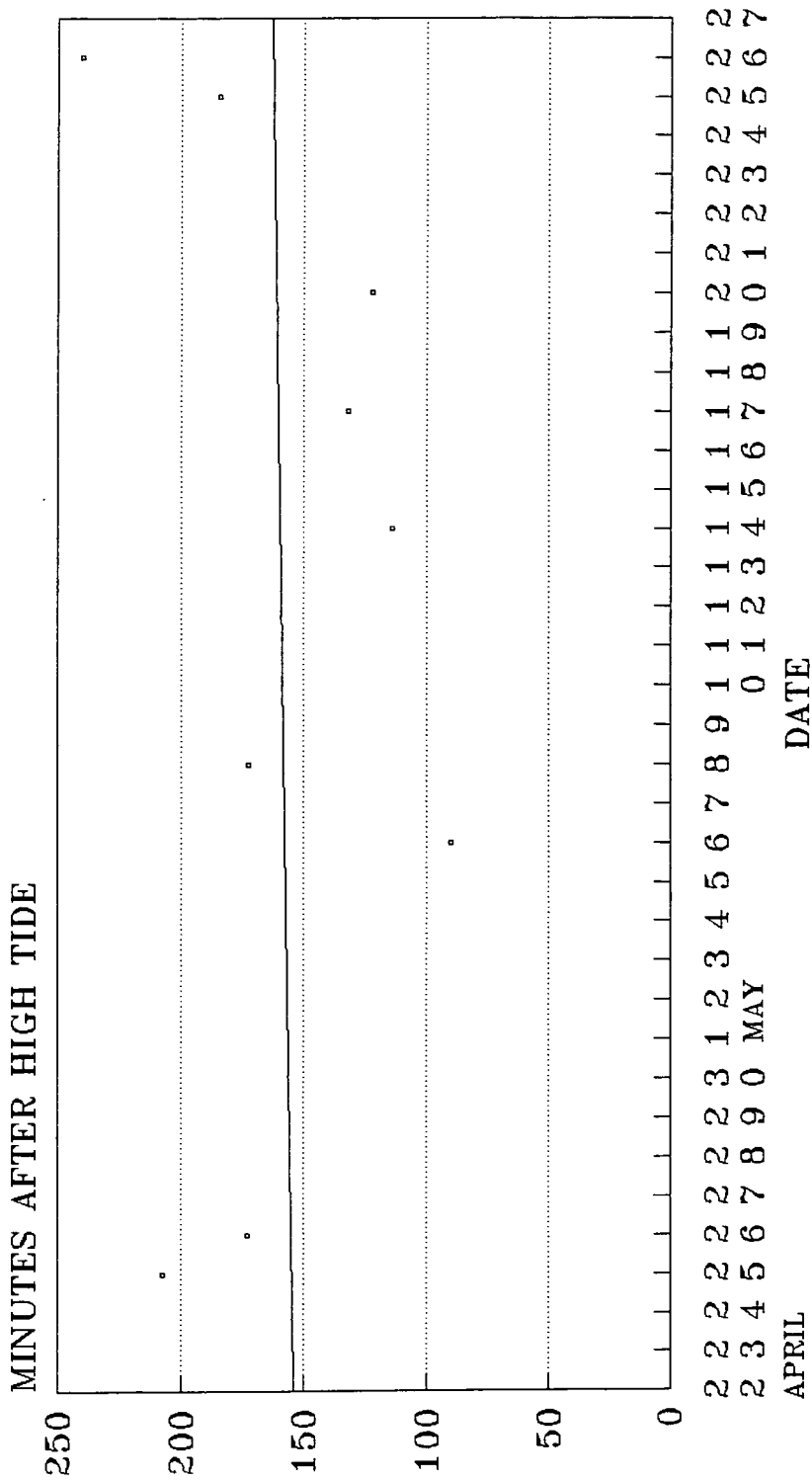
FIG. 6. MEDIAN ARRIVAL TIMES AT THE FEEDING SITE AGAINST DATE.



* P.SANDPIPER

LOW TIDE=0 MINUTES.

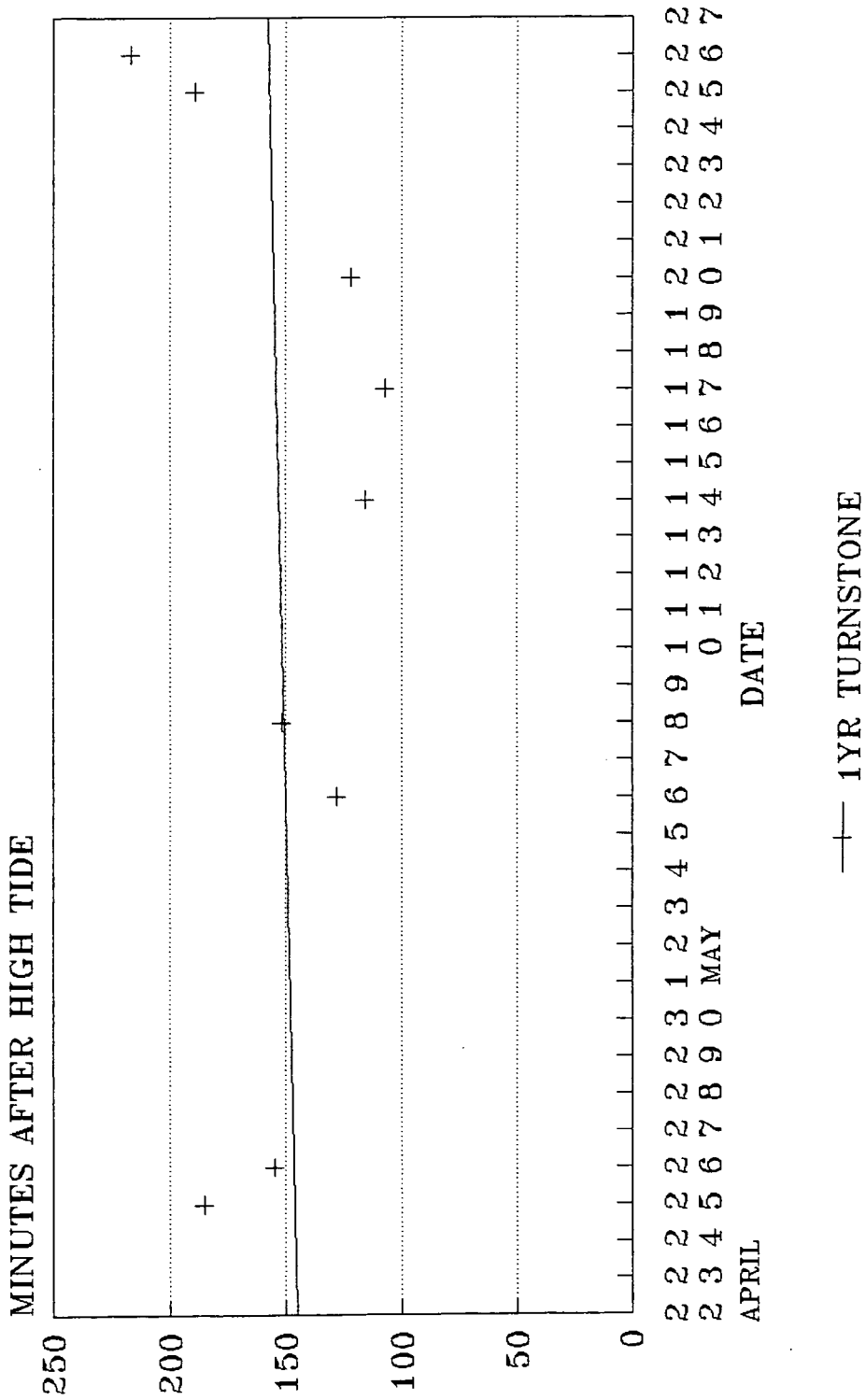
FIG. 7. MEDIAN DEPARTURE TIMES FROM THE FEEDING SITES AGAINST DATE.



— ADULT TURNSTONE

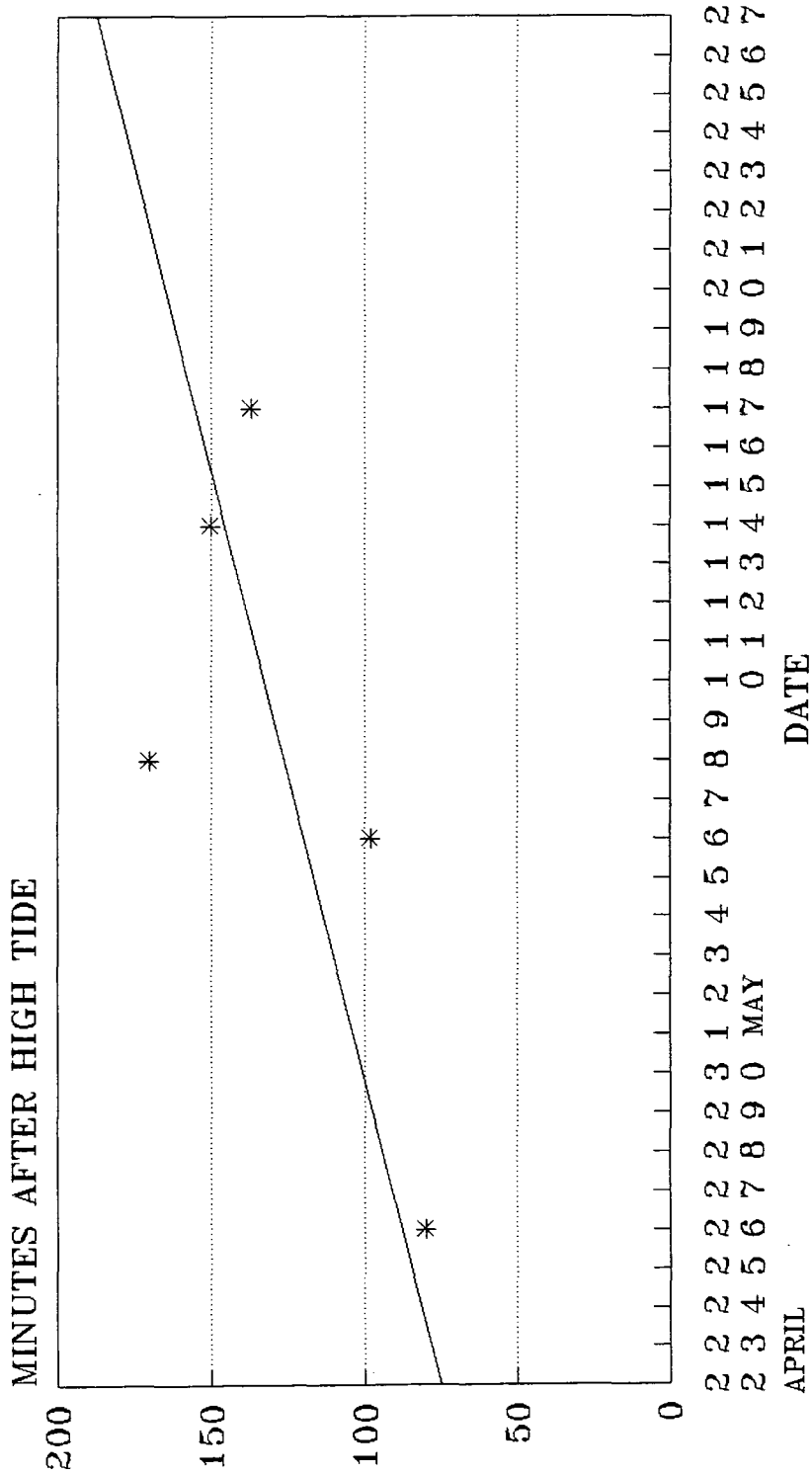
LOW TIDE=0 MINUTES.

FIG. 8. MEDIAN DEPARTURE TIMES FROM THE FEEDING SITES AGAINST DATE.



LOW TIDE=0 MINUTES.

FIG. 9. MEDIAN DEPARTURE TIMES FROM THE FEEDING SITES AGAINST DATE.



*— P.SANDPIPER

LOW TIDE=0 MINUTES.

The null hypothesis can be rejected for the departure times of Turnstones and adult Turnstone. These show significantly later times of departure in late than in early May. In all other cases the null hypothesis has to be accepted. The test is not valid for Purple Sandpipers which have less than the required number of sample days for the test.

The 50% arrival/departure times were also analysed against date for spring and neap tides separately (spring tides taken as equal to or greater than 4.8 metres, neap equal less than 4.8 meters). Spring tides cover more of the feeding areas and therefore should effect feeding times.

TABLE 4
SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE FEEDING SITES ON NEAP AND SPRING TIDES.

NEAP TIDES.

SPECIES/AGE	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	12	.2860	.105	6*	.0000	.500
T.STONE AD	6*	.1429	.393	3*	.5000	.333
T.STONE 1YR	6*	.5429	.133	3*	-.5000	.333
P.SAND	5*	-.3000	.312	2*	1.0000	.500

SPRING TIDES.

SPECIES/AGE	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	4*	-0.4472	.276	12	.3392	.140
T.STONE AD	2*	-1.0000	.500	6*	.2571	.312
T.STONE 1YR	2*	-1.0000	.500	6*	.4286	.198
P.SAND	-	-	-	3*	.5000	.333

r = Spearman rank correlation coefficient.

s = significance level.

* = less than the minimum required sample size.

In all cases except two, the minimum number of sampling points needed to use the test was not reached. Turnstones did not show a significant difference in median arrival and departure times at the feeding site for either spring or neap tides so the null hypothesis has to be accepted.

The Kruskal-Wallis analysis of variance (distribution free) was carried out on the median arrival/departure times at the feeding areas for each species/age categories. The null hypothesis was that no significant difference exist's between the group mean arrival/departure times of adult and first year Turnstones and Purple sandpipers.

TABLE 5
KRUSKAL-WALLIS ANALYSIS OF VARIANCE FOR MEDIAN
FEEDING TIMES.

	K-W	SIG
ARRIVAL	4.73	.0939
DEPARTURE	1.85	.3945

The results are not significant at the 0.05 rejection level so the null hypothesis has to be accepted.

ii) Roost site data.

The median arrival and departure times at roost were analysed by date using Spearman rank correlation for adult and first year Turnstones, Turnstones and Purple sandpipers. The null hypothesis was that no change in median arrival/departure time in relation to high water occurs with increasing date. Data plots are shown in Figs. 10-13.

TABLE 6
SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE
TIMES AT THE ROOST WITH DATE.

SPECIE/AGE	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	14	.5077	.032	7	-.7500	.026
P.SAND	10	-.0973	.155	5*	-.9000	.019

r = Spearman rank correlation coefficient.

s = significance level.

* = less than the minimum required sample size.

The null hypothesis has to be accepted for arrival times of Purple sandpipers (departure result is not valid). For both arrival and departure times of Turnstones however the null hypothesis can be rejected (significance < 0.05) and the alternative hypothesis accepted that times change significantly with date. Turnstone arrival times expressed as minus values (minutes before high tide) are positively correlated with date; therefore birds arrive closer to high tide as date increases. Departure times (minutes after high tide) are negatively correlated with date. Birds therefore left sooner after high tide as date increased.

FIG. 10. MEDIAN ARRIVAL TIMES AT THE
ROOST SITE AGAINST DATE.

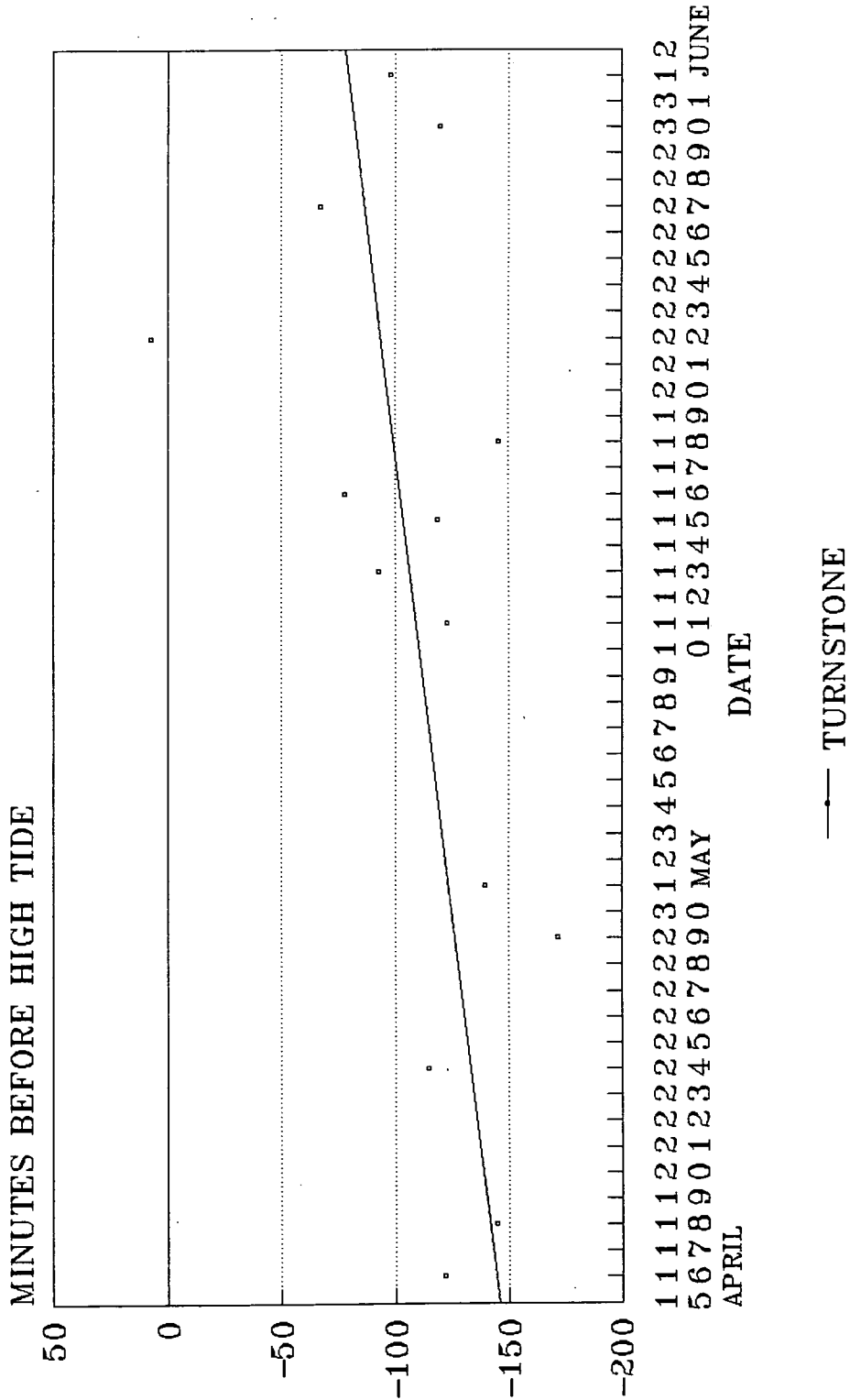
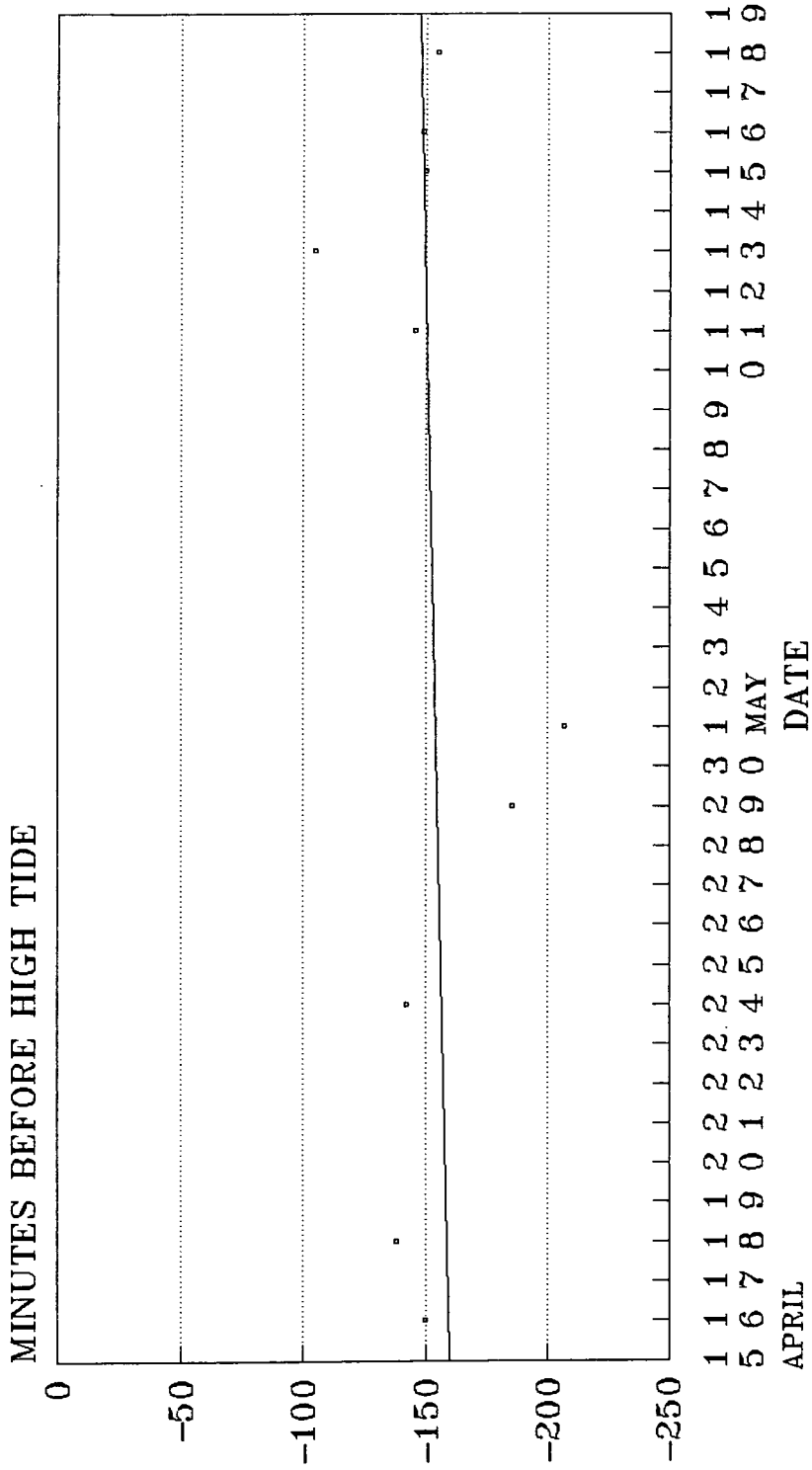


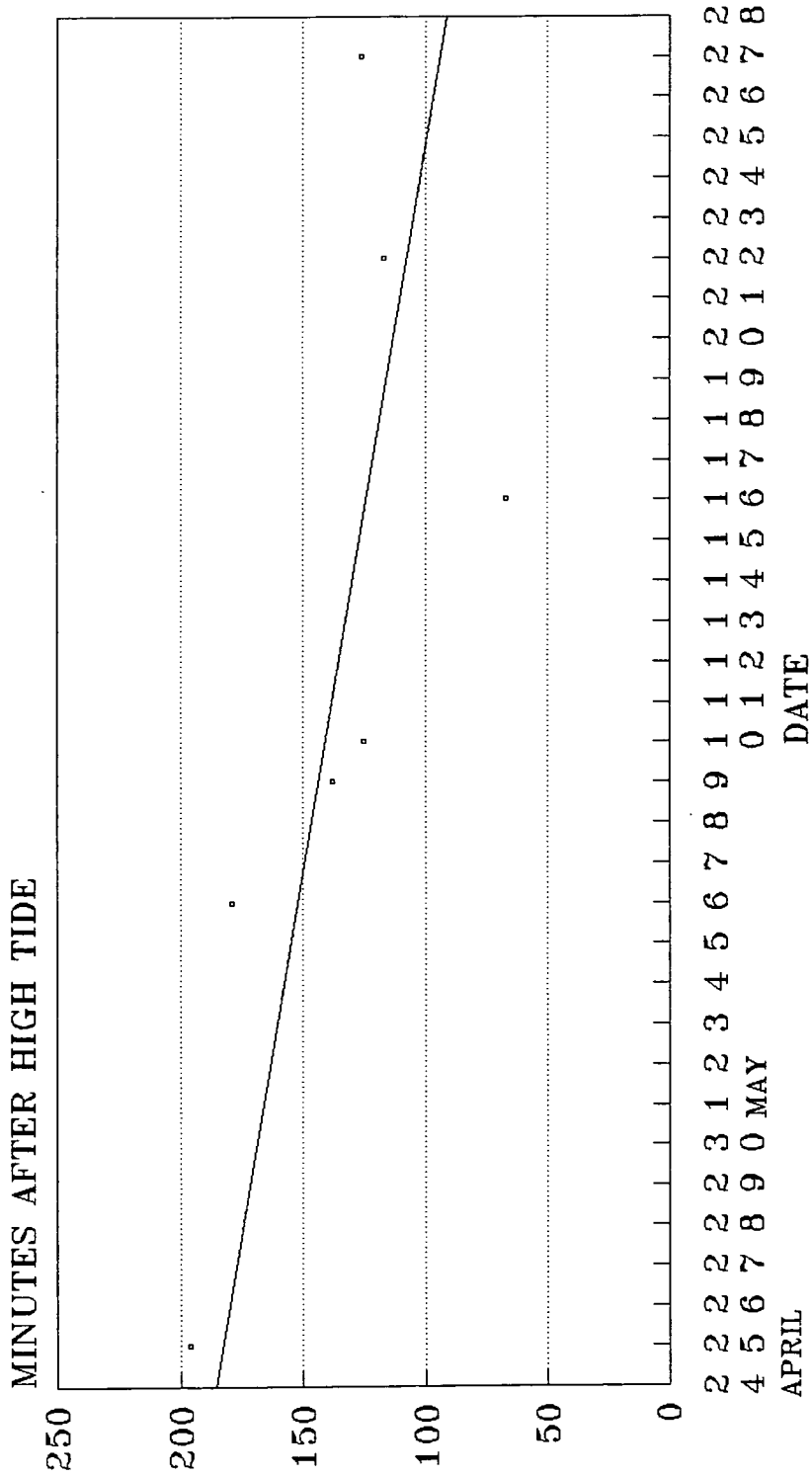
FIG. 11. MEDIAN ARRIVAL TIMES AT THE
ROOST SITE AGAINST DATE.



— P. SANDPIPER

HIGH TIDE = 0

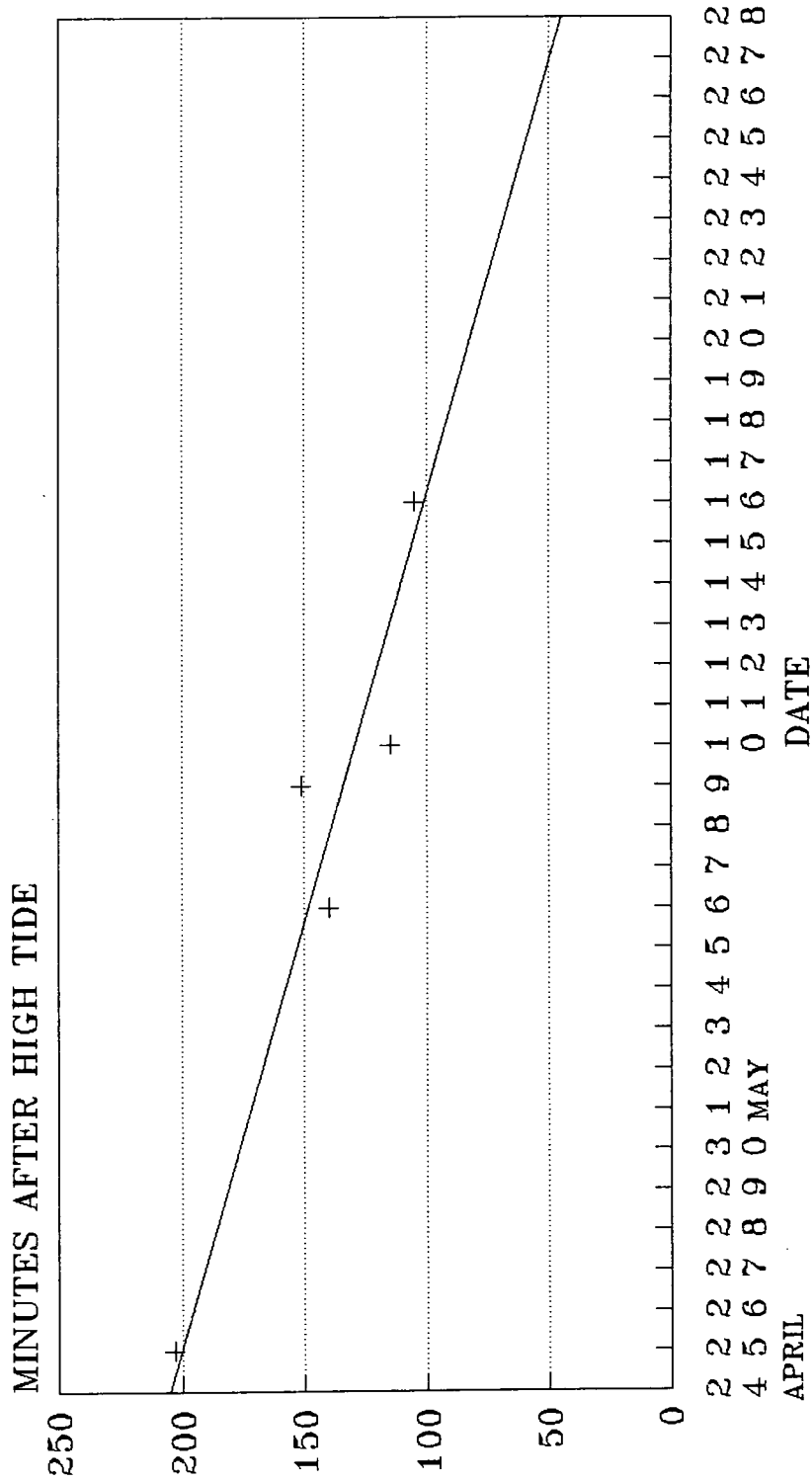
FIG. 12. MEDIAN DEPARTURE TIMES FROM THE
ROOST SITE AGAINST DATE.



—•— TURNSTONE

HIGH TIDE = 0

FIG. 13. MEDIAN DEPARTURE TIMES FROM THE ROOST SITE AGAINST DATE.



+— P. SANDPIPER

HIGH TIDE = 0

The data was then reanalysed for spring and neap tides (using 4.8 metres as the cut-off height see 2) feeding site data) which may influence times of arrival/departure.

TABLE 7
SPEARMAN RANK CORRELATIONS OF MEDIAN ARRIVAL AND DEPARTURE TIMES AT THE ROOST ON NEAP AND SPRING TIDES.

NEAP TIDES.

SPECIES	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	3*	.5000	.333	4*	-1.000	.000
P.SAND	1*	-	-	3*	-0.500	.333

SPRING TIDES.

SPECIES	ARRIVAL			DEPARTURE		
	n	r	s	n	r	s
T.STONE	11	.5000	.058	3*	-0.500	.333
P.SAND	9	.0167	.483	2*	-1.000	.500

r = Spearman rank correlation coefficient.

s = significance level.

* = less than the minimum required sample size.

The null hypothesis has to be accepted for Turnstone and Purple Sandpiper arrival on spring tides. Without the inclusion of neaps with spring tides (as in Table 6) the arrival and departure times of Turnstones show no correlation with date.

A Mann Whitney U-test (distribution free) was applied to the median roost arrival/departure times of Turnstones and Purple Sandpiper. Null hypothesis is that no difference exists between the two species.

TABLE 8
MANN WHITNEY U-TEST MEDIAN ROOST TIMES.

	U	PROB
ARRIVAL	23.5	.0065
DEPARTURE	16.0	.8075

The null hypothesis is rejected for arrival, but can be accepted for departure when a significant difference in times

of the two species does occur.

3.3 Determination of feeding and vigilance rates.

i) Feeding rates.

Feeding rates of adult and first year Turnstones, Turnstones and Purple Sandpipers were correlated (product moment correlation coefficient) against date to determine if any relationship exist's between peck rate and date. The feeding (peck) rate was first transformed to log10. Regression plots of the data are illustrated in Figs. 14-16.

TABLE 9
FEEDING RATES CORRELATED WITH DATE.

SPECIES/AGE	n	r	rsq x100	sig
T.STONE	180	.39294	15.44	.0000
T.STONE AD	105	.45497	20.70	.0000
T.STONE 1YR	75	.38640	14.93	.0006
P.SAND	48	.48885	23.89	.0004

r = product moment correlation coefficient.

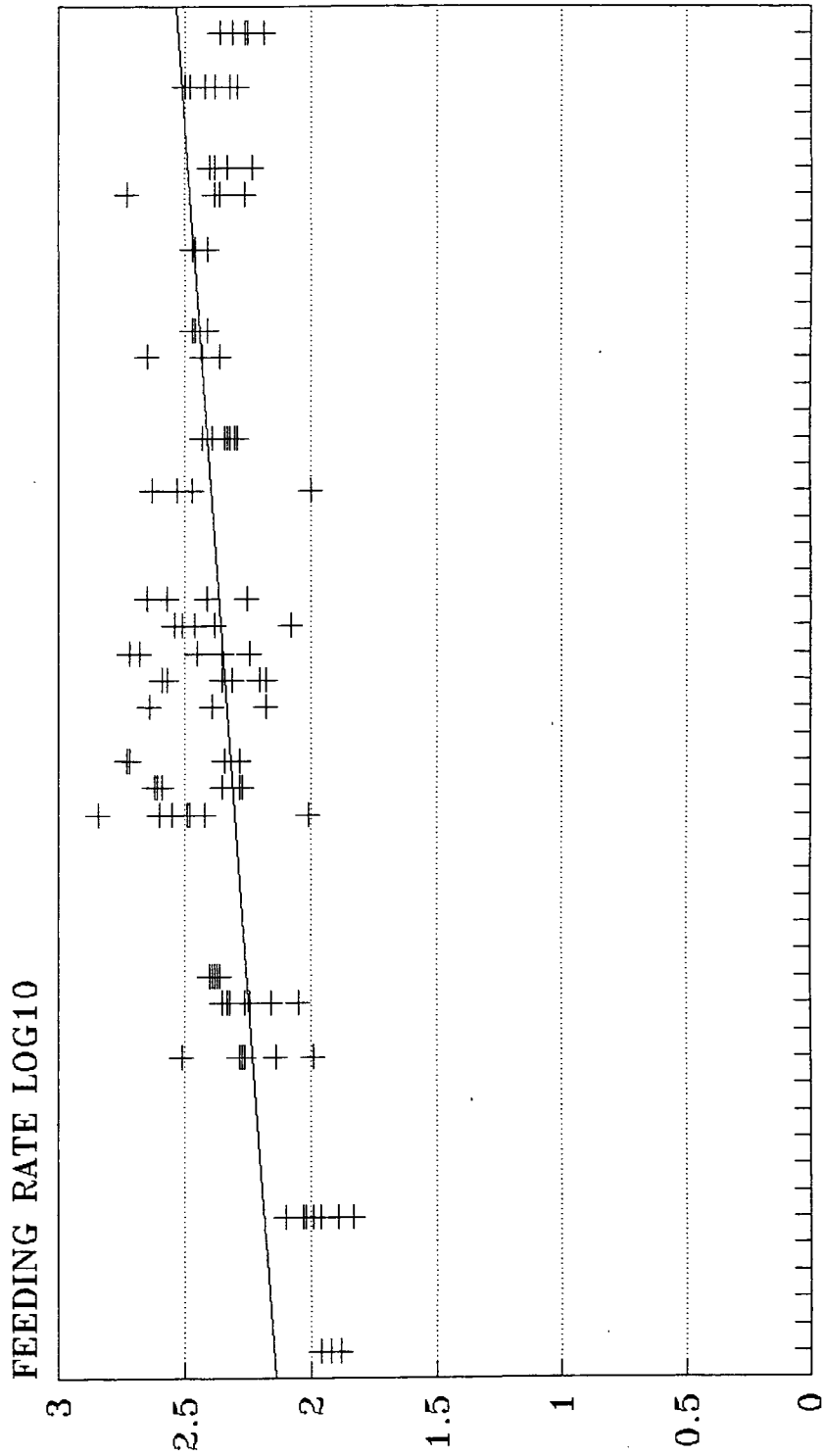
sig = significance level.

rsq x100 = r squared (coefficient of determination) multiplied by 100. This expresses as a percentage the amount of variance explained.

The results show that feeding rates became progressively faster with increasing date, all categories (species/age) being less than 0.05 significant. The amount of variation explained by date is highest for Purple Sandpiper (23%) in comparison to 15% for Turnstones. This low percentage is due mainly to the effects of first year (14%) in the combined species data set. Adult Turnstones show a 20% feeding rate variation, explained by date, approaching that shown by Purple sandpipers.

The log transformed feeding data were then analysed for spring and neap tides; heights equal to or over 4.8 meters were classed as springs and less than 4.8 as neaps. The difference in tidal height/range between springs and neaps may effect the quality of feeding available so influencing feeding rates.

FIG. 14. FEEDING RATE REGRESSION PLOT
ADULT TURNSTONE.



1111111122222223123456789111111112222222223312
 01235678901234567890 MAY 012346789012345678901 JUNE
 APRIL DATE

FIG. 16. FEEDING RATE REGRESSION PLOT
PURPLE SANDPIPER.

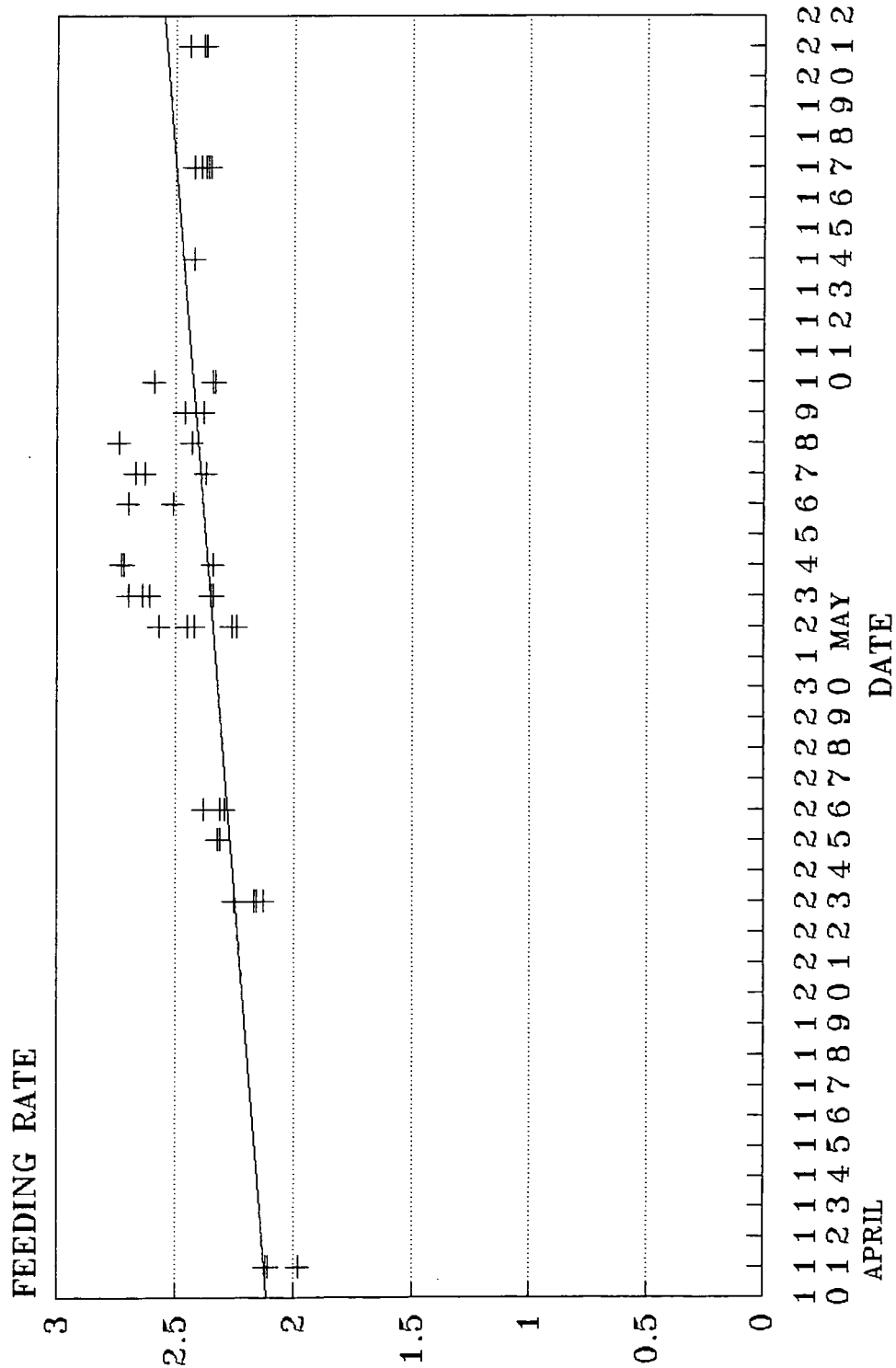


TABLE 10
FEEDING RATES ON SPRING AND NEAP TIDES CORRELATED
WITH DATE.

SPP/AGE	SPRING				NEAP			
	n	r	rsq x100	sig	n	r	rsq x100	sig
TSTONE	123	.39628	15.70	.0000	57	.44178	19.51	.0006
TS AD	74	.48679	23.69	.0000	31	.46063	21.21	.0091
TS 1YR	49	.38060	14.48	.0000	26*	.45260	20.48	.0203
PURP	23*	.17095	2.92	.4354	25*	.72450	52.49	.0000

SPEARMAN RANK

TS 1YR					26	.437	sig <0.05
PURP	23	.331	not sig	0.05	25	.605	sig <0.01

r = product moment correlation coefficient.

sig = significance.

rsq x100 = r squared (coefficient of determination)

multiplied by 100. This expresses as a percentage the amount of variance explained. * = borderline sample size.

On both spring and neap tides all the results show significant positive correlation between feeding rates and date with the exception of Purple Sandpipers on spring tides. This is not apparent in the combined data set (Table 9). Sample sizes less than thirty are borderline for product moment correlation (Fowler & Cohen 1986) so Spearman rank correlation was also applied. Purple Sandpiper feeding on spring tides was again found not to be significantly correlated with date (>0.05). Turnstones, including adults and first years, appear to increase their feeding rate over the study period. The amount of variation in peck rate explained by date shows little difference between adults (21%) and first year birds (20%) on neap tides. Greater difference occurs on spring tides with first year Turnstone variance (explained) being only 14% compared to 23% in adults. Although Purple Sandpipers show no correlation on spring tides they do for neap tides with the amount of variance explained being over 50%.

The feeding rates between the species/age categories were analysed using oneway analysis of variance (ANOVA) to establish if any significant difference in feeding rate exists

between species. A Tukey test was used to show groups differing within the 0.05 significance level.

TABLE 11
ONEWAY ANALYSIS OF VARIANCE BETWEEN FEEDING RATE
AND SPECIES/AGE CATEGORIES.

SOURCE OF VARIATION	SUM SQ	DF	MEAN SQ	F RATIO
BETWEEN	315102	2	157551	14.5249
WITHIN	2440574	225	10846	
TOTAL	2755676	227		

(SUM SQ = sum of squares, DF = degrees of freedom, MEAN SQ = mean squares).

F PROB = .0000

Tukey test - groups different at 0.05 level=

Adult from first year Turnstone.

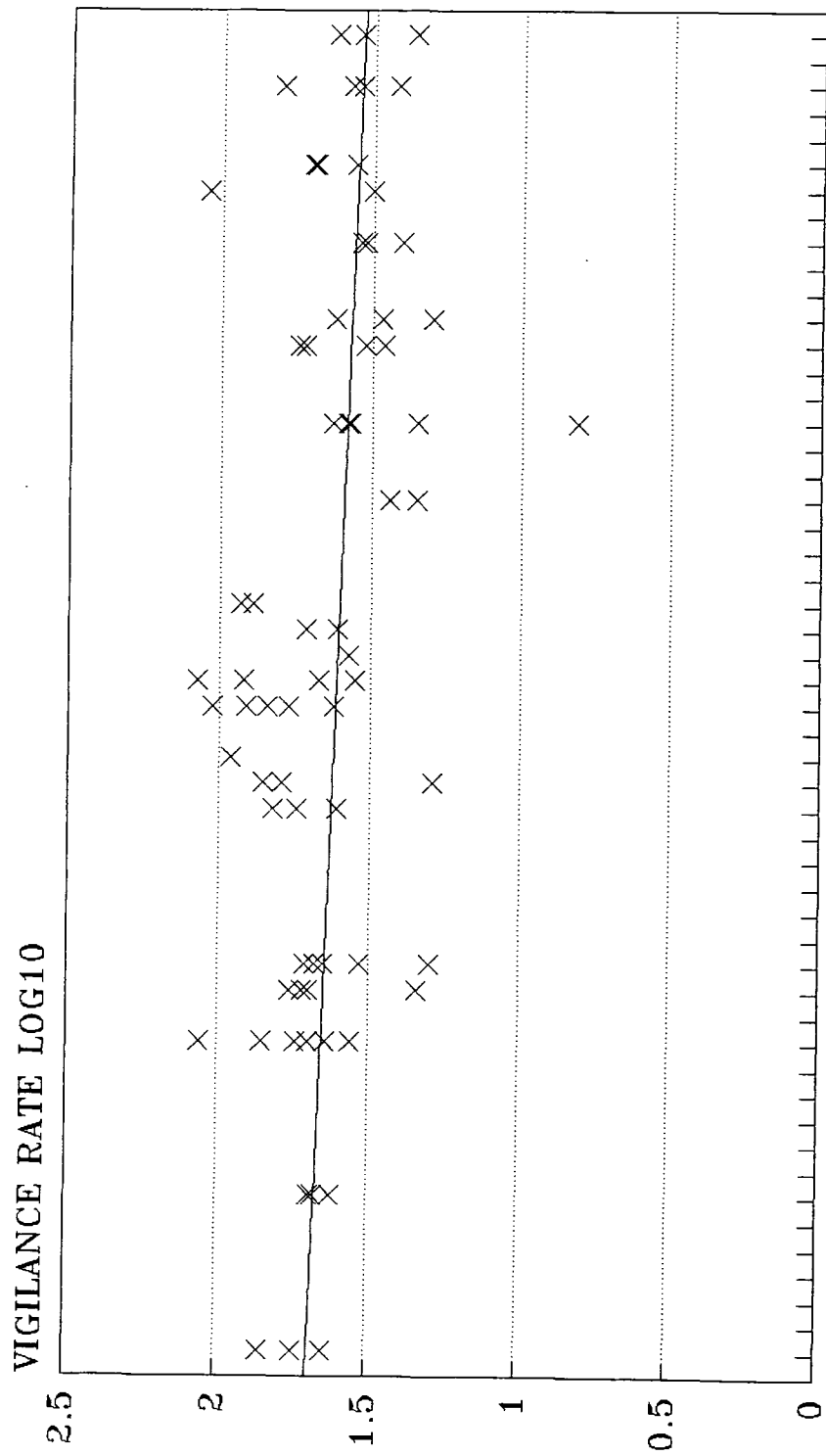
Purple Sandpiper from first year Turnstone.

Both adult Turnstone and Purple Sandpiper feeding rates differ significantly from those of first year Turnstones which exhibit a much lower mean (176 per five minutes) and maximum range (398). No significant difference exists between the feeding rates of adult Turnstone and Purple Sandpiper. Both show broadly similar means of 241 and 272 pecks per five minutes respectively.

ii) Vigilance rates.

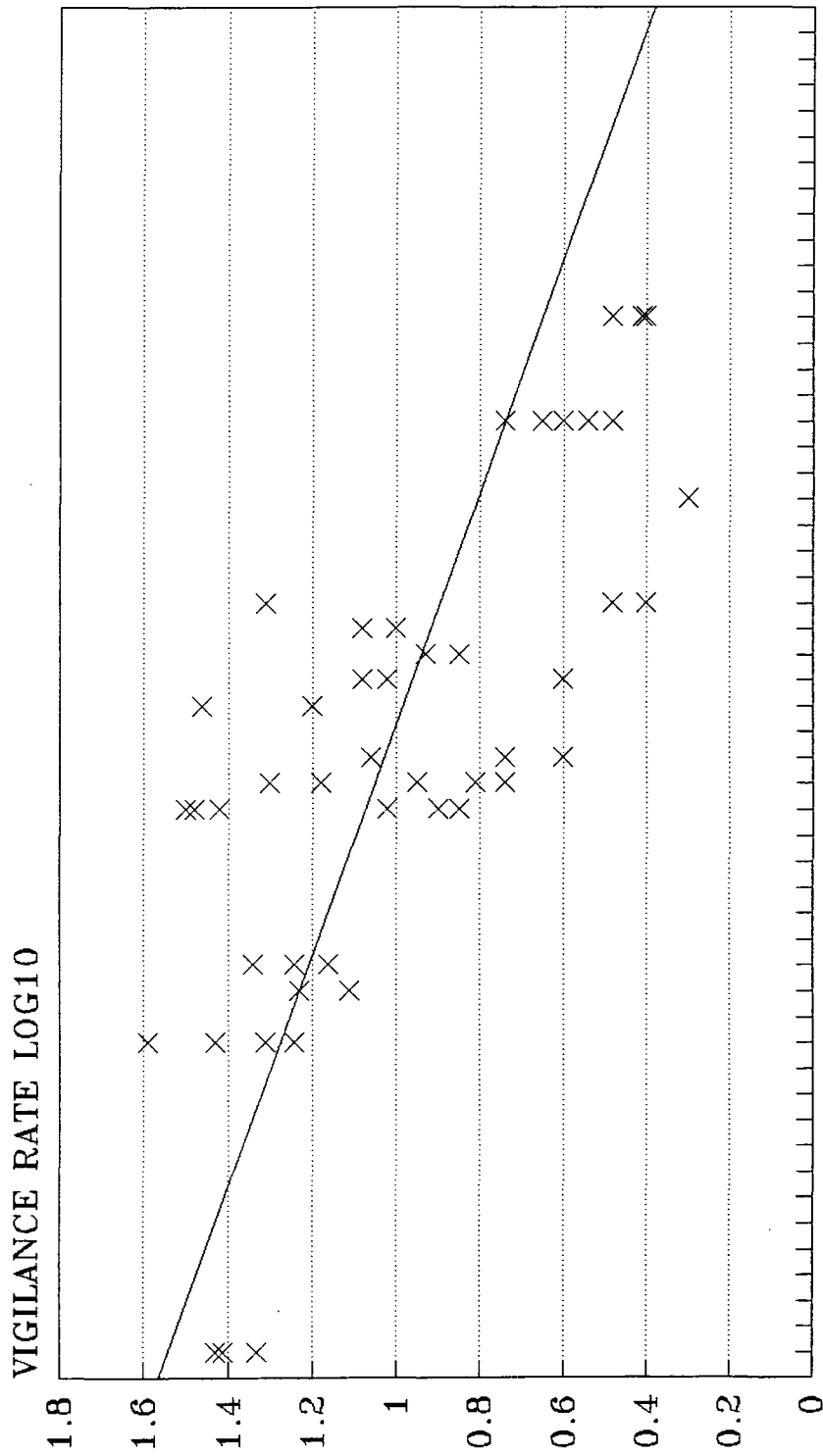
Vigilance rates for species and adult/first year Turnstone categories were correlated against date to determine if any relationship exists between vigilance rate and date. The vigilance rates were first transformed to log₁₀. Regression plots of the data are illustrated in Figs. 17-19.

FIG. 18. VIGILANCE RATE REGRESSION PLOT
FIRST YEAR TURNSTONE.



1111111112222222222312345678911111111122222222223312
 012345678901234567890 MAY 0123456789012345678901 JUNE
 APRIL DATE

FIG. 19. VIGILANCE RATE REGRESSION PLOT
PURPLE SANDPIPER.



11111111222222231234567891111111122222223312
 012345678901234567890 MAY 0123456789012345678901 JUNE
 APRIL DATE

TABLE 12
VIGILANCE RATES CORRELATED WITH DATE.

SPECIES/AGE	n	r	rsq x100	sig
T.STONE	180	-.34994	12.24	.0000
T.STONE AD	105	-.55941	31.29	.0000
T.STONE 1YR	75	-.29348	08.61	.0106
P.SAND	48	-.74627	55.69	.0000

r = product moment correlation coefficient.

sig = significance level.

rsq x100 = r squared (coefficient of determination) times by 100. This expresses as a percentage the amount of variance explained.

All species/age categories show a significant ($P < 0.05$) negative relationship between rate of vigilance and date. However the amount of variation in vigilance explained by date differs considerably. In first year Turnstones only 8% is explained compared to 31% in adult birds, and Purple sandpipers show 55% of the variation as being attributable to date.

The logged vigilance data were then analysed for spring and neap tides as defined above. Although the difference in tidal height/range between springs and neaps may effect feeding quality (and therefore rate) there is no reason why it should directly effect vigilance rates.

TABLE 13
VIGILANCE RATES ON SPRING AND NEAP TIDES CORRELATED WITH DATE.

SPP/AGE	SPRING				NEAP			
	n	r	rsq	sig x100	n	r	rsq x100	sig
TSTONE	123	-.31829	10.13	.0003	57	-.35329	12.48	.0070
TS AD	74	-.55846	31.93	.0000	31	-.56462	31.48	.0009
TS 1YR	49	-.17870	3.19	.2192	26*	-.29507	8.70	.1434
PURP	23*	-.83960	70.49	.0000	25*	-.60218	36.26	.0014

SPEARMAN RANK

TS 1YR	27	-.325	not sig at 0.05
PURP	23	-.757	sig <0.01
	25	-.631	sig <0.01

r = product moment correlation coefficient.

sig = significance level.

rsqx100 = r squared (coefficient of determination) times by

100. This expresses as a percentage the amount of variance explained.

* = less than the minimum required sample size.

Vigilance rates for Turnstones, adult Turnstones and Purple Sandpiper decreased significantly with date. First year Turnstone vigilance shows no significant decrease when tidally split. Spearman rank correlations were again carried out (as in Table 10). These match the results of the product moment correlation. A high percentage of variation in Purple Sandpiper vigilance rate is explained by date; seventy percent for spring and thirty six percent for neap tides. Adult Turnstone exhibit a similar amount of variance (31%) for both spring and neap tides, in comparison first years (insignificant) have a very low percentage of variation in vigilance explained by date. In the period of study adult Turnstone and Purple Sandpiper (and to a lesser extent Turnstones as a whole) appeared to reduce their vigilance rates as the date increased; first year Turnstones did not.

The vigilance rate for the species/age groupings were analysed by ANOVA to establish if any significant difference in vigilance rates exists between the categories.

TABLE 14
ONEWAY ANALYSIS OF VARIANCE FOR VIGILANCE RATE
AND SPECIES/AGE CATEGORIES.

SOURCE OF VARIATION	SUM SQ	DF	MEAN SQ	F RATIO
BETWEEN	46354	2	23177	80.48
WITHIN	64790	225	287	
TOTAL	111144	227		

(SUM SQ = sum of squares, DF = degrees of freedom, MEAN SQ = mean squares).

F PROB = .0000

Tukey test groups different at 0.05 level=

Adult from first year Turnstone.

Adult Turnstone from Purple Sandpipers.
Purple Sandpiper from first year Turnstone.

The Tukey test shows that all groups possess significantly different vigilance rates. First year Turnstones exhibit the highest vigilance rate with a mean of 48 seconds with that for adult birds (21.25 seconds) being less than half the first year mean. Purple Sandpipers have the lowest mean value (13.23 seconds).

iii) Percentage of observed time spent vigilant.

First year Turnstone show (Fig. 20) the highest percentage of time spent vigilant throughout the study period. In April they spend approximately 20% of their time being vigilant. This decreases to between 10-15% through the rest of the study period. Adult percentage vigilance time starts at between 10-15% decreasing to around 5% by May 2nd. It then fluctuates about this level increasing to approximately 5% again on the 26th and 27th of May.

Purple sandpipers exhibit the lowest percentage vigilance with values of only 8-9% in early-mid April, falling to around 5% by the end of the month. Throughout May their percentage vigilance time never reaches 5% (fluctuating between 1.3-4.4%) and after the 10th remains at around the 1% level.

CHAPTER FOUR DISCUSSION.

The available evidence suggests that adult Turnstones increase the length of their feeding day prior to migration. The median time of departure from their feeding site (Parton Rocks) became later (ie. closer to high tide) over the two month study period. They therefore remained longer at the feeding site. The pattern of arrival at the roost site complemented this, with birds arriving progressively closer to the time of high tide throughout the same period. Adult Turnstone did not, however, show an earlier median time of arrival at the feeding site which might have been expected as a means of increasing the length of their feeding day. Nevertheless, the median departure time from the roost site became earlier after high tide. This may be explained if birds exploited other feeding areas during the early stages of the ebbing tide. Birds therefore utilise feeding areas as they became exposed, with Parton rocks representing the main feeding area at/around low water.

Harris (1979) suggested that Turnstone follow the tide as it ebbs thereby spending the maximum time at the most productive feeding zones. As the tide turns they became less selective, since no core feeding area exists. Birds therefore may remain in the Parton rocks feeding area (departing straight to roost) since different feeding areas possess similar quality of feeding opportunities.

Purple Sandpipers do not show any change in median time of arrival/departure at either the feeding or roost site. Therefore no evidence exists that they increased their duration of feeding prior to migration. This may be because they are more specific in their feeding habitats, being limited almost exclusively to intertidal rocky shore feeding areas. The availability of suitable feeding sites is therefore strictly tidally controlled. In contrast Turnstone have a diverse range of feeding methods which can be used on a variety of substrates, e.g. feeding on beaches, mudflats and along the tideline, although their preferred feeding habitats are rocky/stony coastlines. This means Turnstones are less

restricted by the tide and can feed efficiently at earlier and later stages of the low tide cycle, when feeding for Purple Sandpipers may not be profitable. Small numbers of Turnstone were seen feeding even on grassland areas near the coast over, high water. The greater choice of feeding habitats and the use of alternative feeding areas thus enable Turnstones to increase their feeding day length. Purple Sandpipers were never seen to feed outside of the littoral zone and have only infrequently been observed exploiting other feeding habitats (coastal machair) in Britain (Riley 1992). It seems to be specific food requirements which place severe limitations on their winter habitat choice.

If Purple Sandpipers tried to extend their feeding time on the suitable feeding areas a rise in bird density would have occurred at each side of the low tide cycle (more birds being present on a smaller available feeding area). An increase in the rate of social interactions could therefore have been expected with more aggressive encounters occurring due to increased competition for food. This would have the effect of depressing feeding rates making it unprofitable for Purple Sandpipers to extend feeding times on the intertidal feeding areas available. Feare (1966) notes an increase in intraspecific competition in Purple Sandpipers in poor light conditions (dusk) at which times food was scarce.

First year Turnstones showed no alteration in the median time of arrival/departure at the feeding site. This is to be expected since they do not undergo long distance migration so have no need to increase food acquisition for fat deposition.

Zwarts et al (1978) suggests that wader species can increase the length of their feeding day by either utilising different feeding areas over high water (as exhibited by Turnstones) or feeding over high water at night. It is unlikely that either species in this study is capable of efficient nighttime feeding since both rely on vision, as opposed to touch, to locate prey. Cramp and Simmons (1982) state that Purple Sandpipers are daylight feeders only.

Adult and first year Turnstones and Purple Sandpipers both exhibited feeding rates which increased over the two month study period. In particular adult Turnstone and Purple Sandpipers showed strong correlations ($r^2 \times 100$ approximately 20% in both cases) between increased peck rate and date. First year Turnstones peck rate also increased but to a lesser extent. First year Turnstones would not be expected to show an increase in their peck rate since as previously mentioned they do not undertake long distance migration. The ANOVA analysis of peck rate highlighted this difference with the juvenile rate being significantly different from adults and from Purple Sandpipers.

The increase in the first year peck rate might have been in anticipation of a short northwards spring movement, not as far as the normal breeding area. However in ringing studies (Ens et al 1978) first year Turnstones showed no weight gain in the adult pre-migratory period. Although a small proportion of first year birds do migrate towards the breeding grounds it is extremely unlikely that this could have caused the increase apparent in the data set. Alternatively the increase may be explained by a spring time increase in prey availability. Zwarts (1978) found that Whimbrels *Numenius phaeopus* showed increased feeding rates in April as their main prey species becomes more numerous, due to spring breeding swelling the population. It seems unlikely that first year birds would increase feeding rates solely because prey is more available without some shift in behavioural motivation prompting the change (as Metcalfe & Furness 1984 postulate for adults). This could be a need to accumulate reserves for their short distance migration (as outlined above); or an increased feeding rate may enable first years to decrease the length of their feeding day. The benefits of such an exchange, if it occurs, is ambiguous.

On spring tides Purple Sandpipers showed no increase in peck rate. They may be able to obtain sufficient food/increase food intake on spring tides without increasing their feeding rate. Due to the better quality feeding opportunities available on

spring tides. Purple Sandpipers showed an increase in peck rates on neap tides, when the feeding was not as good. This increase may allow them to gain the extra food required to prepare for migration when feeding quality is reduced. Adults and first year Turnstone both show increases in their feeding rates on both spring and neap tides throughout the two month study period. Both age categories show similar levels of correlation on neap tides but on springs adults show a much stronger correlation of feeding rates with date. Adult Turnstone may make the maximum use of the high quality feeding opportunities offered by spring tides to accumulate food for fat deposition. If the reasons postulated for the difference between Purple Sandpipers and adult Turnstone are correct then they show different strategies of how increased feeding rates are used to enable fat deposition. Increasing feeding rates on neap tides would seem a less efficient strategy than on spring tides when feeding opportunities are at their best. In view of this the Purple Sandpiper result seems questionable.

Through the two month study period a reduction in the vigilance rates of both adult and first year Turnstone and Purple Sandpipers occurred. Adult Turnstone and Purple Sandpipers showed larger reductions in, and overall lower levels of, vigilance than first year Turnstone. ANOVA analysis showed that all three age/species categories have significantly different vigilance levels. First year Turnstone consistently displayed the highest percentage time spent vigilant (Fig 20) and Purple Sandpipers the lowest with adult Turnstone inbetween. Metcalfe and Furness (1984) found that adult Turnstones reduced their vigilance prior to migration but juvenile vigilance remains at a constant level. The results of this study agree with their findings for adult but not for juvenile Turnstone. Their reduction in vigilance may be due to a change in priorities due to the short distance migration juveniles undertake (as outlined above). Metcalfe and Furness (1984) postulate that the reduced vigilance of adults is due to their need to accumulate fat resources prior to migration. This is prompted by a shift in behavioural priorities producing a trade off in vigilance for an increased

investment in feeding rate. They did not however measure the feeding rates in their study. This study shows that an increased feeding rate is associated with a reduction in vigilance.

When the data are split into those collected on spring and neap tides, first year Turnstone show no significant reduction in vigilance for either tidal type over the two month study. This result is more in agreement with the findings of Metcalfe and Furness (1984) than when spring and neap tides are analysed together. Adult Turnstones exhibit a similar degree of correlation for both tidal types although as previously mentioned their peck rate shows a stronger correlation on spring tides. This suggest that birds may be able to increase their peck rate more on springs for a similar reduction in the level of vigilance due to the better feeding opportunities available. Purple Sandpiper vigilance shows a very strong negative correlation on spring tides but no corresponding positive correlation in feeding rate is apparent.

A colour ring study is needed to follow the changes in feeding/vigilance rates and roosting/feeding times of individual birds (both adults and first years). This would make the separation of adult and first year Purple Sandpipers possible, since they cannot be separated in the field. However it seems unlikely that the differences between these will be as large as in Turnstones since the majority of first year birds probably to or near to the breeding grounds, although the actual numbers of first years summering in the Northern regions of Scotland is uncertain (Prater 1981).

It appears therefore that adult Turnstone alter their optimal behaviour to increase their feeding rate. This is used in combination with a lengthening of their feeding day to enable fat deposition for long distance migration. Purple Sandpipers rely on an increased feeding rate to complete the fat deposition necessary for migration. They appear unable to increase their feeding day length due to their narrow winter feeding niche. First year Turnstone show no lengthening of the feeding day and a smaller increase in feeding rates. This

suggests that they have not the same need to gain weight for migration.

The old pier structures at West Harbour represented the major roost site for Turnstones and Purple Sandpipers in Cleveland. The six pier remains, varying in height, size and degree of exposure to onshore waves and winds, formed a complex roosting area, offering a large variation in possible roost location in relation to the degree of shelter provided in a wide range of weather conditions.

Purple Sandpipers appeared to favour the seaward side of the outer piers in relatively calm weather. This was most noticeable earlier in the study period (April) when birds were present in large numbers. Turnstones at this time utilised the flat tops of the outer piers (particularly a high Wooden beam structure) and roosted more readily with Oystercatchers on the inner pier. In late April/May as the numbers of Purple Sandpipers declined they tended to associate more with Turnstones at the roost, with both species often roosting together on top of the wooden structure. Purple Sandpipers appeared to utilise the more exposed outer edges and sides to a greater extent than Turnstones. In bad weather (storms/strong winds) both species preferred to roost on the most sheltered inner pier and on the waste ground just inland of the harbour.

The demolition of the old roost sites and construction of the new stone island roost occurred over the summer when the wintering birds were not present and therefore the roost was not in use. The main question was whether birds would adapt and use the new roost site, possibly in conjunction with the present northern and new southern piers. A good roost site needs to be free from disturbance and offer shelter from the elements (Hale 1980). It is possible that the new roost may suffer a rise in disturbance from increased use of the Yacht Club/Harbour associated with the marina development. The new roost is more limited in both size and complexity it therefore offers a smaller choice of suitable roost location in different weather/sea conditions. Behaviour is the main, most

noticable, way in which birds respond to environmental change (Goss and Custard 1990). A study of intra-specific and inter-specific species interactions at the roost will show whether or not roost site quality has decreased. If roosting space is limited a rise in aggressive interactions, due to increased competition for both space and shelter, would be expected to occur. Both species tended to avoid roosting near gulls, which were frequently seen to disturb roosting birds. Gulls roosted/loafed on certain areas of the inner and outer piers. With their demolition gulls could utilise the new island roost site. This could cause increased disturbance to Turnstones and Purple Sandpipers and could be a major factor reducing roost site quality. Three possible outcomes exist which may be different for each of the two species involved:

i) That birds will adapt and similar numbers will utilise the new roost site (ie it remains the major Cleveland roost site).

ii) Birds do not adapt and change their roost location, joining an existing or forming a new roost, at a local or greater scale.

iii) A combination of i) and ii) occurs in response to a reduction in quality of the West Harbour roost site, with some birds using the new West Harbour roost and others being displaced.

The first outcome depends on the quality of the new roost site for the birds. If of equal quality, and birds are able to adapt, there is no reason why numbers utilising the roost should change. Outcome two would be extreme but could hypothetically occur. Option three seems perhaps the most likely result, and could easily be envisaged if a slight decline in roost quality occurred.

A salient question is how important are good roost sites in limiting the population size in a region or, in the extreme, the distribution of a species? Purple Sandpipers are limited to sites which afford secure stony resting areas left uncovered by the highest spring tides (Cramp & Simmons 1982). The only other sites in Cleveland where they roost, in only

small numbers, are North and South Gares. Their more specific roost site needs may mean that they will be more affected than Turnstones by a reduction in roost site quality.

Establishment of a new local roost by either species would seem highly unlikely given the general shortage of good roost sites. It should be fairly easy for birds to move and join existing roosts, particularly roosts containing conspecifics. Important questions are how faithful are birds to specific roost sites and how much exchange occurs between nearby roosts? Breary (1982) found that Turnstones using the South Gare roost showed a high degree of fidelity to both their roosting and feeding areas. It was obvious (from flight direction) that some Turnstones arriving and departing to the south at West Harbour came from the South Gare area. These birds did not use the South Gare roost although it makes energetic sense (shorter flight distance) to do so. This bypassing could easily be explained by either the benefit of a safer roost (less disturbance) or in terms of information exchange. A possible alteration in the feeding distributions of the two species within Cleveland could result from changes in roost site utilisation. Alternatively birds may have to increase the distance travelled between roosting and feeding sites if the same feeding areas are utilised.

Monitoring the numbers utilising different roost sites will provide some indication of the effects of the changes caused by the West Harbour redevelopment. A colour ring study would establish what changes occur in the roosting/feeding locations of individuals. Together these studies will establish the extent to which any redistribution occurs. These studies would preferably be implemented before the redevelopment started so that the established patterns are known. Behavioural studies of social interactions will indicate how the quality of the new roost affects its usage by each species.

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APPENDIX 1.1:

EXAMPLE OF FEEDING SITE, FORAGING DURATION, DATA.

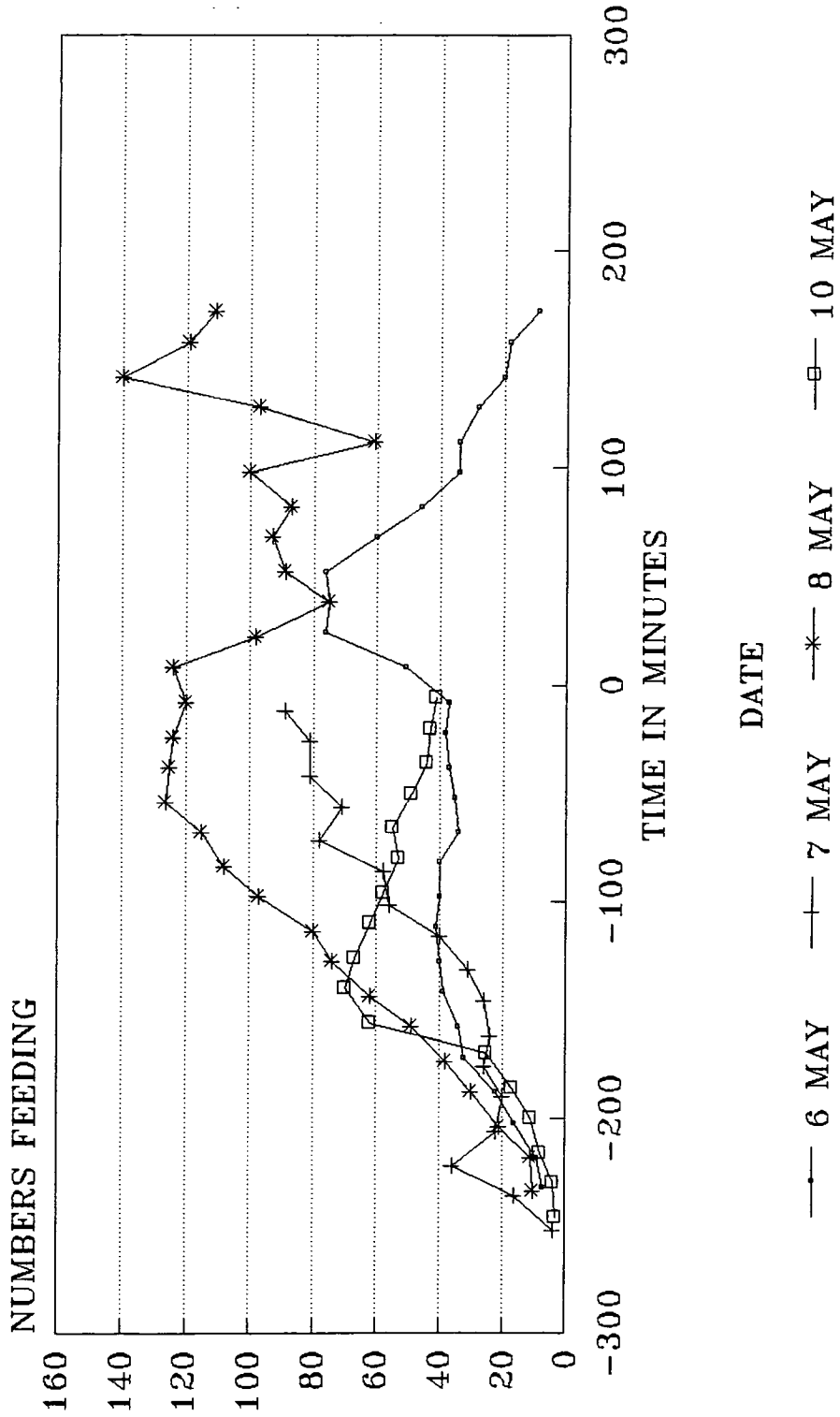
ARRIVAL AT PARTON ROCKS FEEDING SITE 7th MAY 1991.

TIME	SPECIES /AGE	NUMBERS FEEDING	TOTAL NUMBER PRESENT	PERCENTAGE FEEDING
206	A	22	24	91.67
"	J	3	3	100
191	A	20	20	100
"	J	3	3	100
"	P	4	4	100
176	A	26	26	100
"	J	3	3	100
"	P	3	3	100
161	A	24	24	100
"	J	3	3	100
"	P	2	2	100
146	A	26	26	100
"	J	4	4	100
"	P	19	20	95.00
131	A	31	31	100
"	J	4	4	100
"	P	29	29	100
116	A	40	40	100
"	J	4	5	80
"	P	21	22	95.45
101	A	56	64	87.50
"	J	5	5	100
"	P	42	44	95.45
086	A	58	68	85.29
"	J	3	5	60.00
"	P	43	43	100
071	A	78	83	93.96
"	J	7	8	87.50
"	P	45	45	100
056	A	71	80	88.50
"	J	7	8	87.50
"	P	45	47	95.74
041	A	81	84	96.43
"	J	7	9	77.77
"	P	44	44	100
026	A	81	89	91.01
"	J	8	9	88.89
"	P	42	42	100
011	A	89	95	93.68
"	J	8	10	80.00
"	P	43	46	93.47

TIME= minutes before low water (low water = 0 minutes).
 SPECIES/AGE: A= Adult Turnstone, J= First year Turnstone
 P= Purple Sandpiper.

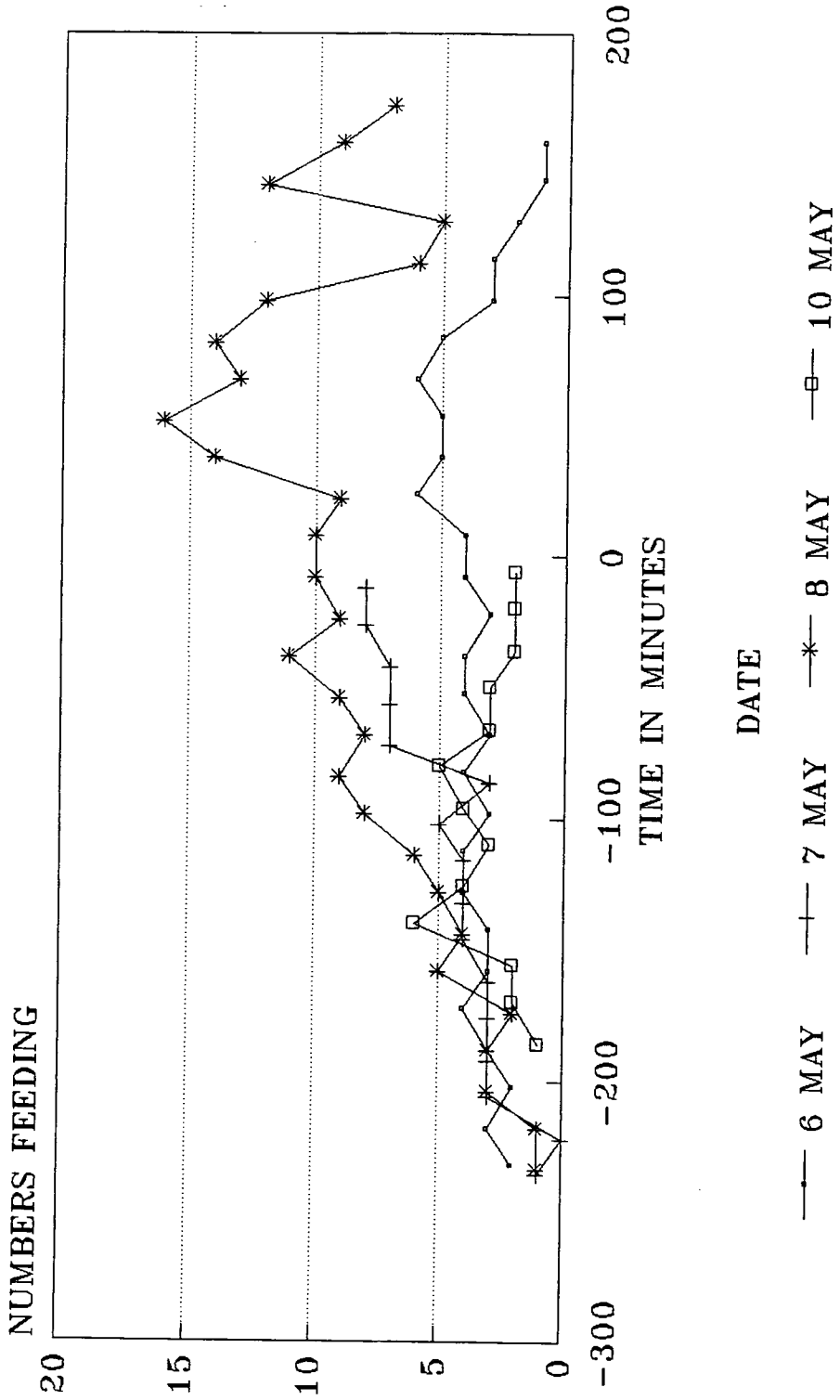
N.B. Departure recorded as above except in minutes after low water.

APPENDIX 1.2a EXAMPLE OF NUMBERS FEEDING
 THROUGH THE LOW TIDE CYCLE.
 ADULT TURNSTONE.



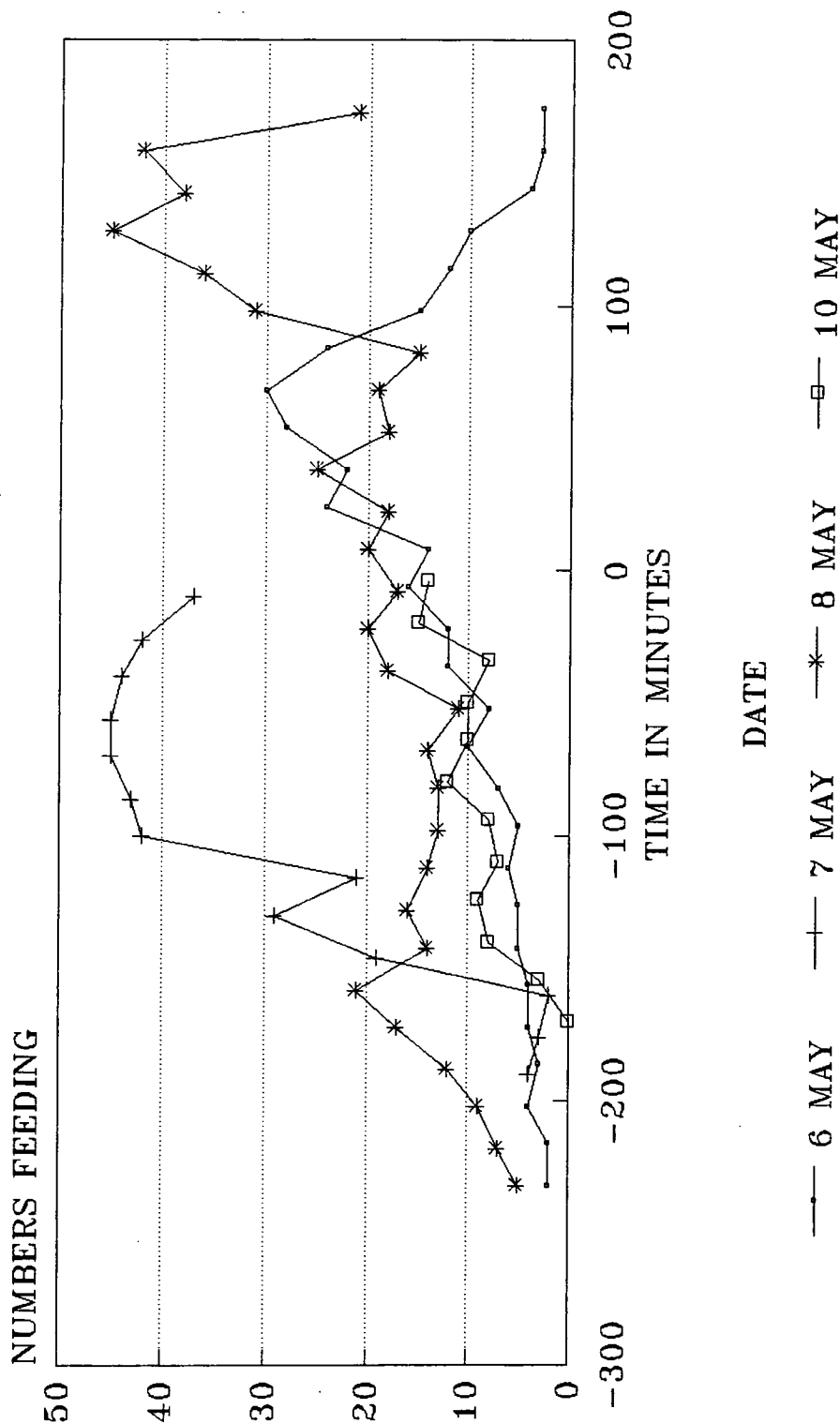
LOW TIDE = 0

APPENDIX 1.2b EXAMPLE OF NUMBERS FEEDING
 THROUGH THE LOW TIDE CYCLE.
 FIRST YEAR TURNSTONE.



LOW TIDE = 0

APPENDIX 1.2c EXAMPLE OF NUMBERS FEEDIN
 THROUGH THE LOW TIDE CYCLE.
 PURPLE SANDPIPER.



LOW TIDE = 0

APPENDIX 1.3.

MEDIAN ARRIVAL/DEPARTURE TIMES AT THE FEEDING SITE.

DATE	AD T.STONE		1YR T.STONE		P.SAND.	
	ARRIVAL	DEPART	ARRIVAL	DEPART	ARRIVAL	DEPART
APRIL						
23	-124	-	-259	-	-100	-
25	-	+207	-	+185	-	-
26	-	+173	-	+155	-	+80
MAY						
6	-127	+90	-217	+128	-10	+98
7	-109	-	-101	-	-114	-
8	-126	+172	-45	+152	+30	+170
10	-163	-	-151	-	-143	-
14	-	+114	-	+116	-	+150
17	-	+132	-	+107	-	+137
20	-98	+122	-110	+122	-	-
21	-161	-	-206	-		
24	-171	-	-209	-		
25	-	+184	-	+189		
26	-	+240	-	+217		

LOW TIDE = ZERO MINTUES.
 - = MINUTES BEFORE LOW TIDE.
 + = MINUTES AFTER LOW TIDE.

APPENDIX 1.4.

EXAMPLE OF ROOST SITE ARRIVAL/DEPARTURE DATA.

WEST HARBOUR ROOST ARRIVAL 16th APRIL 1991.

TIME	SPECIES	DIRECT A/D	NUMBER	CUMULATIVE PERCENT	ROOST POSITION
235	TS	N	5	2.0	O.RCKS
229	*TS	N	8	5.2	"
"	*PS	N	6	5.8	"
226	PS	N	7	12.5	"
218	*PS	S	3	15.4	"
"	*TS	S	8	8.4	"
207	TS	N	13	13.6	"
201	PS	N	4	19.2	"
176	TS	N	18	20.8	"
"	PS	N	6	25.0	O.PIER
174	PS	N	6	30.8	"
"	TS	N	24	30.3	O.RCKS
168	PS	N	4	34.6	O.PIER
157	PS	S	3	37.5	O.RCKS
156	PS	S	5	42.0	"
142	TS	S	30	42.3	"
122	TS	S	20	50.1	W.GRD
120	PS	N	60	100	O.PIER
112	TS	N	25	60.0	W.GRD
109	TS	S	6	62.3	"
102	TS	N	35	76.2	"
100	PS	CIP			O.RCKS TO O.PIER
99	TS	"			O.RCKS TO I.PIER/W.GRD
94	TS	S	18	83.3	W.GRD
93	TS	S	32	96.0	"
65	TS	S	10	100	"

TS = Turnstone.

PS = Purple Sandpiper.

TOTALS: TURNSTONE 252 PURPLE SANDPIPER 104.

TIME = minutes before high water (high water = 0 minutes).

DIRECT A/D = direction of arrival/departure (North/South).

NUMBER = number of birds.

CUMULATIVE PERCENT = for each species.

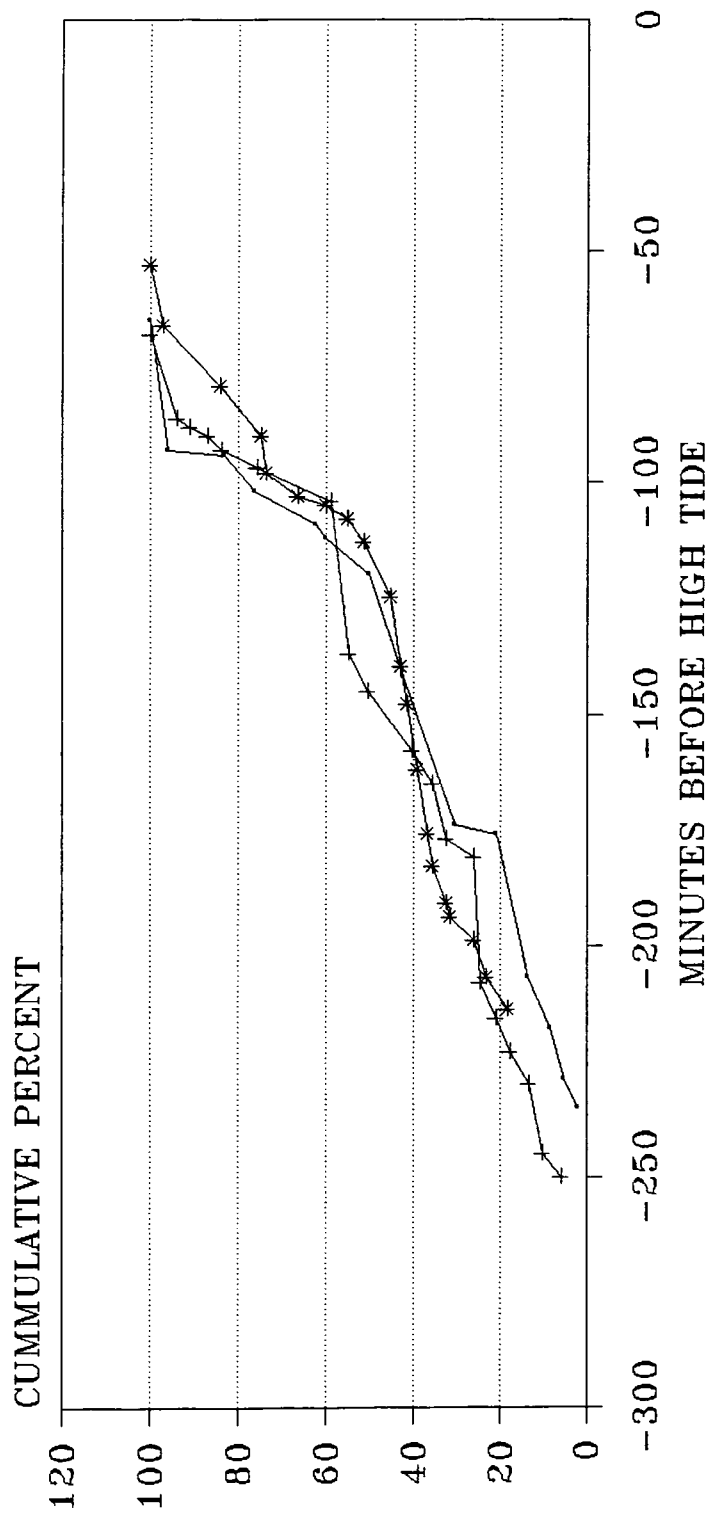
ROOST POSITION: O.RCKS = Outer rocks, O.PIER = Outer pier (remains), I.PIER = Inner pier (remains),

W.GRD = Waste ground.

CIP = change in roost site position.

N.B. Departure from roost recorded as above, except in minutes after high water.

APPENDIX 1.5a EXAMPLE OF ROOST SITE
 CUMMULATIVE PERCENTAGE ARRIVAL/DEPARTURE
 CURVES; TURNSTONE.



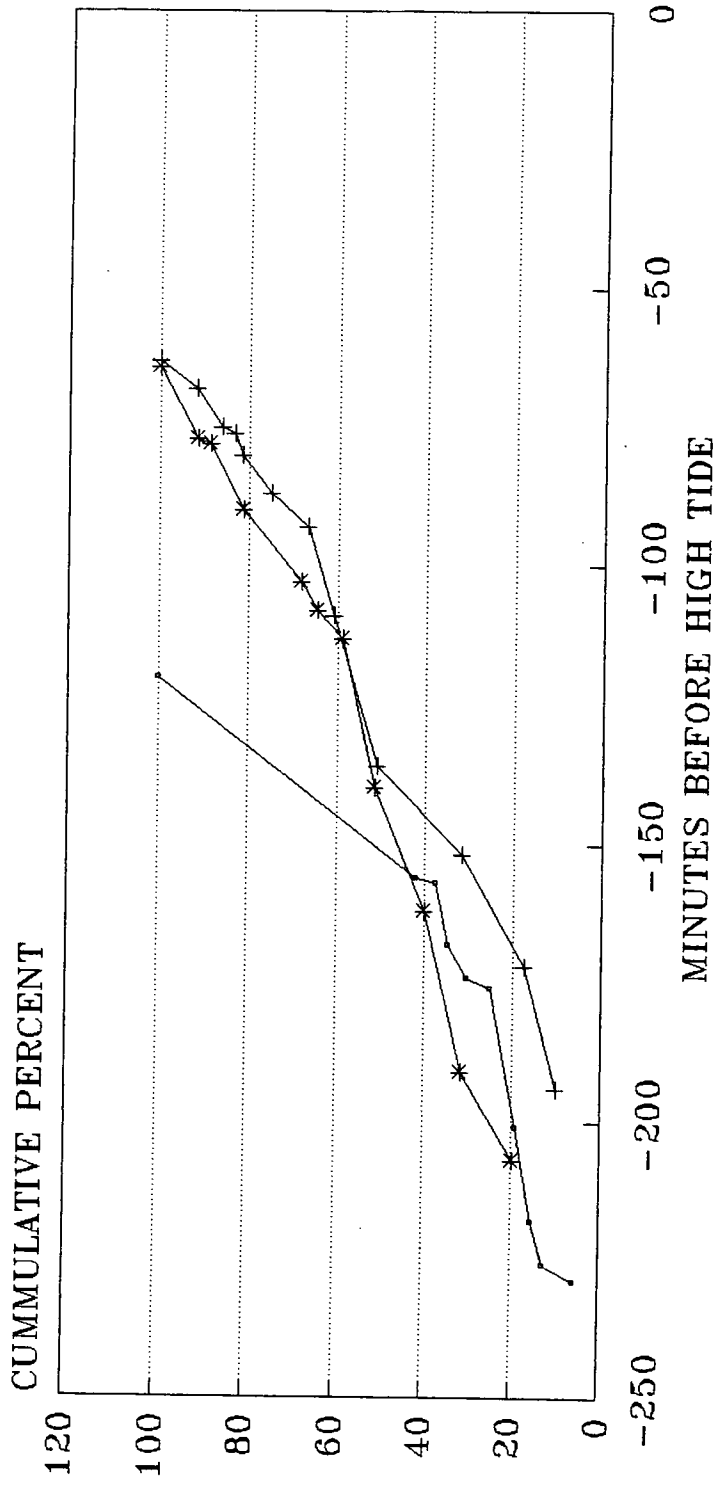
DATE, TIDE & NUMBER

— 16/4 5.6 252 — 18/4 5.3 239 *— 24/4 4.6 248

Number - Total number at roost site.

Tide - Tide height in meters.

APPENDIX 1.5b EXAMPLE OF ROOST SITE
 CUMMULATIVE PERCENTAGE ARRIVAL/DEPARTURE
 CURVES; PURPLE SANDPIPER.



DATE, TIDE & NUMBER

—•— 16/4 5.6 104 —+— 18/4 5.3 120 —*— 24/4 4.6 107

HIGH TIDE = 0

APPENDIX 1.6.

MEDIAN ARRIVAL/DEPARTURE TIMES AT THE ROOST SITE.

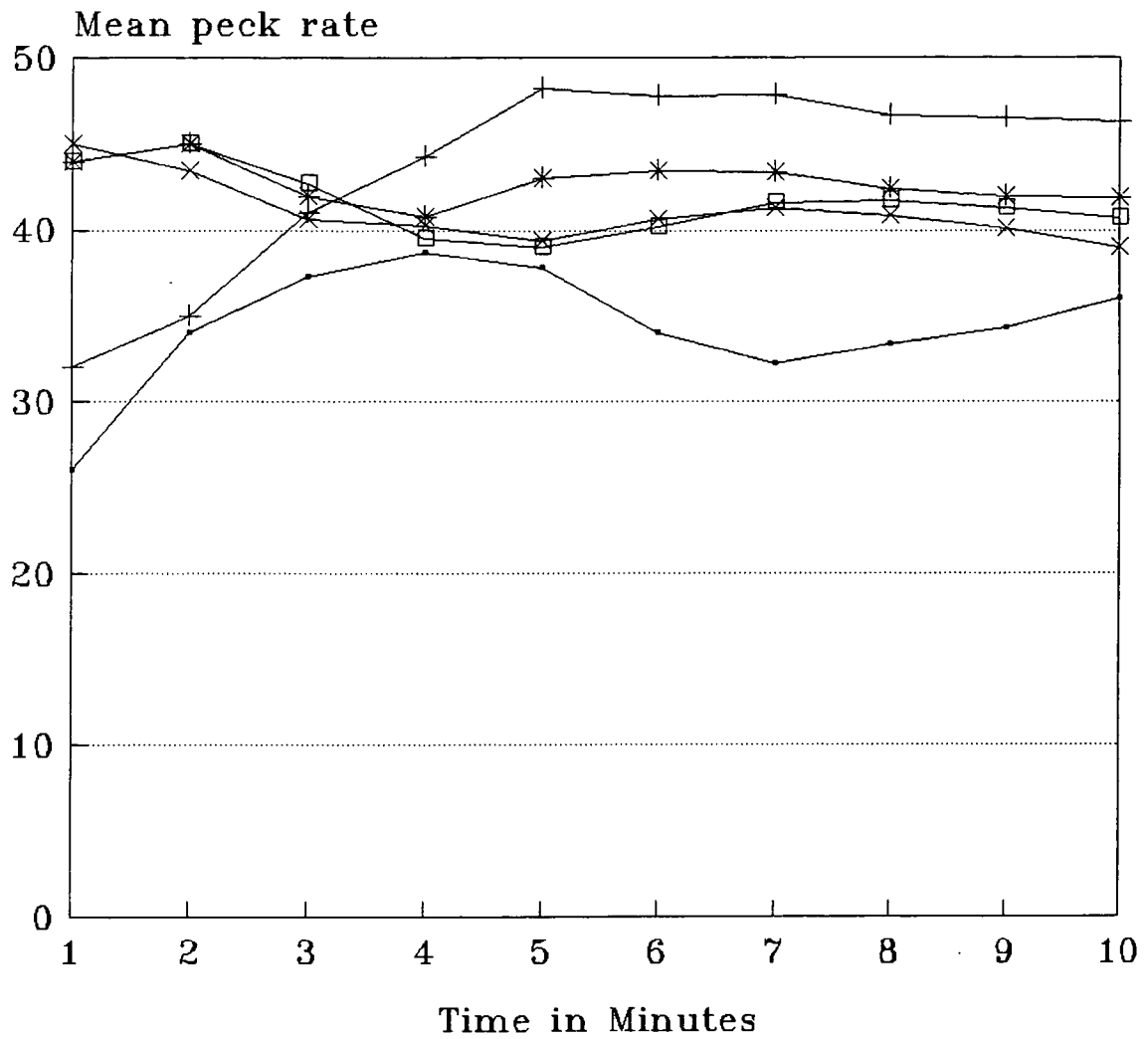
DATE	TURNSTONE ARRIVAL	DEPARTURE	P. SANDPIPER ARRIVAL	DEPARTURE
APRIL				
16	-122	-	-150	-
18	-145	-	-138	-
24	-115	-	-142	-
25	-	+196	-	+203
29	-242	-	-186	-
MAY				
1	-140	-	-207	-
6	-	+179	-	+140
9	-	+138	-	+151
10	-	+125	-	+115
11	-123	-	-140	-
13	-93	-	-105	-
15	-119	-	-150	-
16	-78	+67	-149	+105
18	-146	-	-155	-
22	+7	+117		
27	-67	+126		
30	-120	-		
JUNE				
1	-98	-		

HIGH TIDE = ZERO MINUTES.

- = MINUTES BEFORE HIGH TIDE.

+ = MINUTES AFTER HIGH TIDE.

APPENDIX 1.7a ADULT TURNSTONE.
 EXAMPLE DATA; ESTIMATION OF PECK RATES.

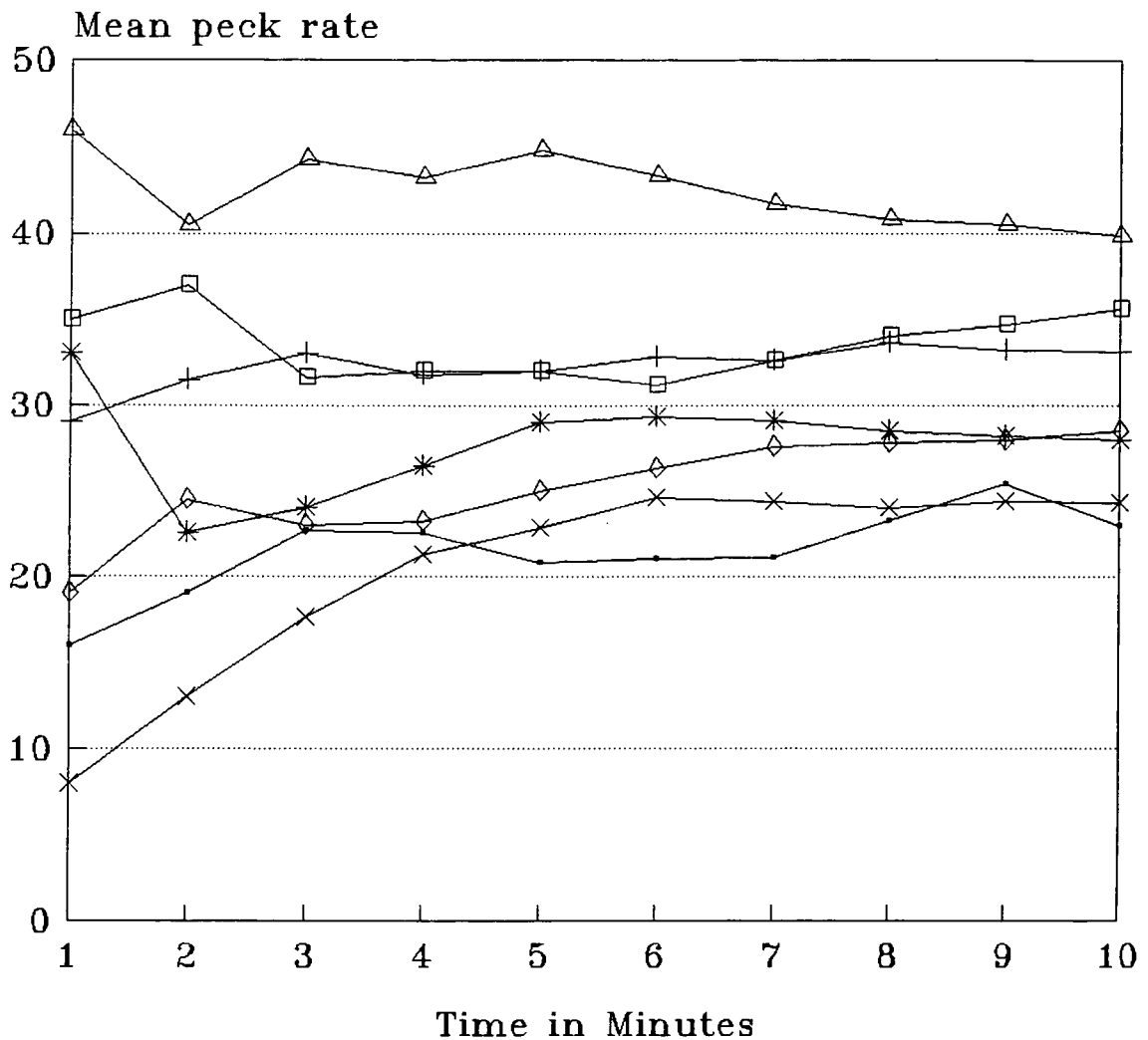


DATE & SUBSTRATE

—•— 2/5 Sh-Sd	—+— 2/5 Sh-Sd	—*— 3/5 Rk
—□— 3/5 Rk	—×— 3/5 Rk	

SUBSTRATES: Sh=Shingle, Sd=Sand, Rk=Rock.

APPENDIX 1.7b FIRST YEAR TURNSTONE
 EXAMPLE DATA; ESTIMATION OF PECK RATES.

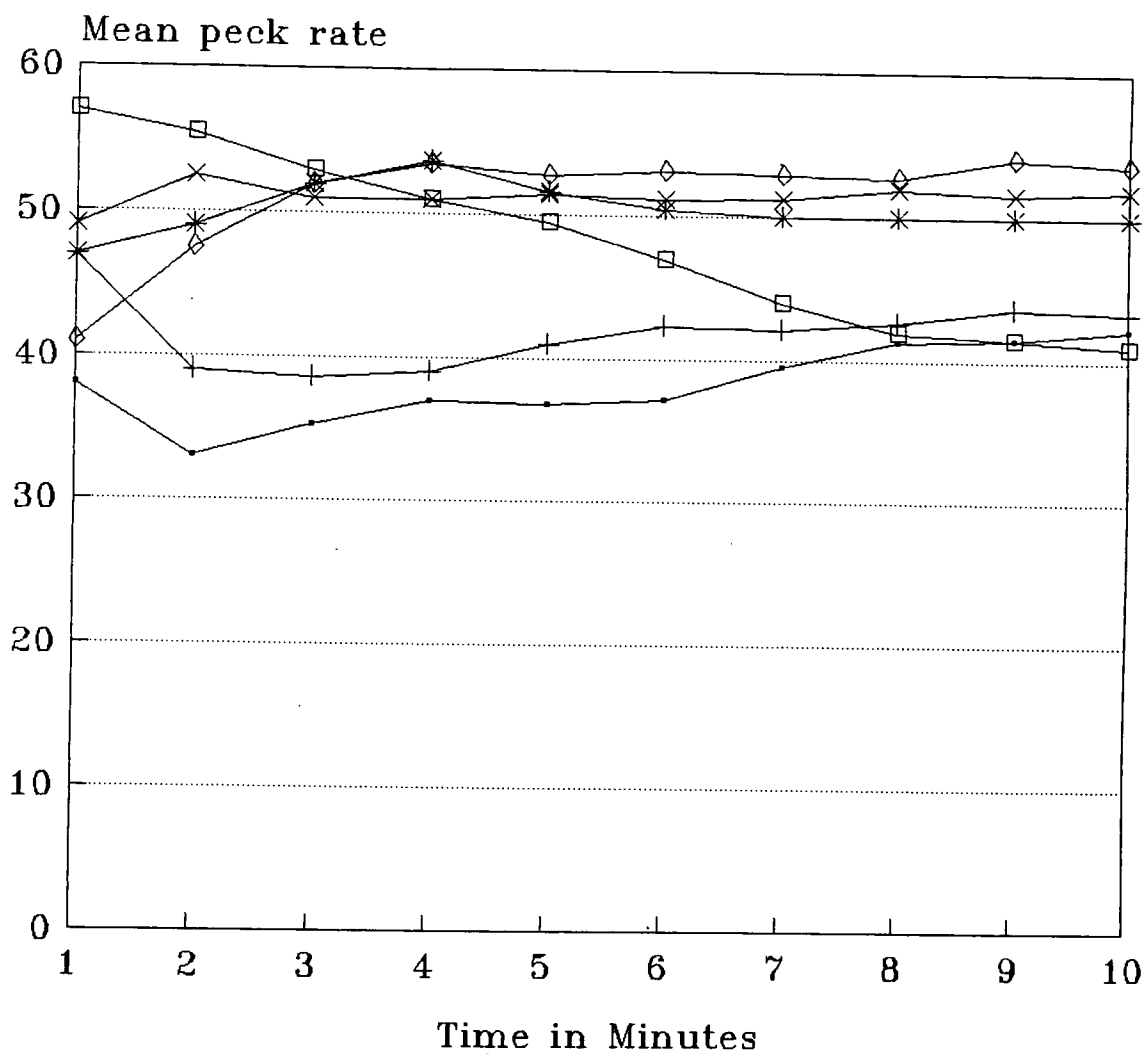


DATE & SUBSTRATE

—●— 2/5 Sd —+— 3/5 TL —*— 4/5 RP —□— 6/5 Sd
 —x— 6/5 Mb —◇— 6/5 Mb —△— 6/5 Sd-Rk

**SUBSTRATES: Sd=Sand, TL=Tideline, RP=Rockpool,
 Mb=Mussel bed.**

APPENDIX 1.7c PURPLE SANDPIPER
 EXAMPLE DATA; ESTIMATION OF PECK RATES.



DATE & SUBSTRATE

- | | | |
|---------------|------------|------------|
| —●— 2/5 RK | —+— 3/5 RK | —*— 3/5 RK |
| —□— 3/5 TL/RK | —×— 4/5 RK | —◇— 4/5 RK |

SUBSTRATES; RK=Rock, TL=Tideline.

APPENDIX 1.8.

PECK AND VIGILANCE DATA.

EXAMPLE OF DATA COLLECTED ON THE 23rd OF APRIL 1991.

SPECIES/AGE	PECK RATE		TOTAL	VIGILANCE RATE	
	TOTAL	MEAN		MEAN	
P.SAND	196	39.2	17.5	3.5	
AD TS	245	49.0	18.5	3.7	
AD TS	237	47.4	27.0	5.4	
1YR TS	152	30.4	51.5	10.3	
P.SAND	239	47.8	22.0	3.6	
AD TS	236	47.2	28.5	5.7	
1YR TS	159	31.8	33.5	6.7	
AD TS	242	48.4	24.5	4.9	
1YR TS	199	39.8	20.0	4.0	
AD TS	228	45.6	50.5	10.1	
P.SAND	206	41.2	14.5	2.9	
1YR TS	151	30.2	48.0	9.6	
1YR TS	122	24.4	44.5	11.2	
AD TS	251	50.2	21.0	4.2	

P.SAND - PURPLE SANDPIPER.

AD TS - ADULT TURNSTONE.

1YR TS - FIRST YEAR TURNSTONE.

PECK RATE: TOTAL = NUMBER OF PECKS PER FIVE MINUTES.

VIGILANCE RATE: TOTAL = SECONDS SPENT VIGILANT PER FIVE MINUTES.

