POOLE HARBOUR STUDY GROUP

BIRD INVERTEBRATE PREY AVAILABILITY IN POOLE HARBOUR

N.S.Thomas, R.W.G.Caldow, S.McGrorty S.E.A.leV. dit Durell, A.D.West and R.A.Stillman

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EXECUTIVE SUMMARY

1. Introduction

English Nature commissioned the following report, with the objective of establishing a baseline against which future verification of favourable conditions of the interest features within the Poole Harbour SPA may be established. The primary consideration in this respect is the food availability for the bird species within the system. The data have been presented with respect to the physical environment; the invertebrates, including distribution, descriptive communities and their relationship to the physical environment and; birds, including their relationship to invertebrate availability and energetic value. Bird data is based on a study of the wildfowl and waders birds using the Harbour over the period 1991-1998. (Pickess, B. P. & Underhill-Day, J.C., 2002).

2. Methodology

Sampling for invertebrates was completed by coring, based on a single 10.6 cm diameter core to a depth of 30 cm per site. Additional sampling was employed to collect lower density species, using counts and surface scraping/dredging. A total of 80 sites were sampled using a grid of 500 m by 500 m. All macro-invertebrates in each core sample were counted and identified to the level of taxonomic detail necessary for the purposes of quantifying the important types of bird food.

For each species processed, the raw data relating the ash-free dry mass (mg) of an individual invertebrate to its length (mm) were compared and a linear regression model fitted to the data. Species-specific regression equations were then used to generate the predicted values for the ash-free dry mass (mg) of an individual. Biomass was then calculated for each species at each site.

Invertebrate data has been presented in the form of abundance tables and distribution plots for those species that contributed most to the biomass. These data have been further analysed using the PRIMER package, which utilises a site classification and ordination technique.

Energetic availability calculations have been completed for the invertebrates based on the WeBs sectors used in the bird study. In addition a value has been calculated for the harbour as a whole. The calculation has been constructed in two parts. In each sector the mean biomass contributed by each species for that sector was calculated. Although the productivity for each sector was also calculated, the energy available to birds was based on the mean biomass, as this is a conservative value which represents the biomass present at the beginning of the over-winter period.

The next stage comprised several separate calculations relevant to each bird species feeding in each sector. The energy requirement of each of the birds and the energy provided by their preferred species was calculated for the whole of the over-winter period that the birds were present. Numerous assumptions were included in the calculation that erred on the side of caution with respect to energetic availability. The most important were the ratio of energy requirement to basal metabolic rate of the birds, which was set at 4:1 and the area of intertidal available to the feeding birds, which was calculated to be 39% of the total intertidal area due to the double high tide

3. Physical Environment

The results indicated that the areas to the west and south-west of the Harbour, generally contained the finest sediments, with many of the other more sheltered sites consisting of fine silty sediments. Silty sand sites were evident in the wider Wareham Channel area and at several low water sites both in the southern Harbour area and southern Holes Bay. Sand was predominantly located towards the Harbour mouth, although several sites occurred along the main channel. Mixed sediments were scattered throughout the Harbour.

The double tidal regime results in those areas in the Harbour that are below 1.5m (above LAT) only becoming exposed for 3 hours or less per tidal cycle. In general the algal cover was most prevalent in the sheltered areas where finer sediments were located. Most of the sites where 100% algal cover was recorded were found in Holes Bay, Wareham Channel and south west of Brownsea Island.

4. Invertebrate Composition and Biomass Distribution

A total of 61 invertebrate species were found in the survey of the Harbour, these comprised of 23 annelids (20 polychaetes), 20 crustacea, 15 molluscs and 3 other species including diptera, ascidians and cnidaria. The maximum number of species at any site was 21 (site 40) and the minimum was 1 (site 17). The greatest concentration of sites with high species number was in the area south and west of Brownsea Island although Holes Bay also supported several sites with large numbers of species.

Abundances ranged from 8 per square metre to 76,761 per square metre. The majority of sites with high numbers of individuals were found in Wareham Creek and Lytchett Bay. The highest abundances were generally recorded at the finer sediment sites, where little algal cover occurred.

The most characteristic species within Poole Harbour, other than the small annelids were the large polychaetes, *Nereis virens* (King Ragworm), *Arenicola marina* (Lugworm), *Hediste diversicolor* (Ragworm) and *Nephtys hombergii* (Catworm) as well as a group of bivalve molluscs, including *Mya arenaria* (Sand Gaper), *Cerastoderma edule* (Common Cockle), *Scrobicularia plana* (Peppery Carpet Shell) and *Tapes phillipinarum* (Carpet Shell also known as the Manila Clam)

The analyses of the invertebrates have resulted in the description of 6 clusters of sites based on species similarity. These communities demonstrated a distribution in the Harbour with respect to various physical conditions:

- Cluster A contained relatively few species per site (8.4) and was characterised by a group of polychaetes, primarily *Hediste diversicolor, Cirratulus filiformis* and *Malacoceros fuliginosus*. This community occurred in the finer sediments in the upper Harbour
- Cluster B comprised more species and had a larger number of individuals per site. The principal species of the group consisted of *Cirratulus filiformis* and *Tubificoides* sp. A significant contribution to the group was also made by the bivalve *Cerastoderma edule*. This cluster was found in the middle reaches of the Harbour;
- Cluster C was characterised by low abundance and very low biomass (4g m^{-2}) and supported a variable group of species, including many of the species that characterised the two major clusters. The species that contributed to the separation of this cluster were the small bivalve *Abra tenuis* and the polychaete *Nepthys hombergii*. This community was found in variable sediment types, generally more sandy mud, scattered throughout the Harbour;
- Cluster D was characterised by the low mean number of species per site (5.3) also with relatively low biomass and abundance. The oligochaete *Tubificoides* was the characteristic species of this cluster, in association with the polychaete *Hediste diversicolor* and the amphipod *Corophium volutator*. The cluster was found in the upper reaches of the small creeks and sheltered locations (probably near freshwater input);
- Cluster E, although relatively low in species numbers (7.7) and abundance supported the highest mean biomass. This was due to the frequent presence of the bivalve molluscs *Cerastoderma edule* and *Tapes philippinarum*, as well as the high biomass species *Carcinus maenas* (Common Shore Crab) and the *Nereis virens*. This group was found in discrete mixed sediment areas
- Cluster. F, supported a relatively large number of species, with high biomass, despite generally low abundance. This was due to the presence of the high biomass species *Nereis virens* and the lugworm *Arenicola marina*. The small annelids, particularly the polychaetes *Scoloplos armiger* and *Spionid* indet were also characteristic. This community was found in the sand sediments in the entrance to the Harbour

Biomass ranged from 0.65g per square metre to 113g per square metre. The highest biomass values were recorded at sites near the foreshore of Poole town, including the entrance to Holes Bay and Parkstone Bay. The small annelids contributed the largest percentage of overall biomass (35%), with the bigger polychaetes *Hediste diversicolor* and *Nereis virens*, comprising a slightly smaller proportion (26%). The bivalves in general also contributed significant proportions of the overall biomass (>25%).

5. Birds and Prey Availability

The distribution of the birds within the harbour indicates that, with respect to total bird numbers, the most important sectors were SE2 (Brands Bay), W4 and W2W (Wareham Channel), which were three of the largest areas in the Harbour. Several species demonstrated well defined spatial requirements in Poole Harbour, most clearly evident for avocet and to a lesser extent species such as grey plover and redshank.

A comparison of the predicted number of birds (bird days) that be can supported (S_p) against the number that have historically been supported (S_a) was calculated. The former is based on a simple ration approach that does not take account of bird species interactions or intra species competition. Using this calculation the overall invertebrate energy available within the intertidal area of the Poole Harbour system has been demonstrated to exceed, by 3.5-4 times, that required by the wading and wildfowl birds that feed on them. This is within the range described in other studies as likely to be sufficient to sustain bird populations, although this may not apply to all species exploiting the Harbour.

The following constraints must be taken into consideration with regard to these values:

- The available intertidal invertebrate food is likely to be an over-estimate, due to the inclusion of both larger (over size) prey and smaller individuals. Both of these fractions of the invertebrate populations however, will contribute to the survival of the populations and will provide a resource to sustain birds in subsequent years.
- There are limitations on availability of the invertebrates due to the tidal conditions in the Harbour. This has been taken into account, to some extent, in the calculation, but a more accurate estimation may be made in future using tidal contours and individually calculated factors per bird sector.
- The value of 4 x Basal Metabolic Rate (BMR) for calculation of energy requirement for birds may be regarded as precautionary as it is at the upper end of published values.
- Interference between birds, both between species and individuals within species will considerably reduce availability for some species of bird.
- The ratio (S_p: S_a) cannot be sustained at parity as birds will leave or stave as soon as the food resource falls to the threshold value that is required to meet the daily energy demands, i.e. well before all the food is exhausted.

To provide an indication of which species of bird may be subject to restriction due to prey availability, individual consideration of bird species resources against requirements were calculated. Most of the species demonstrate available food resources compared to their historic use, to be well in excess of 10:1. The species that exist below this level are shelduck, oystercatcher and curlew, all of which have high energy requirements per individual. In particular the requirements of shelduck and curlew exceeded the energy available in sectors SE2 (Brands Bay) and W5 (Wareham Channel).

In the case of the oystercatcher, recent work by Goss Custard, *et al* (2004) indicates that in the order of 8 times the estimated requirement of this species is needed to ensure survival of a population through to the next breeding season. This agrees reasonably well with the estimated predicted number of bird days, against the actual number for this bird in Poole Harbour, at 7.3:1.

Given that the invertebrates appear to be able to sustain the current populations, the low values for shelduck and curlew may be the result of several factors; the food requirement for these species have been over-estimated; the available food has been under-estimated; the birds have a more catholic diet than that employed in the assessment including exploitation of alternative non-intertidal food resources; or that they are able to survive in a more food restricted and hence competitive environment.

The overall assessment of energy balance indicates that some degree of stress on the bird populations may exist, however, the individual species assessments and the sectoral analysis suggests that this does not apply to all species. It is proposed that more species-specific studies may need to be conducted for those birds where the actual number of bird-days recorded at the site are approaching the predicted number of bird-days based on food availability (e.g. shelduck and curlew, both of which are recognised as being of considerable conservation importance). This would be particularly important for those bird species that are declining in number in Poole Harbour, although local trends in bird populations would need to be set against national background variation.

INTRODUCTION

English Nature commissioned the following report from Emu Ltd on the 14th June 2002, with respect to an assessment of the bird invertebrate prey availability in Poole Harbour, based on field-work conducted by the Centre for Ecology and Hydrology (CEH).

This project is considered to be a baseline study that will enable future verification of favourable conditions of the interest features within the Poole Harbour SPA. The primary consideration is the food availability for the bird species within the system.

The specific objectives of the study have been to:

- Conduct a survey of the macroinvertebrates in the intertidal areas of Poole Harbour
- Identify, count and calculate the biomass of macroinvertebrates
- Analyse the sediments for particle size
- Obtain data on the bird distribution in Poole Harbour
- Assess the energetic value of the invertebrate species with respect to the bird populations predating on these species.

The first three sections were completed by CEH during the autumn of 2002 with the sample analysis completed by April of the subsequent year. The remaining two sections were conducted by Emu Ltd. based on the invertebrate data provided by CEH and a study of the birds using the Harbour over the period 1997-1998. Pickess, B. P. & Underhill-Day, J.C. (2002).

The assessment of the energetic value of the invertebrate species and in turn their value to the bird species has been conducted as a simple mass balance calculation. A more complex predictive method is expected to be completed at a later stage using a model proposed by CEH.

Background to Poole Harbour

Poole Harbour is an area of international importance for nature conservation. Much of the Harbour is designated under EU and UK legislation, including a Special Protection Area, RAMSAR Convention site and Site of Special Scientific Interest. Other sites around the Harbour fall within an Area of Outstanding Natural Beauty as well as three National Nature Reserves and three Local Nature Reserves.

The Harbour occupies about 3,600 hectares and comprises extensive intertidal areas, open water and wetlands as well as several islands, the largest of which is Brownsea Island (Fig. 1). The Harbour comprises of a single large basin and two smaller basins, Holes Bay and Lytchett Bay. It has a single channel connecting it to Poole Bay in the English Channel and is fed by several small rivers and streams. In general the harbour water is brackish in character although the low freshwater input results in a relatively stable salinity regime.

The Harbour has an unusual double high water, which is particularly pronounced on spring tides. The tidal regime has a limited range with spring tides of about 1.5m.

A considerable body of work on the marine ecology of the harbour has been established by Peter Dyrynda (Dyrynda, 1987, 1991, 1994, 1995, 1998, 2000 & 2001) and CEH (formerly the Institute of Terrestrial Ecology), for example Maskell, Creer, Hornby, May, Durrell and Gray (1996); Caldow, McGrorty, Durell, and West (2003) and Caldow, McGrorty, West, Stillman & Anderson (in press). The Harbour is characterised by several intertidal species associated with the mud flat areas, including the Ragworm, *Hediste diversicolor* and the King Ragworm *Nereis virens*, the latter of which is sought after by anglers. Dyrynda (2003) also indicates the presence, in the intertidal mudflats, of a characteristic anemone *Cereus pedunculatus* and the burrowing polychaete *Amphitrite johnstoni*. The more sandy sediments closer to the Harbour mouth support species such as the lugworm, *Arenicola marina* and the catworm *Nephtys* *hombergii*, as well as numerous cockles *Cerastoderma edule*.

Similarly there is a considerable literature on the birds within Poole Harbour, with a recent, comprehensive review article completed by Pickess. B. P. & Underhill-Day, J.C. (2002). This article has been employed in this report with respect to bird numbers and distribution data, as it summarises information for the period 1991-1998, based on WeBS counts. Of the wildfowl and waders relevant to this study (i.e. making significant use of the invertebrate prey resource), the Harbour supports internationally important numbers of shelduck and black-tailed godwit and nationally important numbers of avocet, dunlin, curlew and redshank. Other birds considered in the present study include oystercatchers and grey plover.

To provide a framework for the interpretation of the invertebrate data with respect to the bird data, the same sectors, as are applied to the WeBS counts, have been used for the presentation of much of the invertebrate energetic values (see Fig. 2).

Report Structure

The report is comprised of several sections relating to:

- The physical environment
- The invertebrate data including distribution, descriptive communities and their relationship to the physical environment.
- The bird data including relationship to invertebrate availability and energetic value.

METHODOLOGY

Survey Plan

At the outset of the project to survey the invertebrate food resources of Poole Harbour's bird populations, there was no definitive plan as to the distribution of the sampling effort across the Harbour. Following discussions between CEH, EN and the Environment Agency (EA), it was decided that the sampling stations should be spread evenly across all the intertidal areas of Poole Harbour rather than being concentrated solely in those 'more important' parts of the harbour known to be favoured bird-feeding areas. This was deemed to be the most appropriate way in which to gather information on the *potential* food resources available throughout the harbour, irrespective of whether they are currently exploited by the existing populations of birds. It was also agreed that the best protocol (and one that could be applied easily to other locations) for establishing a standard set of baseline sampling stations, which could be revisited in future monitoring exercises, was to utilise the intersections of the Ordnance Survey (OS) grid to define the locations of the sampling stations (Fig. 3.).

A grid of 500 m by 500 m when superimposed on the map of the harbour resulted in 80 OS grid intersections falling between Mean High Water and Mean Low Water as marked on the OS Explorer OL15 map. It was decided that restricting the sampling stations to lie within these tidal bounds was a more appropriate way in which to sample sites to which birds gain access on a regular basis, rather than extending the lower sampling limit to include all areas above Lowest Astronomical Tide. The precise location of each sampling station was determined to the nearest metre from the OS grid co-ordinates.

Sampling protocol

The sampling protocol to be employed at each sampling station was agreed following discussions between CEH, EN and the EA. The main features of the sampling protocol were:

i) using a small deep core (88 sq cm x 30cm deep) to sample the smaller/ more abundant invertebrates,
ii) using a 0.25 sq m scrape of the surface sediment to sample the larger/ less abundant, near-surface dwelling invertebrates,
iii) assessing *Arenicola marina* density by visual inspection of surface casts over an area of 1 sq metre, and
iv) taking a surface scrape of the sediment for particle size analysis (top 5mm only).

It was also decided that it would be valuable to make records at each sampling station of any noteworthy features e.g. presence of vegetation, shell beds, sediment characteristics etc.

Further discussions between CEH and the EA resulted in a decision to expand this protocol at a number of agreed sites, including collection of a 5cm deep core of sediment for further particle size analysis at a total of 46 sediment sampling stations. 250ml and 500ml of surface sediments (top 5mm) were also collected at these stations for the Environment Agency to complete chemical analysis. These data are currently held by the EA and do not form part of this report.

In addition, it was agreed that specimens to be used in establishing the relationship between biomass and size for each of the key invertebrate species should be removed from the main samples prior to their fixation in formalin. In some cases it was, however, necessary to collect additional samples from around the harbour if insufficient data could be obtained from the main samples.

The detailed methodology associated with each component of the survey, the subsequent processing of the samples, and data analyses is presented in the following sections.

Field Methodology

Locating the Sampling Stations

The survey was conducted over September and October 2002. Teams of two CEH staff visited sampling stations at low water on spring tides either on foot or with the aid of the Royal National Lifeboat Institution (RNLI) hovercraft. Teams of three CEH staff visited other sampling stations aboard a boat over high water on neap tides. Samples were collected from as close as practically possible to the pre-determined locations of the sampling stations. A hand-held GPS was used to record the precise coordinates at which each sample was actually taken.

Benthic Invertebrate Sampling

At each sampling station, a single 10.6 cm diameter sediment core was removed with a steel coring pipe to a depth of 30 cm. The bottom half of the core was immediately broken up and sorted by hand to locate the large invertebrates that occurred at this depth. Any such invertebrates were placed with the top half of the core in a labelled plastic bag for further processing. These samples were sieved through a 0.5 mm nylon mesh sieve using seawater to wash out the remaining sediment. This was done either immediately on return to land or, if this was not possible, on the morning following collection. In the latter case, samples were kept at 5°C in a cold-room overnight. All the contents of the sieve (debris included) were fixed in a solution of 4% formalin (40% formalin diluted 1:9 with seawater). Once fixed for a number of days, the samples were washed in freshwater and preserved in IMS prior to processing.

At each sampling station, a randomly chosen area of 0.25 sq meters of the mud surface was 'dredged' using a hand-net with a mesh-size of 2 mm. The larger, near-surface dwelling organisms within the net were collected. These samples were frozen on return to the laboratory at CEH.

At each sampling station, a randomly assigned 1 x 1 m area of the mud surface was inspected (as far as possible given water clarity and weed cover) and the numbers of *Arenicola marina* casts within it counted.

Sediment Sampling

The amount of liquid in all containers of sediment was minimised as far as was practically possible, given that many sediment samples had to be taken through the water column at sampling stations that were visited by boat over high water on neap tides. The stainless steel scoop and teaspoon used to take the samples were washed in seawater between each sampling station.

Particle Size Analysis (PSA) (surface only)

At each sampling station two to three scrapes of the surface sediment (top 5mm only) were removed with a stainless steel teaspoon. These were placed together in a labelled plastic bag and frozen on return to the laboratory at CEH prior to further processing.

Particle Size Analysis (PSA) (top 5cm)

At each of the 46 designated sampling stations a stainless steel scoop provided by the EA was used to take a sample of the surface sediment to a depth of 5 cm (regardless of the presence/absence of black anoxic material). This was placed in a 120 ml plastic pot labelled with the sampling station number. The same scoop was used to collect samples of 250ml and 500ml of surface sediment (top 5mm and avoiding anoxic material) for a variety of chemical analyses by the Environment Agency. These sediment samples were frozen on return to the laboratory at CEH prior to further processing.

Collection of specimens for establishing biomass-length relationships

Individual invertebrates to be used in establishing these relationships were either removed from the main set of 80 samples at the time of sieving, prior to their being fixed in formalin, or were collected separately, specifically for this purpose. For each species, an attempt was made to collect a number of individuals that together spanned the range of sizes present in the harbour. In all cases, single live specimens were placed in individual plastic bags and frozen on return to the laboratory at CEH prior to further processing.

Sample Processing

Benthic Invertebrates

All macro-invertebrates in each core sample were counted and identified to the level of taxonomic detail necessary for the purposes of quantifying the abundance of the various important types of bird food (i.e. species level for all except those such as small worms e.g. oligochaetes, capitellids, spionids, and others such as Nemerteans, Actinarians and Dipterans etc). The length of all individual macro-invertebrates (of species that were deemed to be sufficiently abundant and likely to be of importance as prey for birds) was measured to the nearest millimetre. This was not done in the case of very scarce or exceedingly numerous but very small organisms such as Cirratulid and Tubificid worms. Because some worms were broken either during the coring or sieving process, only worm heads were counted. The length of any broken worms was estimated from the 'breadth' of the remaining front part in comparison with intact specimens present.

All macro-invertebrates in the 'dredged' net samples were also counted, identified to species and measured. As these samples were not intended to sample the smaller species, only data on the larger species were gathered from these net samples.

In practice, the numerical densities of most species were derived from the core samples. Numerical densities were derived from the net samples in the case of *Carcinus maenas, Crangon crangon, Tapes phillippinarum, Crepidula fornicata, Macoma balthica,* all *Littorina spp, Gibbula umbilicalis* and *Hinia reticulata*. The overall numerical density of *Cerastoderma edule* at each sampling station was calculated by combining estimates of the density of individuals <6mm derived from the core and of individuals >6mm from the net sample taken at the same location.

Biomass-length relationships

For each species collected (excepting small worms - see below) individual specimens were processed as follows. Each animal was removed from the freezer, its length (mm) measured (after slight defrosting in the case of worms) and placed in its own individual, pre-dried and weighed crucible to thaw completely. In the case of bivalve molluscs the flesh was removed and processed. In the case of molluscs and crustaceans that are typically eaten whole by birds e.g. *Hydrobia ulvae* and *Carcinus maenas* each animal was processed intact.

The crucibles plus wet flesh were dried overnight in an oven at 90^0C. After the initial period of drying, crucibles were transferred to a desiccator. When cooled to room temperature, each crucible was weighed on a balance accurate to 0.0001 g, the weight (crucible + dry flesh mg) noted, and then returned to the desiccator. Crucibles were returned to the oven for a further 3-4 hours of drying and the procedure repeated until there was no further weight loss (i.e. the samples were dried to constant weight).

The crucibles were then transferred from the desiccator to a muffle furnace and burned at 550^0C, normally for 4-6 hours. The crucibles were then placed in a desiccator, allowed to cool to room temperature and weighed (crucible + ash mg). This procedure was repeated as necessary, burning for further periods of 2 hours until constant weight was achieved.

Subtraction of the final weight (crucible + ash mg) from that attained at the end of the previous stage in the process (i.e. crucible + dry flesh mg) yielded the ash-free dry mass (mg) of each individual specimen of known length.

In the case of species of 'small' worms, a selection of 100 individuals was processed *en masse* in a single crucible, without their individual lengths being measured. In all other respects the procedure was the same as that described above. The final ash-free dry mass was divided by 100 to derive the value per individual. This value was applied in calculating the biomass densities of many of the small worms found in the survey.

Particle Size Analysis

All sediment samples (80 surface scrapes and 46 small cores) were stored frozen. Each sample was first thawed and then thoroughly mixed with a metal spatula. A sub-sample of c30-50 ml was then passed through a 1 mm mesh sieve to remove any invertebrates, algae, other detritus (e.g. shell fragments) and any sediment particles >1 mm in diameter. Particle size distribution between 0.1 and 1000 µm was determined from the sieved sub-samples using a Coulter LS130 laser diffraction analyser. This machine automatically recalibrates various functions between samples and is serviced annually and tested against a series of industrial standards. In the case of samples in which there were inorganic mineral sediment particles > 1 mm in diameter, a note was made in the data set of the nature of these particles, but the contribution of these coarse particles to the overall sediment sample composition was not analysed volumetrically.

Calculation of biomass densities

For each species processed, the raw data relating the ash-free dry mass (mg) of an individual invertebrate to its length (mm) were transformed using a $\log_e$ transformation of both parameters to equalise the variance and allow a linear regression model fitted to be fitted to this data. Using appropriate back-transformation correction factors, the species specific regression equations were then used to generate the predicted values for the ash-free dry mass (mg) of an individual within each millimetre size class across the full size range for that species. These predicted values were then multiplied by the numerical density of individuals within each millimetre size class of the relevant species at each of the 80 sampling stations to yield a value for the biomass density of that size class at that station. The biomass densities of all size classes present at each station were then summed to yield the total biomass density of a species at each of the 80 sampling stations, from which the overall average biomass density of each species across the harbour was derived.

In the case of *Arenicola marina*, for which only the density of casts was assessed at each sampling station, the biomass density at each was calculated by multiplication of the cast density by the average ash-free dry mass of all the individuals processed, to derive the ash-free dry mass – length relationship for that species.

In the case of many of the small tube-dwelling worms, and other small worms, that were not assigned to size classes, the biomass density at a given sampling station was calculated by multiplying the simple numerical density at that station by the average ash-free dry mass of a small worm that was derived from processing 100 such small worms.

In the case of several crustaceans, for which species-specific ash-free dry mass - length relationships were not derived (e.g. *Microdeutopus gryllotalpa*), the relationship derived for *Gammarus locusta* in converting numerical densities to biomass densities was used. In cases in which these crustaceans were also relatively scarce e.g. *Mesopodopsis slabberi* the overall average harbour-wide biomass density was derived by multiplication of the average harbour-wide numerical density (of individuals of all sizes) by the predicted ash-free dry mass of an individual *Gammarus locusta* of the average length of those few individuals found in the 80 samples (n=11 in the case of *M. slabberi*).

In the cases of some very scarce bivalves e.g. *Mya arenaria, Scrobicularia plana,* for which ash-free dry mass - length relationships were nonetheless derived, the overall average harbour-wide biomass density was derived by multiplication of the average harbour-wide numerical density (of individuals of all sizes) by the predicted ash-free dry mass of an individual of the average length of those few individuals found in the 80 samples (n=7 in the case of *Mya arenaria* and n=6 in the case of *Scrobicularia plana*).

Biomass densities were derived for all 'species' whose average numerical density across the harbour exceeded 3 individuals per square meter.

Sample Archiving

The contents of each core sample (including detritus), processed for the purposes of identification, have been stored in a pot containing stabilised IMS, and labelled with station number and date. Pots have been stored in sealed plastic boxes. The contents of each 'dredged' net sample have been frozen in separate polythene bags, labelled with station number and date. These are stored in the freezer room at CEH Dorset. The remainder of all sediment samples that were sub-sampled for particle size distribution analyses have been returned to the freezer at CEH Dorset.

Data Analysis

Invertebrate Data Analysis

Data has been presented in the results in the form of individual species distribution plots, based on the species that contributed most to the biomass. These data have been further analysed using the PRIMER package, which utilises a site classification technique (Bray-Curtis similarity) and a site ordination system employing (Multi-Dimensional Scaling) (Clarke & Warwick, 2001). The preferred output was based on 4^{th} root transformed data. Further statistical procedures have also been employed using this package including SIMPER, which identifies the species that have contributed most to the separation of sites, and BIOENV, which identifies the most influential environmental variables.

Bird Distribution Data

The bird distribution data has been taken from Pickess, B. P. & Underhill-Day, J.C. (2002), which provides values for the relevant bird species, in the WeBS counts areas, on an 8 year average basis (1991-1998). These data have been presented with respect to the species that are major utilizers of the invertebrate prey species.

Mass Balance Calculation

Introduction

The calculation is composed of three major parts as follows:

- Energetic content of the invertebrate communities utilising the field survey and laboratory analysis completed by CEH in autumn 2002.
- A basic data parameters component comprising all the assumptions relating to the energy provided by the invertebrates and used by the birds.
- A calculation of bird energy requirements balanced against energy available.

Energy Availability

The energy content provided by the invertebrates is based on the field survey conducted by CEH during the autumn of 2002. The equations, explaining the weight to length ratios, so that energetic value for each individual can be calculated, are presented in Appendix 1. From these the full spreadsheet of species and biomass was calculated. This spreadsheet , containing all the basic details of the sampling stations, all the species identified at each site, their numerical density, size and biomass, is the functional basis of the overall calculation.

Basic Data Parameters

The basic data assumptions are presented in an attached spreadsheet (Appendix 2). The data included in this sheet are fundamental to all of the subsequent calculation sheets. All values used in subsequent calculations and linked to other pages or other cells are coloured in grey.

The assumptions comprise the following:

- Energy conversion values from kcal to kJ. This has been necessary as much of the historic literature with respect to invertebrates and birds is based on kcal values. The value quoted is an internationally accepted SI conversion value.
- Bird weights for calculation of energetic requirements are taken from a variety of literature including Wilson and Parkes, (1998) Kersten and Piersma (1987) and from the RSPB web site.
- The preferred prey of each species is taken from a wide variety of literature listed in the references and from pers. comms with CEH (letter 06/11/03).
- Energy requirements for each of the bird species have been calculated from the equation of Lasiewski and Dawson, (1967) providing the basal metabolic rate.
- Energy consumption, which takes into account energy required to meet the Basal Metabolic rate (BMR), assimilation efficiency and activity of the birds, has been defined using Evans, Herdson, Knights and Pienkowski (1979) and Kersten and Piersma (1987), with consideration of other literature including Nagy, Girard and Brown (1999). A precautionary approach has been adopted with a worst case value of 4 x BMR employed.
- The number of days each bird is present in the harbour, during the over-winter period (which includes both autumn and winter in most cases), is taken from the 'Important Birds of Poole Harbour and their Status', report by Pickess and Underhill-Day (2002).
- The production to biomass ratio of each of the important invertebrate species based on annual production is taken from a variety of literature. Considerable variation is evident in the calculation of P/B ratios, relating to the fraction of the population being measured, the time of year and the method of calculation. In general the autumn-winter productivity is very low with the majority occurring during the spring and summer. Few broad seasonal estimates are available but a value of 25% has been set for this study. Because a degree of uncertainty exists with respect to winter productivity the calculation presents both measured autumn standing stock values and standing stock plus production values. The conservative, measured autumn biomass has been used in the summary calculation.
- Energy conversion values for the invertebrates have been provided, initially employing kcal from gAFDW values, as these are available in the literature (Evans et.al (1979), with respect to differing components of the invertebrate fauna. These are then converted to kJ from kgAFDW, the latter being the values used in the calculation after multiplication of the initial mg per m^2 per species per site, by the area of each bird sector.
- The final aspect is the area of each of the bird sectors. To enable a clearer idea of where the invertebrate resources are available and how these correspond to the bird numbers, the WeBS sectors have been adopted. It should be acknowledged that bird distribution, with respect to feeding behaviour, is not static, hence basing a calculation on a sectoral format may not truly represent the value of the area to the birds However, the bird data are based on means calculated over 8 years and hence should provide an idea of relative value. This is primarily intended as a guide to assist with management of the Harbour, particularly where rich invertebrate areas correspond with similarly rich

bird use areas. This will be augmented by both a whole harbour estimation of energy availability and requirement and by the identification of the greatest value areas based on individual site data.

Two sources of information were employed for the calculation of the sector areas. The first of these is the area available according to the report of the WeBS data, which extended down to low water of spring tide. The second is based on area calculated using an Admiralty chart (2611), which extends to CD. There are considerable differences in some parts of the harbour, which may be accounted for by inclusion of extensive low water areas on the Admiralty chart that are effectively inaccessible for most of the tide. To take this into account a tidal exposure factor has been included, which represents the proportion of the whole intertidal area available to be exploited by the birds over the period of a tidal cycle. This has been calculated from Poole Harbour tide gauge data as 39% exposure over a neap and spring tide period. When calculated in comparison to the WeBS areas, the Admiralty data with a tidal factor is more conservative in its estimation of intertidal area available.

Calculation of Energetic Values

Calculations have been completed for most of the bird sectors, with an overall value calculated for the whole harbour. Two of the sectors were not sampled for invertebrates, hence they have been included only within the overall calculation.

The calculation sheets are in two parts. The first of these, with an example illustrated in Appendix 3, is linked directly to the source biomass data in an Excel file ENINVERTEBRATES.XLS (summary biomass and summed numbers of individuals in Appendix 4). For each sector a single file was established summing all of the relevant biomass values for each species. This was then used to calculate the mean biomass contributed by that species for the whole sector, as well as the standard deviation of the biomass, the maximum biomass and the production. Those sections on the calculation page marked in light grey draw source data from the Basic Data Parameters page, while the sections marked in dark grey are linked to the individual site and species data in ENINVERTEBRATES.XLS. Only example or summary sheets have been included in this document as they comprise a considerable amount of information. All information is included on the CD accompanying this report.

The next stage comprises several separate calculations relevant to each bird species feeding in each sector. Each bird species has a value for number of birds present, recorded on a once per month basis. The calculation on energy required by each bird is based on the number of birds recorded in this one survey day in the month, multiplied by the number of days the bird is present during the autumn and winter. The energy requirement of the each of the birds and the energy provided by their preferred species can then be calculated. Clearly more than one bird species can feed off the same invertebrate species, so an overall sector value has also been calculated. The different values enable an estimation to be made of where prey species-specific shortfalls may exist, and hence priority to enhancement management may be directed. This is of course tempered by the fact that in many cases birds move within the harbour to exploit other resources or are feeding off different species of invertebrate.

Each of these sector pages has been combined on to one page to give an overall harbour total in relation to the birds present. The total has been calculated by using both summed sectoral data, which employs a meaned value for bird requirements over the autumn and winter period, but also overall harbour values for the bird species, which takes account of variation through the over-winter period.

RESULTS

The results have been presented in relation to the following sections:

- The physical environment
- The invertebrate data including distribution, descriptive communities and their relationship to the physical environment.
- The bird data including relationship to invertebrate availability and energetic value.

Interpolation of data is employed in those figures where gradients may be evident. The parameters applied to each plot are given in Appendix 5.

Physical Environment

The physical environment has been recorded and described during the field exercise and all basic data are included in Appendix 5. These include the sample locations, both those planned and those actually sampled. The site locations are illustrated in Fig. 3.

Sediment Character

The sediments of the Harbour are for the most part fine muds, with almost 80% of the sites sampled having a median diameter less than 63 µm. The remaining sites comprised of sands to fine sands with a median diameter less than 500µm. Figure 4 illustrates the distribution of the sediments within the harbour. The different fractions presented in the Appendix 5 table have been employed to describe the sediment types. i.e. fine silt, silt/fine sand and sand. The median diameter generally corresponds to the dominant substrata type, however, mixed sediment types have also been identified and these have been plotted as a separate set of sites in Fig. 4.

The plotting of the predominant sediment type (the sediment fraction representing more than 45 % of the total sediment sample) or mixed sediment type indicates a clear distribution in the Harbour. The areas to the west and south-west of the Harbour, adjacent to the small creeks and channels of Middlebere Lake, Wych Lake and Wareham channel generally contained the finest sediments, with many of the other more sheltered sites consisting of fine silty sediments. More silty sand sites were evident in the wider Wareham channel area and at several low water sites both in the southern Harbour area and southern Holes Bay. The sites that were composed of the greatest amount of sand were located towards the Harbour mouth, although several sites occurred along the main channel, adjacent to the islands and headland features. Mixed sediments were scattered throughout the harbour with several areas in Holes Bay and a group of sites to the south of Brownsea Island into Brands Bay.

Tidal height and exposure

The majority of the sites sampled (70%) were located in the mid to upper shore area. The tidal range sampled was from 0.2m above Lowest Astronomical Tide (LAT) to 2.1m above LAT. A comparison of the tidal height against mean period of exposure during both neap and spring tides has been plotted in Fig. 5, illustrating that most of the intertidal area below 1.5m (above LAT) is uncovered for less than 180 minutes (3 hours) per tidal cycle.

Macroalgal cover

The macroalgal cover comprised primarily *Ulva* spp and *Enteromorpha* spp. Percentage cover ranged from 0 to 100%. Comparison with the tidal height and exposure indicated no relationship, i.e. the cover of macroalgae was highly variable at all tidal heights. In general the algal cover was most prevalent in the sheltered areas where finer sediments were located. This has been illustrated in Fig.6 which demonstrates the sheltered nature of most of the sites where 100% cover was recorded, including Holes

Bay, Wareham Channel and south west of Brownsea Island. Much of the lower percentage cover by algae was also noted in the area to the south and south-west of Brownsea island. The majority of the low to zero percentage algal cover was at low water sites or at sites with higher percentage sand composition.

Biological Environment

Basic ecological data

A total of 61 species were found in the survey of the Harbour, these comprised of 23 annelids (20 polychaetes), 20 crustacea, 15 molluscs and 3 other species including diptera, ascidians and cnidaria. The maximum number of species at any site was 21 (site 40) and the minimum was 1 (site 17). The greatest concentration of sites with high species number was in the area south and west of Brownsea island (Fig. 7), although these were also mixed in with a large number of low density sites. Holes Bay also supported several sites with large numbers of species.

Abundances ranged from 8 per square metre to 76,761 per square metre. The majority of sites with high numbers of individuals were found in Wareham Creek and Lytchett Bay (Fig. 8). There were also several sites in sheltered locations on the southwestern shore, including Arne bay and Newtown Bay where high abundances were recorded. The highest abundances were generally recorded at the finer sediment sites, where little algal cover occurred. The distribution of these sites suggest that shelter is an important factor in encouraging the high abundances.

Biomass ranged from 0.65g per square metre to 113g per square metre. The highest biomass values were recorded at sites near the foreshore of Poole town, including the entrance to Holes Bay and Parkstone Bay as well as scattered sites on the south-western shores, Harbour mouth and in Wareham Channel, although the single highest value was noted in Holes Bay, site 55. (Fig. 9).

Individual species distribution

The distribution of the species that contributed most to the biomass have been displayed in Figs. 10 to 24. These are illustrated in terms of mg of biomass per square metre.

Cirratulis filiformis (Fig. 10)
This species contributed the majority of the small annelid biomass. Biomass exceeded 52,000mg per square metre, with the maximum occurring at site 11 in Wareham Channel. Several other high biomass sites were noted in Wareham Channel as well as in Lytchett Bay. Other isolated high values were noted in sheltered, low water locations where high levels of fines were found in the sediment.

Tubificoides sp. (Fig. 11)
The other large contributor to the small annelid biomass was the oligochaete *Tubificoides* sp. This taxon was sporadically distributed around the harbour, with the greatest biomass values generally located on the southern shore, although the single highest value was founds at site 10 in Wareham Channel. The greatest values were located towards the mid-upper shore at sites with high fines values in the sediments.

Malacoceros fuliginosus (Fig. 12)
M fuliginosus was the only other small polychaete present in large numbers, with a maximum biomass of 5,870mg per square metre found at site 46 in Holes Bay. Other than this location the highest biomass values were found in Wareham Channel, Lytchett Bay and in various locations on the south western shore. This species was similar to *C. filiformis* in that it was found in sheltered conditions in sediments with high levels of fines.

Nereis virens (Fig. 13)
N. virens contributed the largest overall biomass of any species in the harbour, however, this was highly concentrated at a relatively few sites, due to the high individual biomass of this species. The single

highest biomass of 100,898 mg per square metre was found at site 55 in Holes Bay, comprising one individual. Other high values were scattered around the harbour at a variety of sites, generally in areas with low tidal exposure and with high fines sediments.

Hediste diversicolor (Fig. 14)
The other major contributor to the biomass of the large polychaetes was *H. diversicolor*. This species was found in the greatest densities in Wareham Channel and Lytchett Bay, with the single largest value found at site 4. Other sites included several in the vicinity of Poole town foreshore and in Middlebere Lake. Large quantities of fines in the sediments was an important factor influencing the distribution of this species, although the location of most of the sites with high biomass in Wareham Channel, suggests that the influence of freshwater was also important in the distribution of this species.

Other contributors to polychaete biomass were made by *Arenicola marina* (Fig. 15) and *Nephtys hombergii* (Fig. 16). Both of these species were generally distributed towards the harbour mouth with high biomass sites found, in particular, to the south of Brownsea Island and on the Poole foreshore. *Nephtys hombergii* was more widely distributed including several, generally lower biomass, sites in Wareham Channel. *Arenicola marina* was clearly related to the more sandy sediments, whereas *N. hombergii* was found in mixed sand and muddy sediments.

Mya arenaria (Fig. 17)
The largest contributor to biomass due to the mollusca, was from *Mya arenaria*, although this species has a very high individual biomass and distribution was highly sporadic. Sites occurred near the harbour mouth as well as extending almost to the head of Wareham Channel.

Cerastoderma edule (Fig. 18)
A similarly high biomass was contributed by *C. edule*, although this species was more evenly distributed, occurring throughout the harbour. The highest biomass values were noted in Holes Bay with several further sites in the southern part of the Harbour. This species was also present in all sediment types and on all shore levels, although not generally noted in the areas subject to freshwater input at the head of Wareham Channel or Middlebere Lake and Wytch Lake.

The other large bivalve molluscs, *Tapes phillipinarum* and *Scrobicularia plana*, also contributed a large proportion to the overall biomass. *T. phillipinarum* (Fig. 19) was generally distributed in discrete patches, including groups of sites in Wareham Channel, Holes Bay and in the vicinity of Ower Bay, with the highest density occurring off Poole foreshore. *Scrobicularia plana* (Fig. 20) was found at only 5 locations, but contributed significant amounts to the biomass, where present.

The remaining bivalve mollusc, *Abra tenuis*, contributed very little to the overall biomass, although it made contributions to various sectors where discrete patches occurred, particularly Lytchett Bay and in the vicinity of Round Island (Fig. 21).

The prosobranchs molluscs also made limited contributions to the biomass with *Hydrobia ulvae* (Fig. 22) occurring over a range of sites, generally in sheltered upper shore areas, including several of the enclosed bay areas similar to *Abra tenuis*. The highest biomass sites were located in fine sediments and in many cases with dense algal cover. The other prosobranch found in the Harbour at high biomass was from the *Littorina* species group, occurring at very few sites, but at high biomass when present, e.g. site 71 with 37,810 mg per square metre.

In general the Crustacea contributed little to the overall biomass, although several species had discrete distributions, hence they made contributions to well defined areas. In particular, the small Isopod, *Cyathura carinata* contributed to the biomass in relatively small areas at the head of Wareham Channel, Lytchett Bay and Holes Bay (Fig. 23). The single highest density was noted at site 11, typical of the low tidal exposure and high fines sediment sites in which this species was found. *Corophium volutator* also demonstrated a relatively discrete distribution (Fig. 24), with the highest abundances in the upper shore sites of the Middlebere and Wych Lake areas.

Multivariate analysis of data

The results of the multivariate analysis of the data are presented in Appendix 6. A variety of transformations and data formats were employed of which several are presented. The final dendrogram and ordination are illustrated in Fig. 25. Based on the dendrogram, six major groupings were identified, defined as clusters A to F. When viewed on the ordination plot it is evident that some distortion of the data has occurred in the production of the 2D interpretation, hence the relatively high stress factor of 0.25 (which represents the goodness of fit to the real inter-site similarity). The clusters identified in the dendrogram, however, show a relatively clear separation and may be considered as discrete groupings of sites.

Table 1 summarises the composition of each of these clusters. Two large clusters exist (A and B) comprising 26 and 19 sites respectively.

Cluster A contained relatively few species per site (8.4) and was characterised by a group of polychaetes, primarily *Hediste diversicolor, Cirratulus filiformis* and *Malacoceros fuliginosus*. The most abundant species was *C. filiformis*. Overall abundance was high with an average of 16,800 individuals per metre squared per site. Biomass was also at a relatively high level in excess of 30g per square metre.

The distribution of this cluster (A) illustrated in Fig. 26, indicates that most sites were located in Wareham Channel, although other sites from this cluster were also found at isolated locations throughout the harbour. Table 2 indicates the physical conditions existing at the sites in this cluster. The sediments at these sites clearly comprised of fine silts and clays, with only very small quantities of sand. The algal cover was generally low, although highly variable. The period of tidal exposure was very limited with most sites occurring towards low water.

Appendix 6 indicates that the reason clusters A and B separated was due to the greater abundance of the oligochaete *Tubificoides* sp. in cluster B and the reduced abundances of the polychaete *Hediste diversicolor* and the isopod *Cyathura carinata*. In general Cluster B comprised more species and had a larger number of individuals per site than cluster A. The principal species of the group consisted of *Cirratulus filiformis* and *Tubificoides* sp. A significant contribution to the group was also made by the bivalve *Cerastoderma edule*, which along with the high biomass values contributed by the small annelids has resulted in a relatively high biomass of 33g per square metre.

The distribution of the sites from cluster B were relatively well defined, comprising a large area in the vicinity of Round Island and Green Island as well as a group of sites in Holes Bay (Fig. 26). The physical conditions present in these sites suggest a relatively high level of fines, but with a greater proportion of sand than was found in the Cluster A sites. Algal cover was also relatively high, although quite variable. The shore position of these sites was also variable, although generally from around mid-shore level.

Cluster C comprised only four sites, characterised by low abundance and very low biomass (4g m^{-2}). This cluster supported a variable group of species, including many of the species that characterised the two major clusters (A & B), particularly *Cirratulus filiformis, Hediste diversicolor* and *Cerastoderma edule*. The species that have contributed to the separation of this cluster from most of the others, were the small bivalve *Abra tenuis*, the polycheate *Nepthys hombergii* and an indeterminate anemone. The distribution of this cluster was highly sporadic (Fig. 26) including an isolated site in Wareham Channel, around Round Island and towards the Harbour mouth. The physical data suggests that these sites were from highly variable sediment types, containing significant quantities of sand but also comprising large quantities of silt. The sites were generally from low shore sites with only limited tidal exposure.

Cluster D was characterised by the low mean number of species per site (5.3) also with relatively low biomass and abundance. The oligochaete *Tubificoides* was the characteristic species of this cluster, in association with the polychaete *Hediste diversicolor* and the amphipod *Corophium volutator*. The sites were generally located in the upper shore, in the small channels and peripheral areas of the harbour (Fig.26). Sites 75, 61 and 47, which were unclassified in the MDS analysis, but were closely associated with this cluster have also been included in this group on the illustration. The sediment characteristics of the cluster were similar to those of cluster A with high fine sediment levels. The sites also supported relatively high levels of algae (mean value 55%). Although no records of salinity were made it is likely that this cluster was associated with freshwater input, based on the site locations.

Cluster E although relatively low in species numbers (7.7) and abundance supported the highest mean biomass. This was due to the frequent presence of the bivalve molluscs *Cerastoderma edule* and *Tapes philippinarum*, as well as the high biomass species *Carcinus maenas* and the King Ragworm *Nereis virens*. The sites from this cluster were in relatively well defined locations, including a group of sites in the entrance to Holes Bay and two sites south of Brownsea Island. The sediments were characteristically mixed, from a wide range of levels on the shore.

The final Cluster, F, supported a relatively large number of species, with high biomass, despite generally low abundance. This was due to the presence of the high biomass species *Nereis virens* and the lugworm *Arenicola marina*. The species that characterised this cluster were generally small annelids, particularly the polychaetes *Scoloplos armiger* and *Spionid* indet. The sites from this cluster were all from the lower reaches of the Harbour, including several sites by the Harbour mouth and in the vicinity of Brownsea Island. The physical characteristics of the sites was typically sandy with very little fine silt. Generally the sites were from mid to upper shore.

The BIOENV analysis (Appendix 6) revealed that the physical environmental factors that most affected the separation of the clusters were a combination of percentage fines (<63 microns), the percentage coarse sediment and the tidal exposure period. Of these, the percentage coarse sediment was the single most influential factor.

Table 1. Site clusters summary biological information

	A	B	C	D	E	F
Total no sites per cluster	26	19	4	12	6	8
Total no sp per cluster	31	41	15	24	20	30
Mean no sp per site	8.4	11.1	7.5	5.3	7.7	9.3
Mean no individuals per site	16802	17746	1975	6455	3229	6950
Mean Biomas mg AFDW per site	30191	33491	4731	9300	40962	33899
Top 50% frequency In order of occurrence	Hediste diversicolor Cirratulus filiformis Malacoceros fuliginosus Cyathura carinata Hydrobia ulvae Cerastoderma edule Tubificoides	Cirratulus filiformis Tubificoides Cerastoderma edule Anemones (unident) Malacoceros fuliginosus Abra tenuis	Cirratulus filiformis Abra tenuis Anemones (unident) Hediste diversicolor Nepthys hombergii Cerastoderma edule Gammarus locusta	Tubificoides Hediste diversicolor Hydrobia ulvae	Cerastoderma edule Hydrobia ulvae Carcinus maenas Nepthys hombergii Anemones (unident) Nereis virens Tapes philippinarum	Cerastoderma edule Tubificoides Spionid spp. Scoloplos armiger Arenicola marina Hydrobia ulvae Nereis virens
Top 50% Abundance	Cirratulus filiformis	Cirratulus filiformis Tubificoides	Cirratulus filiformis Abra tenuis Anemones (unident)	Tubificoides Corophium volutator	Cirratulus filiformis Spionid spp. Hydrobia ulvae	Scoloplos armiger Tubificoides
Internal similarity >75% contribution	Cirratulus filiformis Hediste diversicolor Malacoceros fuliginosus Cyathura carinata	Tubificoides Cirratulus filiformis Anemones (unident) Cerastoderma edule Malacoceros fuliginosus	Cirratulus filiformis Abra tenuis Hediste diversicolor	Tubificoides Hediste diversicolor	Hydrobia ulvae Cerastoderma edule Nepthys hombergii Carcinus maenas	Tubificoides Scoloplos armiger Spionid spp. Cerastoderma edule

Table 2. Site clusters physical descriptions.

[illegible]	A	B	C	D	E	F
Mean and sd of fine silt and clay content % <20um	45	40.3	38.5	43.3	36.7	13.5
	9.9	16.1	17.3	9.2	12.1	14.2
Mean and sd of coarse silt % >20um and <63um	33.1	24.5	22.8	30.7	28.2	9.8
	5.8	10.0	11.1	7.4	11.7	:3.4
Mean and sd of fine sand % >63um <125um	10.5	8.4	8.5	10.5	11.2	5.2
	3.9	3.7	5.8	2.9	4.2	5 ´
Mean and sd of coarse sand >125um	11.9	25.8	32.2	15.6	24.0	71.6
	13.1	26.4	31.2	13.8	27.1	32.4
Mean and sd of percentage algal cover	19.8	49.4	30.0	56.0	34.2	27.1
	38.5	44.8	42.4	41.0	36.8	38.8
Mean and sd exposure in minutes per tidal cycle	135	296	135	284	275	231
	110	232	89	262	164	242
Mean and sd of height above LAT	1.2	1.3	1.1	1.4	1.3	1.3
	0.2	0.5	0.4	0.5	0.5	0.4

Table 3. Summary of bird density as mean annual counts in numbers per hectare

Species	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Shelduck	14	1	5	5	6	4	0	0	4	9	17	17	14	12	12	9	11	1	14	2	1	3	5	8	5	21	4
Oystercatcher	48	17	2	9	21	45	49	73	14	49	30	50	78	47	47	21	7	20	57	21	17	72	119	12	80	59	5
Grey Plover	1	0	0	0	0	0	0	0	0	3	7	4	24	5	3	5	1	7	31	0	0	2	15	0	11	0	0
Avocet	0	0	0	0	0	0	0	0	0	0	0	3	12	56	0	11	1	0	0	1	0	0	0	0	0	0	0
Dunlin	3	1	13	140	26	37	98	38	42	8	40	15	167	105	51	91	23	12	551	1	0	34	352	119	364	142	87
Redshank	1	5	68	110	174	54	5	6	11	13	48	20	30	28	38	16	4	3	52	0	3	14	46	85	2	28	9
Black Tailed Godwit	6	1	17	76	60	13	0	0	0	18	61	14	37	26	64	16	12	1	63	5	2	5	30	36	170	57	105
Curlew	7	1	11	27	42	44	9	0	6	24	15	31	101	97	43	45	15	5	140	4	3	42	115	16	160	153	63

Bird distribution data

The distribution of the birds within the harbour is based on the 1991-1998 yearly averaged data summarised in Pickess & Underhill-Day (2002). Fig.27 illustrates the total number of birds for all the relevant species in each sector. It is evident that in relation to total bird numbers, the largest numbers have been recorded in sectors SE2, W4 and W2W, the three largest sectors in terms of mud area. To indicate the density of the birds, which is more relevant to utilisation of the prey, the subsequent illustrations represent annual average values in numbers per hectare per sector. Table 3 summarises data for all relevant species and Fig.28 to Fig.35 indicates the distribution graphically. For a more full description of bird distribution and reasons for annual and regional variability see Pickess & Underhill-Day (2002).

Shelduck (*Tadorna tadorna*) (Fig. 28)
The greatest density of birds has been recorded in area W5 in Wareham Channel. This is a relatively isolated value, with the majority of the high bird densities occurring in the Southern Central area including sites SC2, SC3, SC4 and extending to SE2.

Oystercatcher (*Haematopus ostralegus*) (Fig. 29)
The majority of the high values for oystercatcher were from Wareham Channel, although several other moderate to high values were noted southwest and northeast of Brownsea Island. Oystercatchers in general were widely distributed around the harbour.

Grey Plover (*Pluvialis squatarola*) (Fig. 30)
The densities of grey plover were discretely distributed into three areas, including two areas on the southwestern shore of the Harbour, in the vicinity of Green Island and in Brands Bay. Relatively large densities were also noted from Wareham Channel in sector W2W.

Avocet (*Recurvirostra avosetta*) (Fig. 31)
The avocet had a very well defined distribution, limited to the vicinity of Wych Lake (SC5) and some of the adjoining sectors. In almost all other sectors the bird was not recorded.

Dunlin (*Chalidris alpina*) (Fig 32)
The densities of dunlin were very high at several locations in the Harbour, but the most noticeable were at SE2 in Brands Bay and several areas in Wareham Channel, particularly towards the head of the channel.

Redshank (*Tringa totanus*) (Fig 33)
The most important area in the Harbour for redshank would appear to be Holes Bay where two very high sector densities were noted. Other areas included Brands Bay and Lytchett Bay.

Black Tailed Godwit (*Limosa limosa islandica*)(Fig. 34)
The highest density bird use by Black Tailed Godwit was noted in the head of Wareham Channel, particularly in W4. Other locations where the bird was found in numbers were sheltered locations including Holes Bay, Brands Bay and Newtown Bay.

Curlew (*Numenius arquata*) (Fig. 35)
This species was located primarily in Wareham Channel, with particularly large densities noted in W4 and W5. Other locations where high densities were noted were Brands Bay and adjacent to Round Island in sectors SC5 and SC4.

Predator Prey Energy Balance

The results of the energy balance calculations are presented in Appendix 7. These comprise the energy requirements of the avifauna and the energy available to each species within each WeBs sector, or in some cases combined sectors. These calculations are based on the contributions made by each invertebrate species averaged across the sites in each sector. These source data are available in the information provided to English Nature as part of this document in a CD. Table 4 summarises the total requirement for each sector and corresponding energy available.

Table 4. Energy available and energy required in each sector.

[illegible]	Energy Requirement (kJ x 10^6)	Energy from Prey Available (kJ x 10^6)	Ratio energy available to required
W6	49.39	72.77	1.5
W5	141.17	164.78	1.2
W4	144.33	430.21	3.0
W3	55.88	339.50	6.0
W2W	120.28	266.50	2.2
W2E	41.56	192.48	4.6
W1/W2	15.04	263.85	17.7
NC3NW/SW	84.91	159.74	1.9
NC3NE/SE	95.44	589.27	6.2
NE3	30.84	745.23	24.2
NE1	20.20	481.14	23.8
SE1	9.48	356.22	37.6
SE2	187.92	264.75	1.4
SC1/2	90.69	127.71	1.4
SC3/6	102.74	474.40	4.6
SC4	123.28	423.91	3.4
SC5	101.63	223.00	2.2
SC7/8	69.46	311.38	4.5
Total	1492.53	5899.83	4.0

The highest requirements for energy were noted in sector SE2 in Brands Bay and two sectors in Wareham Channel W4 and W5. The lowest energy requirement was noted in Area SE1 near the harbour mouth. The corresponding energy due to prey availability demonstrated a slightly different distribution, with the greatest values available in sectors NE3, adjacent to Poole town and in NC3NE/SE in Holes Bay. The former corresponded with one of the lowest energy requirement areas. The total energetic requirement for the Harbour is 1,492 kJ x 10^6, while the total energy available is 5899.83 kj x 10^5. Clearly some sectors had available food reserves well in excess of the sector requirement, particularly those close to the Harbour mouth and near the town of Poole (Parkstone Bay) where the ratios between availability and requirement exceeded 20:1. Lowest ratio values were noted in sectors W6, W5, SE2 and SC1/2. The overall ratio based on the sectoral analysis gives an availability to requirement value of 4 to 1.

The relationship overall between available energy and requirement on a sectoral basis has been expressed in Fig. 36. No clear trend is evident, with both peak energy requirement and minimal requirement occurring in areas with similar available energy values (e.g. 250-350kJ x 10^6). Overall the data suggest that you do not get more birds where food is most abundant. As a consequence it is likely that some sectors will be subject to over-utilisation and others are under-utilised, based on the available food resources. This is further illustrated on the basis of individual bird species requirements in Table 5.

Table 5. Bird energetic requirements and energy available on a per sector basis

Bird Species	[illegible]	W1	W3	WI	WO	WZW	WZE	WF W2	NCAW	HOLF	RED	NFI	SEI	SEY	SSTW	SBU	SCO	SBS	SSTUD
Shelduck	Available	34.2	121.2	250.6	161.9	53.617	54.4	81.7	84.1	87.9	173.8	124.0	97.5	41.5	54.5	178.4	214.7	68.6	56.6
Tadorna tadorna	Required	5.1	56.7	25.3	28.6	25.0	5.4	1.4	24.3	20.3	1.8	0.2	1.7	79.2	44.1	31.3	43.0	38.1	28.3
	ratio	6.8	2.1	9.9	6.4	2.1	8.5	57.0	3.5	4.3	94.6	778.3	56.6	0.5	1.2	5.7	5.0	1.8	2.0
Oystercatcher	Available	31.5	34.1	186.96	130.2	197.6	26.4	158.3	52.0	179.0	301.7	170.5	116.7	43.7	27.2	161.3	111.4	109.1	34.0
Haematopus ostralegus	Required	1.2	14.8	19.8	2.9	29.6	17.8	9.5	5.8	13.3	21.5	12.3	4.8	14.3	19.6	24.2	19.5	11.4	7.2
	ratio	25.3	2.3	9.4	45.0	6.7	1.5	16.6	9.2	13.4	14.1	13.9	24.1	3.1	1.4	6.7	5.7	9.3	4.7
Grey Plover	Available	65.2	153.7	304.6	267.9	105.49	89.4	117.7	109.3	194.7	295.7	167.9	132.9	79.7	68.3	214.5	282.8	78.4	87.2
Pluvialis squatarola	Required	0.0	0.1	1.4	0.0	2.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	4.1	1.3	1.1	3.2	0.7	0.8
	ratio		2408	215		53	429		6903				654	19	51	203	88	116	112
Avocet	Available	70.9	156.9	324.2	236.5	135.54	85.6	105.3	89.6	94.3	201.8	167.8	116.1	69.5	66.8	206.2	250.3	94.5	106.4
Recurvirostra avosetta	Required	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.5	7.2	1.4
	ratio					2479.5	7315.7	1148.7						1802.4	3146.7	471.5	165.2	13.0	73.5
Dunlin	Available	71.5	159.1	324.5	248.8	136.92	88.1	110.6	87.2	87.0	262.1	168.1	116.8	75.4	74.3	207.5	258.9	98.4	109.7
Calidris alpina	Required	3.8	6.3	16.1	5.2	15.5	1.5	0.0	1.7	7.0	3.5	4.3	0.5	24.4	2.1	2.9	7.4	4.8	5.0
	ratio	18.7	25.3	20.2	47.7	8.8	56.7	4257.7	57.1	12.4	74.4	39.0	214.4	3.1	34.9	71.4	35.2	20.8	21.7
Redshank	Available	66.8	156.8	335.5	275.7	138.24	92.9	111.4	89.0	146.1	262.0	164.1	99.4	77.7	72.5	189.8	279.9	195.9	106.5
Tringa totanus	Required	0.9	2.6	0.2	8.0	4.3	1.4	0.3	22.8	15.5	1.6	0.5	0.3	8.7	5.8	5.4	2.8	2.5	1.5
	ratio	78.4	59.3	1637.8	34.4	31.5	68.6	334.2	3.9	9.5	164.1	342.5	316.0	8.9	12.5	35.2	99.5	79.6	55.0
Black-tailed Godwit	Available	30.5	44.2	180.0	154.6	214.88	141.5	172.7	72.7	501.5	468.8	357.2	260.8	223.7	83.1	297.2	178.9	155.3	254.8
Limosa limosa islandica	Required	17.0	9.2	27.6	5.8	4.8	0.0	1.1	12.5	14.5	0.0	0.0	0.2	10.2	12.8	12.8	6.1	4.3	4.6
	ratio	2.3	4.8	6.5	26.4	44.5		156.5	5.8	34.6			1127.8	21.9	6.5	23.8	25.5	36.5	55.9
Curlew	Available	31.5	[illegible]	83.8	129.3	113.26	35.4	36.8	92.8	157.8	195.5	114.9	158.3	44.1	30.6	37.8	75.8	111.3	34.0
Numenius arquata	Required	21.4	[illegible]	54.0	5.4	38.0	14.2	2.5	18.0	24.?	2.3	2.9	1.5	[illegible]	13.2	24.9	33.9	32.5	20.2
	ratio	1.5	[illegible]	1.6	24.2	2.5	2.5	14.5	1.9	5.6	83.6	39.5	104.4	[illegible]	2.3	1.5	2.2	3.4	1.7

Values for individual bird species in relation to energetic requirement and availability is given in Table 5. In nearly all cases the availability of food exceeded the requirement, although exceptions existed for both shelduck and curlew, in sector SE2 and for the latter in W5 as well.

A further consideration of the relationship between the food availability and birds feeding requirement is demonstrated in Table 6. This table summarises the actual number of bird days in the Harbour during one overwinter period, based on the mean values per species over an 8 year period given in Pickess & Underhill-Day (2002). The energy requirements of each species are those used in the overall calculation and indicated in the assumptions page (Appendix 2). The food density is based on the prey specific species data presented for each sector that has been averaged across all sectors for each species. Using the overall area of the harbour it has been possible to calculate the potential bird days for each species using the equation:

$S_p = (f \times A)/r$

Where S_p = the potential bird days; A = the area of the harbour in square metres; r = minimum energy requirement per day per bird and f = food available per square metre. The potential bird days does not take into account any interactions between bird species or within species, reduced efficiency or other factors that may result in a less effective use of available resources.

The table also presents a ratio between the predicted number of bird days S_p and actual number of bird days S_a.

The ratio between potential capacity and actual use varied between a minimum of 3.5:1 to a maximum of 184:1. Two species were found at the minimum value, these were shelduck and curlew. The other species had ratios in excess of 7:1. These data, however, represent utilisation by individual species of what is, in most cases, a shared resource. Therefore, an overall value has been calculated using the total actual number of days for all birds, a species weighted average for the energy requirement and a sectoral based sum for the available energy. A value of 9,932,185 m² has been used as the value for the total exploitable area. This has generated an overall ratio between the predicted number of days and the actual number of days of 3.5:1 for the whole harbour, taking into account the shared resources. This differs from the previous value of 4.0 in Table 4 due to the inclusion of two sectors in the latter calculation (NC1 and NC2) which were not included in the invertebrate energy availability due to lack of data, although they do support birds during most of the over-winter period.

Table 6. Predicted number of bird days in comparison with actual number of days recorded.

[illegible]	[illegible] (S_a)	Energy Required [illegible] per [illegible] (kJ)	[illegible] (kJ [illegible])	[illegible] days (S_p)	[illegible]
Shelduck	347,332	1624.51	200.40	1223037	3.5
Oystercatcher	289,629	1023.84	204.05	1979814	7.3
Grey Plover	27,698	554.76	288.74	5169556	184.6
Avocet	54800	605.66	285.42	4345394	79.3
Dunlin	621505	181.98	272.20	14857672	23.9
Redshank	225138	387.82	287.78	7373941	32.8
Black-tailed Godwit	224586	867.71	382.41	5608407	25.3
Curlew	305387	1383.89	147.34	1055181	3.5
Total	**2,076,332**	**601**	**594.01**	**7,366,855**	**3.5**

DISCUSSION

The current study has demonstrated the distribution of invertebrates in Poole Harbour, with a consideration of the energetic value of these invertebrates and their relative value to the wading and wildfowl birds that over-winter in the area. The construction of a simple model, or mass balance calculation has allowed the estimation of the ratio between energy available and energy required for each of 8 bird species in each of the WeBs count sectors, and across all species and sectors. Furthermore it has been possible to estimate the ratio between the potential and actual number of bird-days supported by the macroinvertebrates within the harbour as a whole. There are several constraints to the use of this data and these will be discussed in this section, along with the nature of the invertebrate composition, biomass and distribution.

Invertebrate Composition and Biomass Distribution

The invertebrate composition in Poole Harbour is typical of the shallow embayments that occur along the UK central south coast, including the harbours in the vicinity of the Solent; Pagham, Chichester, Langstone and Portsmouth as well as the smaller harbour of Christchurch, located between Poole and the Solent (Thomas, 1987; Portsmouth Polytechnic, 1976, Holme & Bishop, 1980; Dixon, 1989). The dominant fauna of these harbours is composed of numerous small annelids, including considerable numbers of cirratulids such as *Cirratulus filiformis* found in Poole Harbour and *Aphelochaeta (Tharyx) marioni* found in the Solent Harbours. The tubificid oligochaetes are also prevalent throughout the region and are frequently found in considerable abundance, particularly where enrichment occurs. The prosobranch mollusc *Hydrobia ulvae* is another characteristic species in all of the harbours, although the occurrence and abundance of this species is subject to some variability as it is frequently associated in very large numbers with the presence of smothering green algae (Nicholls, Tubbs and Haynes, 1983).

In terms of biomass the small annelids contribute a considerable proportion of the total, due to their large numbers. In Poole they constituted 35% of the total biomass, with *C. filiformis* alone contributing 20%. Data for biomass from the similar Solent systems suggests that the small annelids make a lesser contribution, particularly where algal cover exists. Based on studies in Chichester Harbour (Thomas, 1987) and Langstone Harbour (Nicholls, Tubbs and Haynes, 1983), the more numerous prosobranch molluscs, primarily *Hydrobia ulvae*, make up the majority of the biomass in many cases. However, where these are absent the annelids in general are the biggest contributors to biomass.

The most characteristic species within Poole Harbour, other than the small annelids are the large polychaetes, *Nereis virens*, *Arenicola marina*, *Hediste diversicolor* and *Nephtys hombergi* as well as a group of bivalve molluscs, including *Mya arenaria*, *Cerastoderma edule*, *Scrobicularia plana* and *Tapes phillipinarum*. Of the latter group *M. arenaria*, *S. plana* and *T. phillipinarum* are generally not found in any abundance in the environmentally similar Solent Harbours, with *T. phillipinarum* particularly characteristic of Poole Harbour. The large polychaetes and the bivalve molluscs, between them contribute 60% of the biomass, with the large polychaetes constituting 30%. Several species have a high individual biomass, but were not widely present, hence their value to the energetics of the system was concentrated in relatively small areas of the harbour. This is particularly true for the polychaete *N. virens* and the bivalve *T. phillipinarum*. The distribution of these species is therefore of considerable importance in any consideration of their value to bird species. The case of *T. phillipinarum* illustrates this point, as the high biomass this species contributes at site 71 is in an area where, in general, bird counts are low although numbers of oystercatchers, which feed on this species, are relatively high. Hence the area has considerable, species specific value, despite the disturbance and pressure on the area due to the proximity of the activities related to the town of Poole.

Another example of the distribution of prey species having a potentially disproportionate value to the bird species is that of *Corophium volutator*. This species is highly concentrated in its distribution, occurring almost exclusively in Middlebere and Wych Lake areas. This distribution corresponds with that of the avocet, which also occurs almost exclusively in Wych Lake. There will be other contributory factors to the distribution of this bird species, including alternative prey preference and ability to move to other favourable areas in the harbour, however, if this bird species is shown to target this resource specifically the management of the prey population would be important to the bird's survival.

The invertebrate data, when analysed to identify species assemblages, using PRIMER, resulted in the production of several characteristic types. These have been compared to the UK Biotope Classification for UK and Ireland and possible classifications, attributable to the clusters identified, have been listed below in Table 7. The *Hediste diversicolor* based group of biotopes appear to form the basis of two of the biotopes found in Poole Harbour, although the range of variation found in the Harbour does not agree completely with the specific types described in Connor, et. al. (1997). The other biotopes include those in littoral muddy sand based habitats, as well as a group of sites based on mixed substrata. The latter had the poorest fit to any existing biotope, due to the absence of the dominant characterising species, in most cases, i.e. *Mya arenaria*. However, the fact that this species does occur sporadically in Poole Harbour and is believed to be making a comeback, particularly in Wareham Channel, suggests that this biotope is probably valid, given the similarity in the rest of the associated species.

Table 6. Biotopes descriptions fitted to Clusters identified in Poole Harbour.

Cluster	Possible Biotope Classification	Comments
A	**LMU.HedScr.** *Hediste diversicolor* and *Scrobicularia plana* in reduced salinity mud shores.	The lack of *S. plana* as one of the dominant species from this group weakens its similarity to this biotope. However, this was the only major cluster in which this species occurred, numerous dead shells have also been noted and most of the other species, including the other principal species and several subsidiary species, including characteristically *Cyathura carinata*, were recorded.
B	Tentatively **LMS.Pcer.** Polychaetes and *Cerastoderma edule* in fine sand or muddy sand shores.	The slightly more sandy sediments of this cluster and the abundance of *C. edule* and several small annelids, largely excluding *Hediste diversicolor* suggests that this biotope is the most appropriate.
C	Tentatively **LMX.Mare.** *Mya arenaria* and polychaetes in muddy gravel shores.	The more mixed sediments of this cluster plus the presence of several indicative species, including *N. hombergii*, cirratulids and other small polychaetes, *C. edule* and *Gammarus locusta* provide a reasonable fit to this biotope, despite the absence of *Mya arenaria*
D	**LMU.HedOl.** *Hediste diversicolor* and oligochaetes in low salinity mud shores.	This comprised a low diversity group dominated by *H. diversicolor* and oligochaetes, with *Corophium volutator* typically occurring in the reduced salinity conditions.
E	No clear match to a biotope exists.	The dominant species from this assemblage do not match those of any currently listed biotope, although similarity to **LMX.Mare** exists, with *Tapes philippinarum* as a potential substitute for *M. arenaria*.
F	**LMS.MacAre** *Macoma balthica* and *Arenicola marina* in muddy sand shores.	Despite the absences of *Macoma balthica* the remaining species and habitat conditions match those of this biotope well.

In general the clusters correspond to the overall gradient in sediment type across the harbour, with the finer sediments in the upper reaches of the harbour giving way to the sandier sediments near the harbour mouth. Occasional patches of mixed sediment occur scattered throughout the harbour particularly near Brownsea Island.

It should be stressed that the invertebrate assemblages and biotopes identified in this analysis are not static in time and space, with individual populations varying in relation to a range of physical and biological factors, including changes in salinity regime, sediment variation, inter-specific competition, reproductive success, etc. There is no implied absolute value attributable to any particular region of the harbour on the basis of this analysis, given that Poole Harbour operates as a whole ecological system.

Productivity

The productivity of the invertebrate populations is of importance to the bird populations in that annual regeneration of biomass available to the bird populations is essential for the birds survival in the subsequent year. The utilisation of a productivity value, however, in the present study is of limited value. The production to biomass calculation represents a possible increase in energetic value of the invertebrates over the autumn and winter period. The basis for this calculation however is constrained by limited data with respect to seasonal variation in productivity. Most productivity studies provide P:B ratios base on annual estimates. Instantaneous P:B ratios vary considerably throughout the year, with dramatic increases occurring in most species in spring and summer when juvenile development is at a maximum (see for example *Abra tenuis* in Thomas, 1987). This then slows down in late summer and autumn and may result in negative values for certain populations in winter, due to the loss of individual body mass, in the case of many bivalve molluscs, and due to mortality for most other species. The estimate of overall production in this study are based on 25% of the total production value for the year, occurring in the autumn and winter period. This value however, does not take into account individual changes in P:B ratio, which will clearly occur for different species. Until greater detail on the seasonal variation in P:B ratios can be determined, for the invertebrate species contributing as prey to the birds, it is recommended that the total autumn biomass is the most representative estimation of the energy available to the over-wintering birds. It should be stressed, therefore, that the calculations employed and the values presented in this report, with respect to energy available to bird species does not include any calculated productivity component.

Energy Balance

Data constraints

The data used to calculate the energy required by the birds and available due to the invertebrates is subject to several constraints or sources of error. These are as follows:

Bird data records – The bird data records are based on monthly low water counts in a consistent manner that enables accurate estimates of bird numbers. These data have been converted to daily counts on the basis that the same number of bird will be present throughout the month. This may introduce a source of error, but the utilisation of averaged data (over 8 years) will eliminate this error to some extent. Year on year variation has also been accounted for in this manner but long-term trends in populations over the 8 year period have not been included. The structure of the calculation however will allow the introduction of new data with respect to bird numbers. Therefore, English Nature may enter new data for the Harbour when it becomes available.

Areas - the calculation of area for each sector and for the total intertidal area may be calculated in several ways, which in turn affect the calculation of available energy. The preferred option was to utilise the most current and accurate admiralty chart (2611) and then to measure the total intertidal area of each sector, excluding any marinas or other intertidal features. The exposure of these tidal areas based on the proportion of time exposed during a tidal cycle was then calculated based on Poole Harbour tide guage data. This value however is most appropriate to the overall calculation rather than the sectoral values, which contain different proportions of shore level, for example sector SC3, which is largely located in the lower shore area. The sectoral energy values therefore do not in all cases represent the real energetic availability although they will approximate to the correct value and do, when added together, provide an accurate overall estimate.

Individual prey size – The size of the individuals that make up the prey populations were measured to enable calculation of weight to length ratios upon which species biomass was calculated. Energetic value was then estimated based on the size of the individuals in the whole population, per site. Many species of bird will, however, have both minimum and maximum sizes that may be taken. Hence the inclusion of both the smallest fraction and largest fraction of a species population may well overestimate the energy available if they cannot be utilised. However, the degree of error for the smaller size fraction is likely to be minimal due to the relatively limited contribution that the smaller individuals from a population contribute. The size and value of the largest individuals is currently the subject of a study by CEH, which suggests that several bird species may not be able to exploit the whole population of some of their preferred invertebrate prey. This will restrict the available food resource for several species although it will only be of relevance to those species which are at their lower limit of exploitation potential, i.e. low $S_T : S_R$. Two species fall within this group, shelduck and curlew. The recent studies by CEH suggest that curlew may be limited with respect to larger specimens of *Cerastoderma edule* and *Scrobicularia plana*. No data is currently available for shelduck.

Energy availability and bird requirements

The invertebrate energy available within the intertidal area of the Poole Harbour system has been demonstrated to exceed by 3.5-4 times that required by the wading and wildfowl birds that feed on them ($S_T : S_R$). This is consistent with expectations (2.5–8:1) based on current work by CEH on similar intertidal systems, see Goss-Custard, *et al* (2004).

The calculation is based on exploitation of a shared resource using the simple ration approach as defined in Goss-Custard, Stillman, Caldow, West and Guillemain (2003). This approach is based on the principle that the food requirements and availability are uniform and that no interference exists in the system. In these circumstances food availability can be aggregated across any patches that may occur, both in terms of prey availability but also bird use. Goss-Custard, Stillman, West, Caldow and McGrorty, (2002) and Goss-Custard *et al.* (2003) make the point that this method may need to be replaced with a more complex spatial depletion models, in the case of distinct patches occurring with respect to food density or accessibility, or a spatially explicit individual model if birds have differing energetic costs related to movement or food-acquisition between patches.

Several species demonstrate well defined spatial requirements in Poole Harbour, most clearly evident for avocet and to a lesser extent species such as grey plover and redshank. As a consequence these species may require a spatial depletion model to enable a more accurate assessment of their energetic utilisation to be made. Similarly oystercatchers have been identified as feeding within interference driven systems (Goss-Custard, Stillman, West, Caldow, Triplet, dit Durell & Mc. Grorty, 2004), hence their inclusion within a calculation using a simple ration approach is not the most appropriate. The largest drawback to the assessment is that it is not able to predict emigration or mortality rates. Both emigration and mortality will occur during the decline of the available food reserve, before the reserve approaches the minimum requirement for a whole population to survive. In terms of practical management of the ecosystem, the number of individual birds surviving to the end of the winter, and their body condition, are the most important factor. Notwithstanding the above and within the constraints of this study, the application of the daily ration model to estimate maximum number of bird-days, is the most pragmatic option available for the current study. This is despite evident differences in the distribution in invertebrate food density and food preference between bird species. It is recommended, therefore, that a considerable degree of conservatism is required when considering the relationship between the maximum predicted number of bird-days, on the basis of available food, with respect to the actual number supported.

To provide an indication of which species of bird may be subject to some degree of restriction in terms of prey availability, individual consideration of bird species resources against requirements were calculated. These again do not make any allowance for interaction between species. Most of the species demonstrate available food resources compared to their historic use, to be well in excess of 10 to 1. The species that exist below this level are shelduck, oystercatcher and curlew, all of which have high energy requirements per individual. In the case of the oystercatcher, recent work by Goss Custard, *et al* (in press) indicates that in the order of 8 times the estimated requirement of this species is needed to ensure survival of a population through to the next breeding season. This is primarily due to within species, interference competition for food, as well as anticipated wastage during foraging and through prey biomass loss. The estimated predicted population against the actual population for this bird in Poole

Harbour is 7.3:1, which would appear to be in general agreement with the requirement for this species. However, both oystercatcher and curlew have exhibited a decline over the last eight years in Poole Harbour (Pickess & Underhill-Day, 2002) and considering this trend within the context of the national trend for these species would be an appropriate means of determining if these low ratios are indicating that insufficient resources are available.

Given that the invertebrates appear to be able to sustain the current bird populations, the low values for shelduck and curlew suggest that either the food requirement for these species have been over-estimated; the available food has been under-estimated; the birds have a more catholic diet than that employed in the assessment including exploitation of alternative non-intertidal food resources; or that they are able to survive in a more food restricted and hence competitive environment. Curlew takes large biomass individuals, which occur in lower densities and in most cases live at depth in the sediment. It is possible, therefore, that undersampling may account for some of the energetic shortfall for this species. In the case of shelduck it is likely that some additional prey, not currently included in the calculation of their food resource are being exploited e.g. smaller individuals of the larger polychaete worms. The other alternative is that they are feeding in highly specific areas where their food does occur in sufficiently high densities and where competitive interaction is low. By comparing the sectoral calculations of available energy to requirement for these species, it is evident that shelduck has been counted in several areas where it is unlikely to be supported by the invertebrates available. It is therefore probable that the birds are not feeding in these areas and are, instead, foraging more widely in the Harbour for food, for instance moving from area SE2, with low food availability, to high food availability areas SE1, NE1 and NE3. A similar pattern exists for curlew, which suggests a similar feeding strategy. A further explanation is that these species are supplementing their diet with terrestrial invertebrates over high water. Work in Poole Harbour suggests that between 15% and 33% of some species populations (curlew and black-tailed godwit respectively in this example) fed in fields of the Wareham watermeadows (Caldow, Durell, McGrorty, Pearson, Reading, Rispin, West, Rose & Armstrong, 1999).

The overall assessment of food availability and bird use, on a sectoral basis, illustrated in Fig. 36, suggests that the two factors are not related. This is contrary to several previous studies in other areas, although these have tended to relate to individual bird species and specific prey items, see Hamilton, Barbeau and Diamond (2003) and Goss-Custard, Kay and Blindell (1977). See also examples in Evans, Goss-Custard and Hale (1984). The potential causes of this difference may be due to several reasons:

- The current data set comprises multiple bird species and multiple prey species hence identifying an overall relationship is less easy. This is primarily because some bird species are competing for the same food resource, while other bird species are exploiting different resources. Individual species assessments have been attempted with the current data sets but a similar lack of relationship has been found to exist.
- The areas of greatest abundance of food resource are not favourable feeding areas due to factors other than the food resource, e.g. disturbance through vessel activity and human activities in general.
- Food is less readily available due to algal smothering or development of marsh areas.
- Data for birds is based on historic counts, whereas invertebrate data is based on a recent survey for which corresponding bird data has not been presented.

The conclusion from this lack of relationship is that feeding activity is concentrated in a limited number of areas with several other, relatively rich areas, largely unexploited. To some extent this is not an unacceptable situation with respect to management of the system. Under-exploited areas provide a valuable reserve, which may be available as a resource in certain circumstances, e.g. severe weather conditions, as well as enabling over-exploited areas to be repopulated by some invertebrate species, given appropriate juvenile or larval dispersion strategies.

The overall assessment of energy balance indicates some degree of stress on the bird populations may exist, however, the individual species assessments and the sectoral analysis suggests that this does not apply to all species. It is proposed that more species specific studies may need to be conducted for those birds that are demonstrating low ratios of predicted number of bird-days to actual bird-days. These currently include shelduck and curlew. Both of these birds are of considerable conservation importance, shelduck currently occurring in internationally important numbers in Poole Harbour and curlew occurring in nationally important numbers Pickess & Underhill-Day (2002).

The method employed to estimate energetic value available to the birds has been demonstrated to produce data consistent with expectations. The ratio for the harbour overall, of between 3.5-4:1, however does have several constraints associated with the calculation of the value. These include the following:

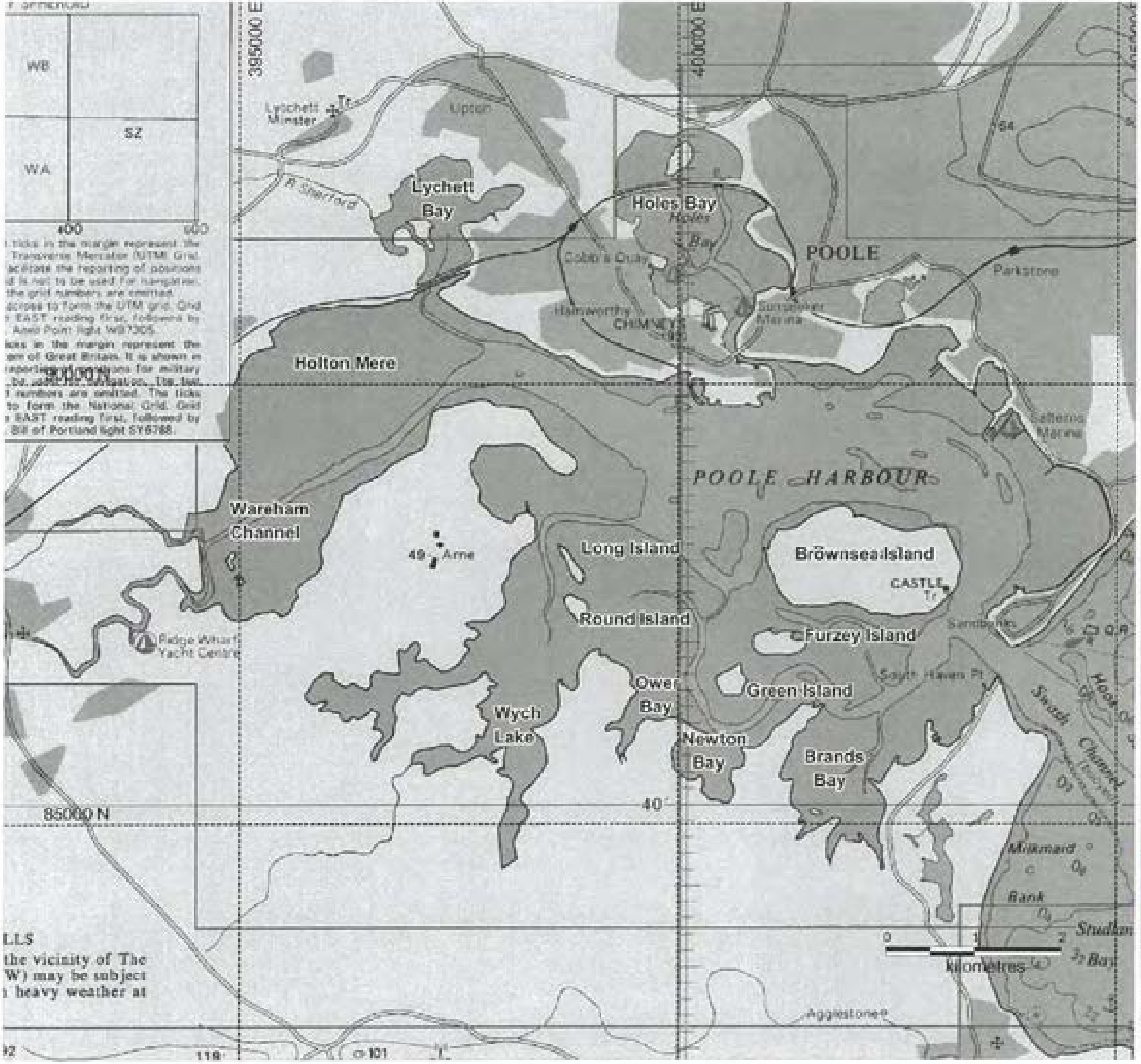
- The available intertidal invertebrate food is likely to be an over-estimate, due to the inclusion of both larger (over size) prey and smaller individuals. Both of these fractions of the invertebrate populations however, will contribute to the survival of these populations and will provide a resource to sustain birds in subsequent years.
- There are limitations on availability of the invertebrates due to the tidal conditions in the Harbour. This has been taken into account in the calculation but a more accurate estimation may be made in future using tidal contours and individually calculated factors per bird sector.
- The value of 4 x BMR for calculation of energy requirement for birds may be regarded as precautionary as it is at the upper end of published values.
- Interference between birds, both between species and individuals within species will considerably reduce invertebrate availability for some species of bird.
- The ratio (S_p: S_a) cannot be sustained at parity as birds will leave or stave as soon as the food resource falls to the lower threshold value that is required to meet the daily energy demands, i.e. well before all the food is exhausted

Inclusion of recent years bird data will allow assessment of current conditions on a more accurate basis. Future assessments will still require similarly large sampling programmes, although gathering of year to year data may enable the programme to be reconsidered, given that some areas may be equally well represented using a reduced sampling array. Consideration should also be given to sampling more effectively the low density but high biomass value species. These strategies would, however, need to be tested over several sampling periods and would need to be based on invertebrate population trends irrespective of bird use. It is recommended therefore that re-sampling the existing sampling array would currently produce the optimum data with respect to consideration of Favourable Condition Status.

FIGURES

Figure 1

Poole Harbour Survey Area



Key

Islands within Poole Harbour

Suvey Location

Emu

Drawing No: J/1/03/0454

Figure No: 1.0

Revision

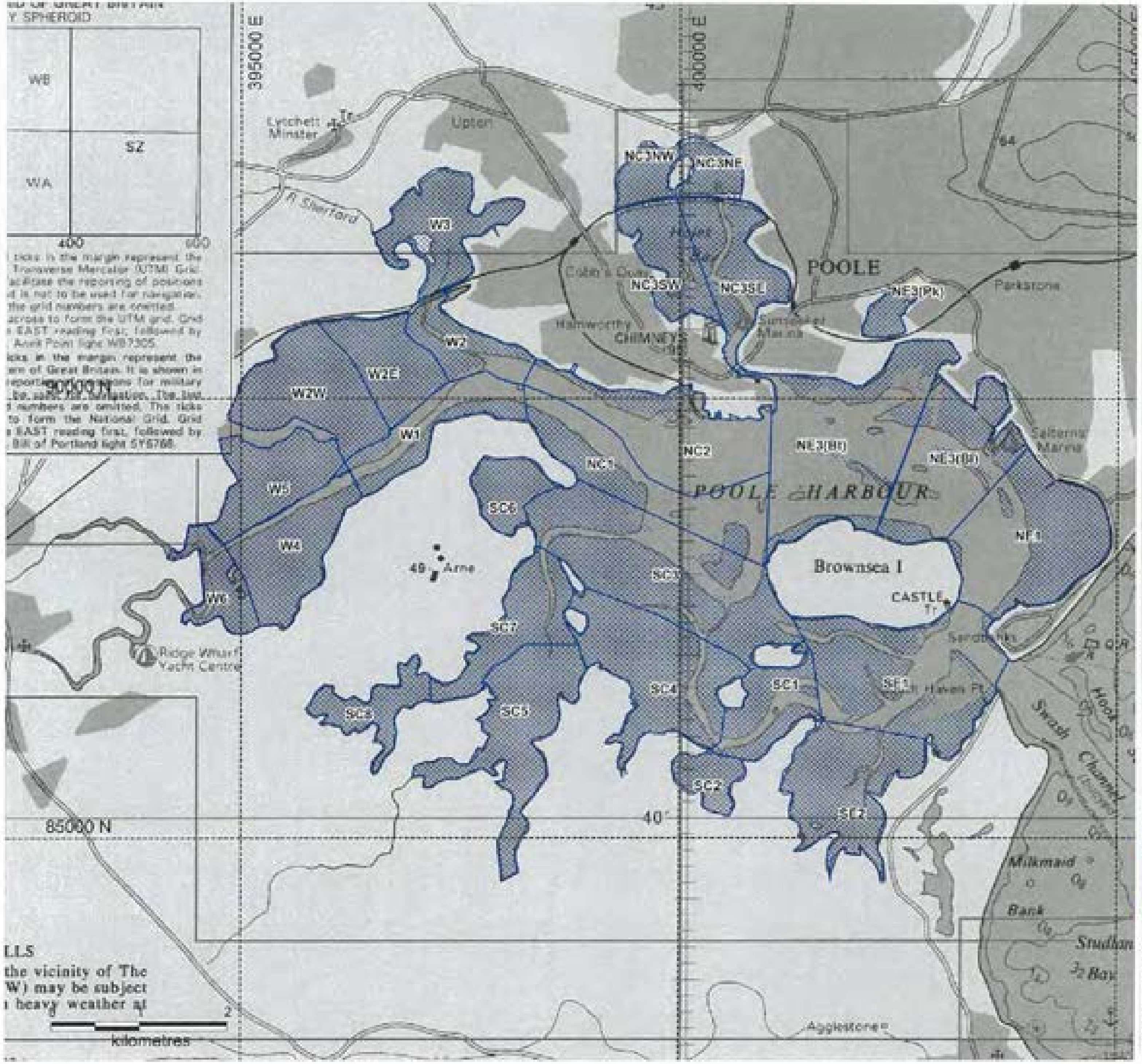


Figure 2

Poole Harbour WeBS Count Sections

Key

Islands within Poole Harbour

WeBS Count Section Boundary

Areas between MHWS and CD as shown on Admiralty Chart No. 2611_0

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	2	

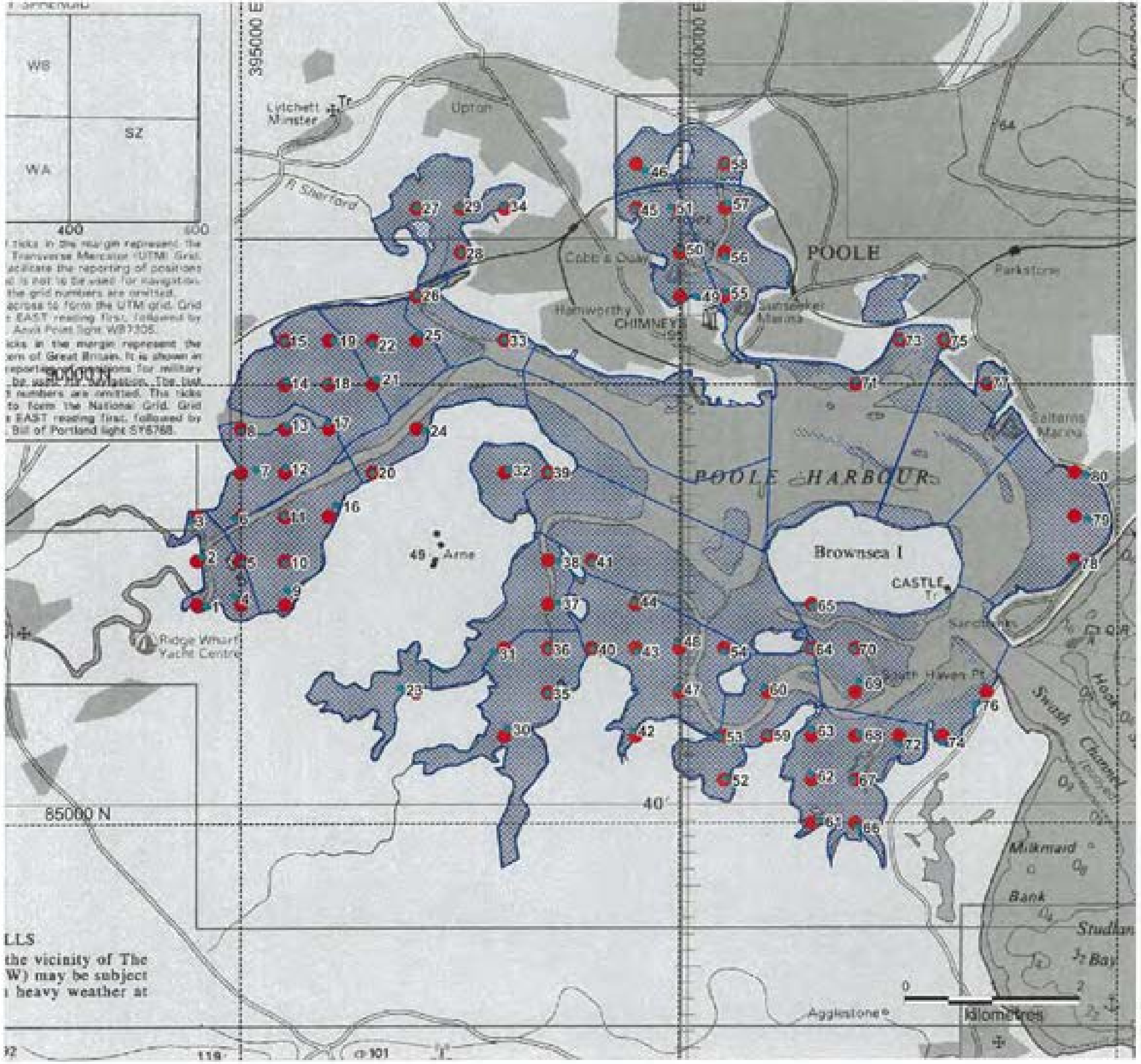


Figure 3

Poole Harbour Sample Locations

Key

English Nature Survey Positions:

- Actual Position
- Map Position

Emu

Drawing No. J/1/03/0454

Figure No. 3

Revision:

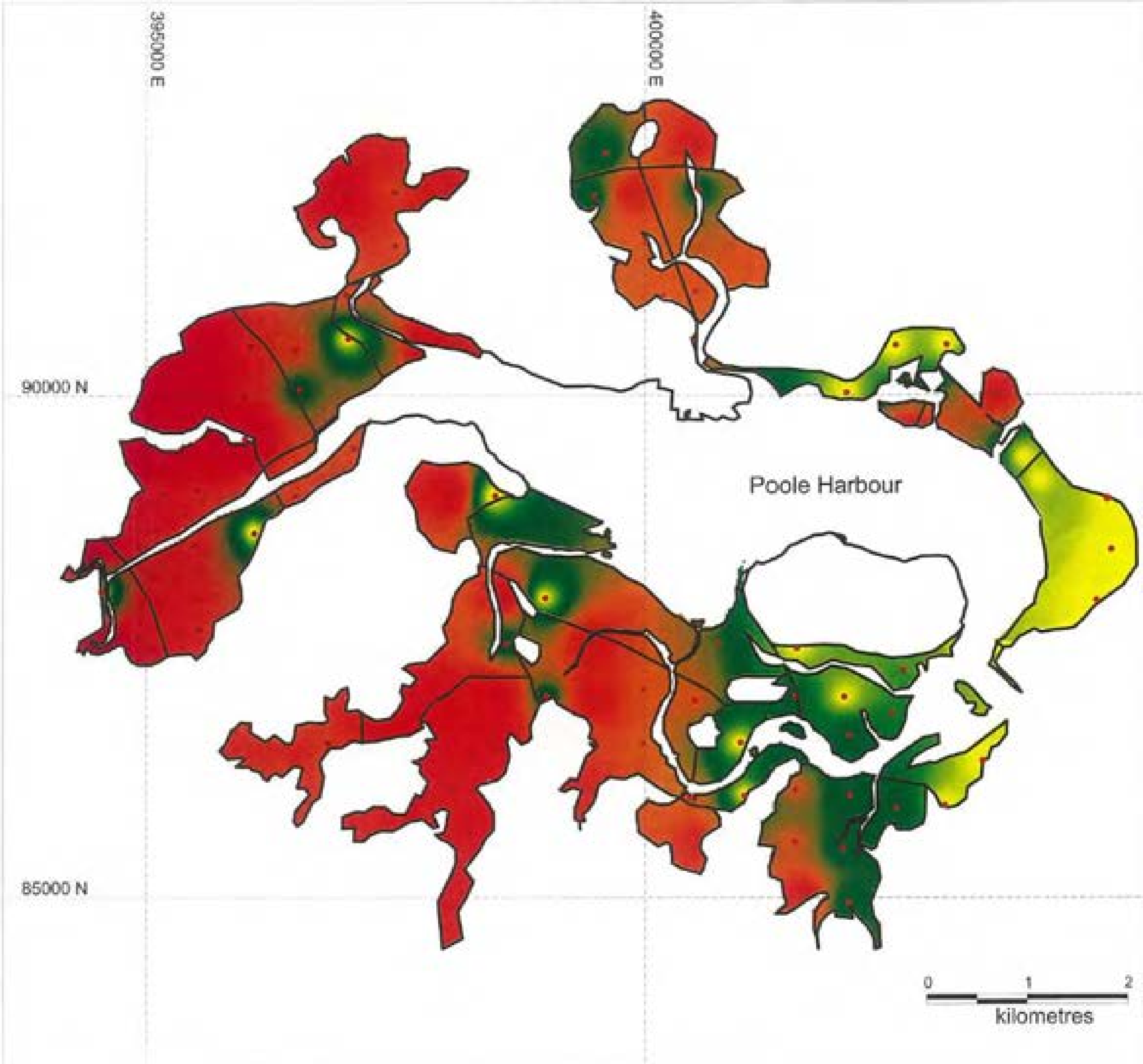


Figure 4

Poole Harbour Invertebrate Study

Sediment Distribution

Key

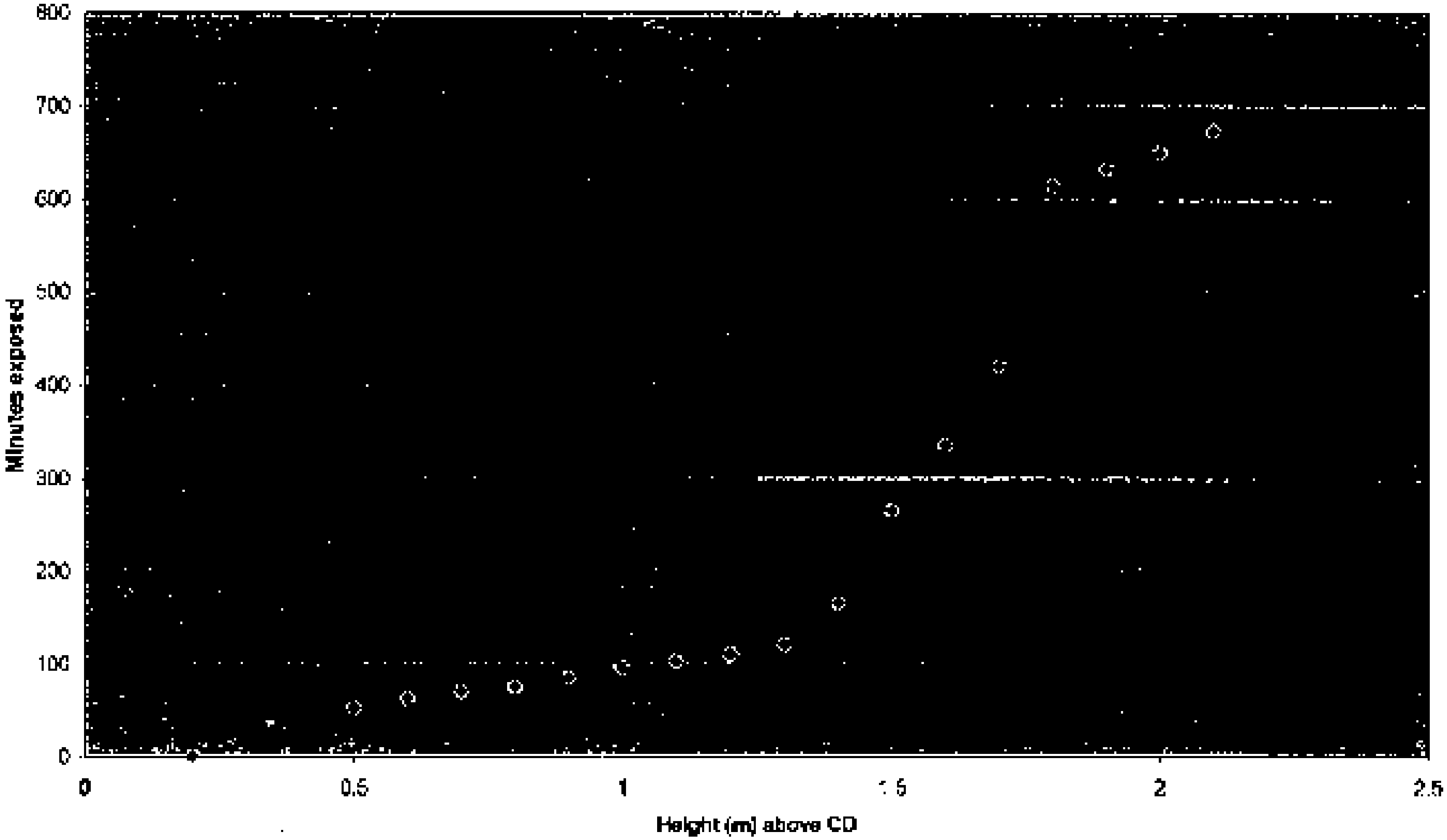
WeBS Count Section Boundary
Area Available to feeding birds

50% Fine Silt - median <20um
45% Silt/Sand - median 20 - 63um
Mixed Sediments
45% Sand - median >63um
Data Sampling Point

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	4	

Figure 5. Tide height against period of exposure in Poole Harbour



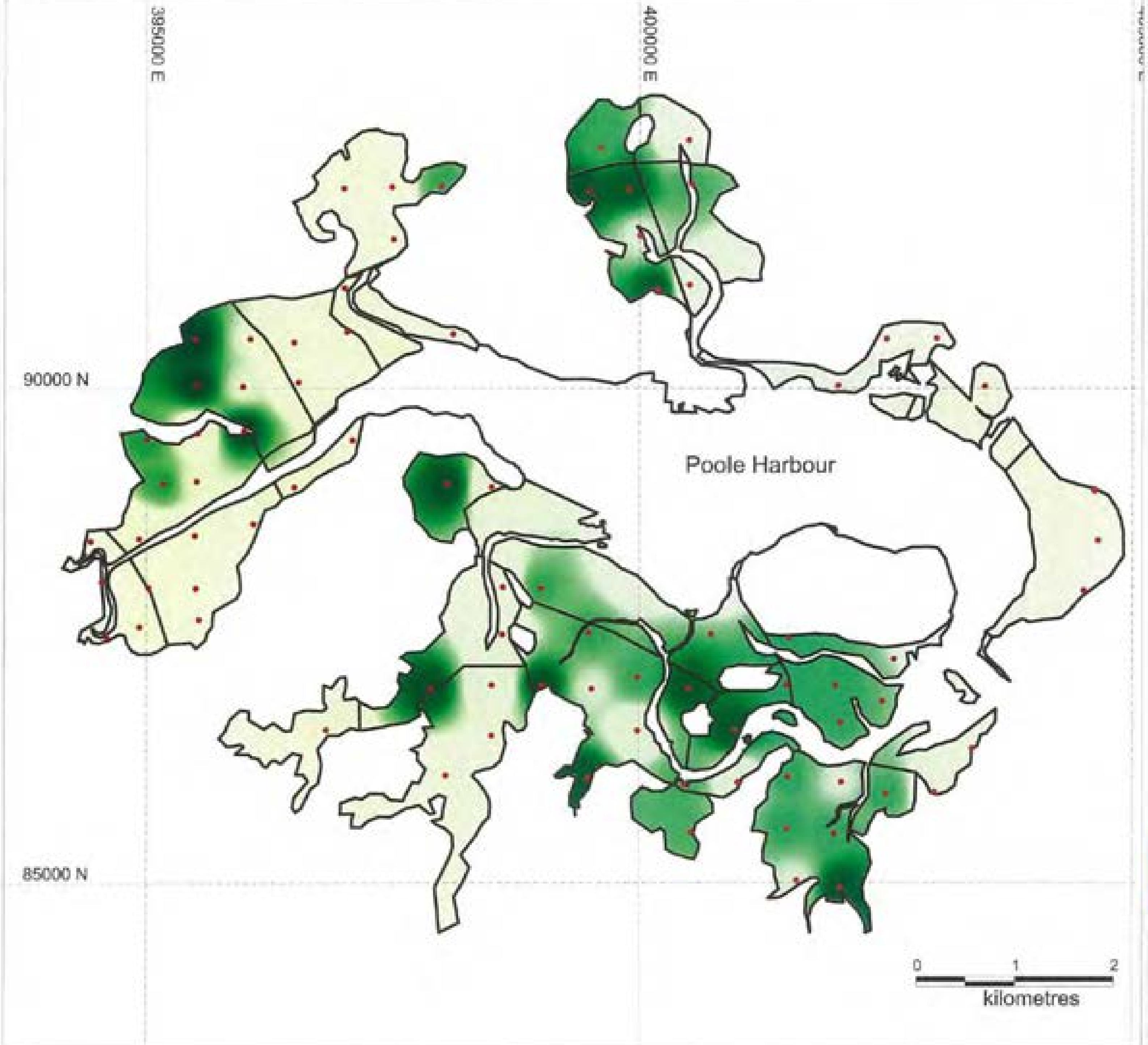


Figure 6

Poole Harbour Invertebrate Study

Algal Coverage

Key

WeBS Count Section Boundary
Area Available to feeding birds

Percentage Algae Coverage

< 25%
>25 <100%
100%

Data Sampling Point

Drawing No. J/1/03/0454

Figure No. 6

Revision

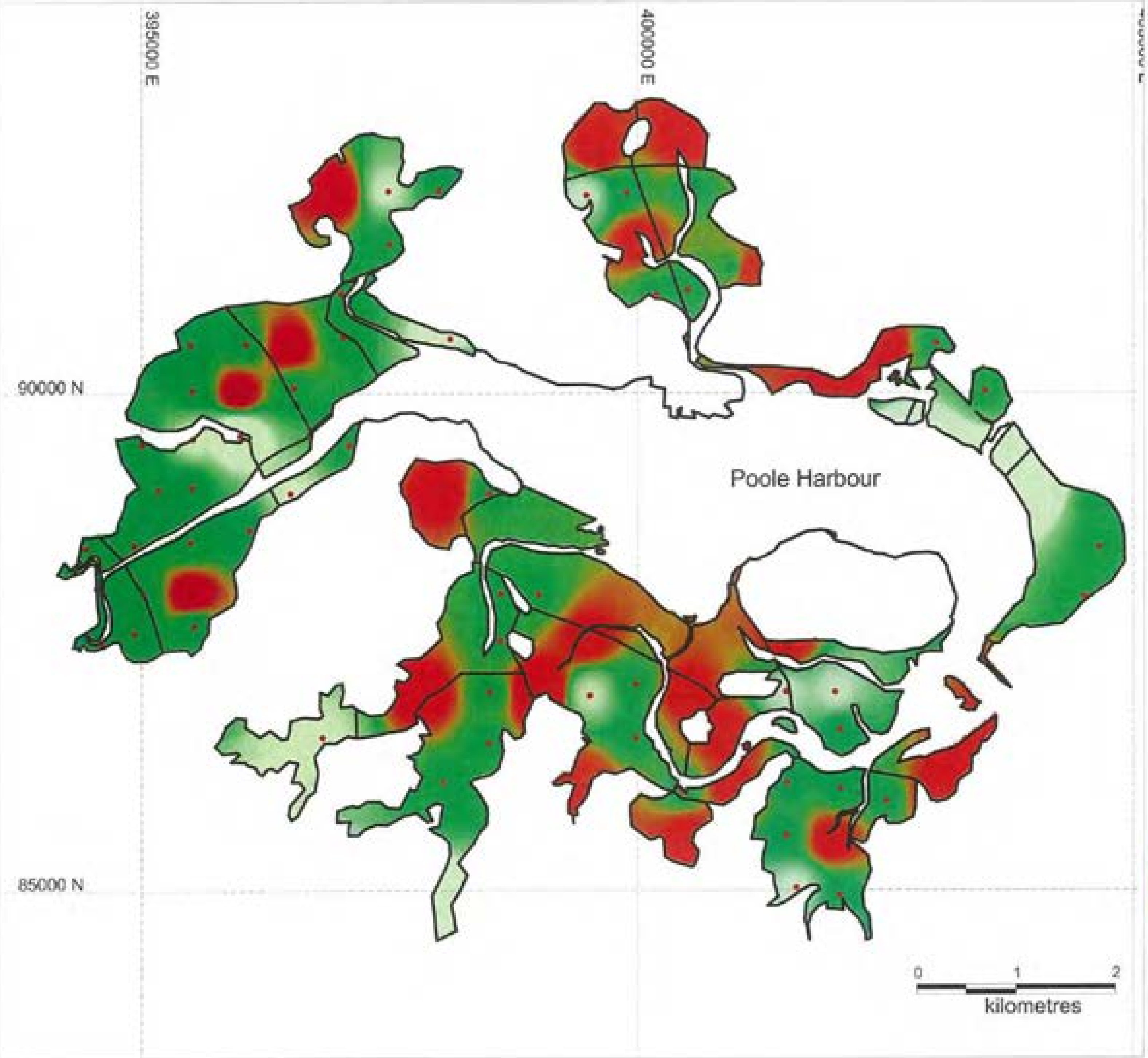


Figure 7

Poole Harbour Invertebrate Study

Number of Species per
Sample Location

Key

WeBS Count Section Boundary
Area Available to feeding birds

Number of Species

<5
>5 <10
>10 <22

Data Sampling Point

Drawing No. J/1/03/0454
Figure No. 7
Revision

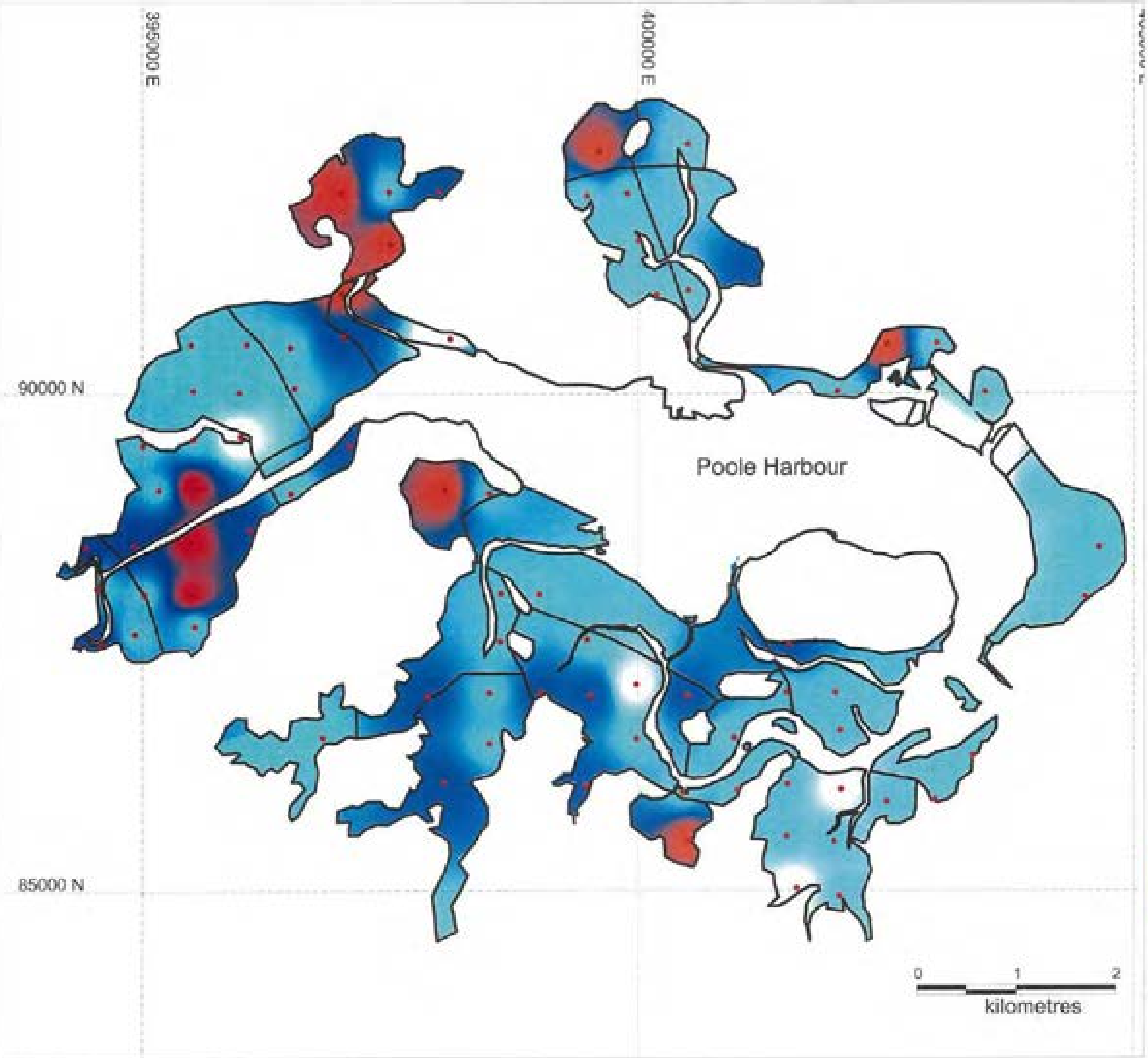


Figure 8

Poole Harbour Invertebrate Study

Number of Individuals recorded per site

Key

WeBS Count Section Boundary
Area Available to feeding birds

Individuals (per sq m)

- <1000
- <10000
- <25000
- >25000

Data Sampling Point

Emu

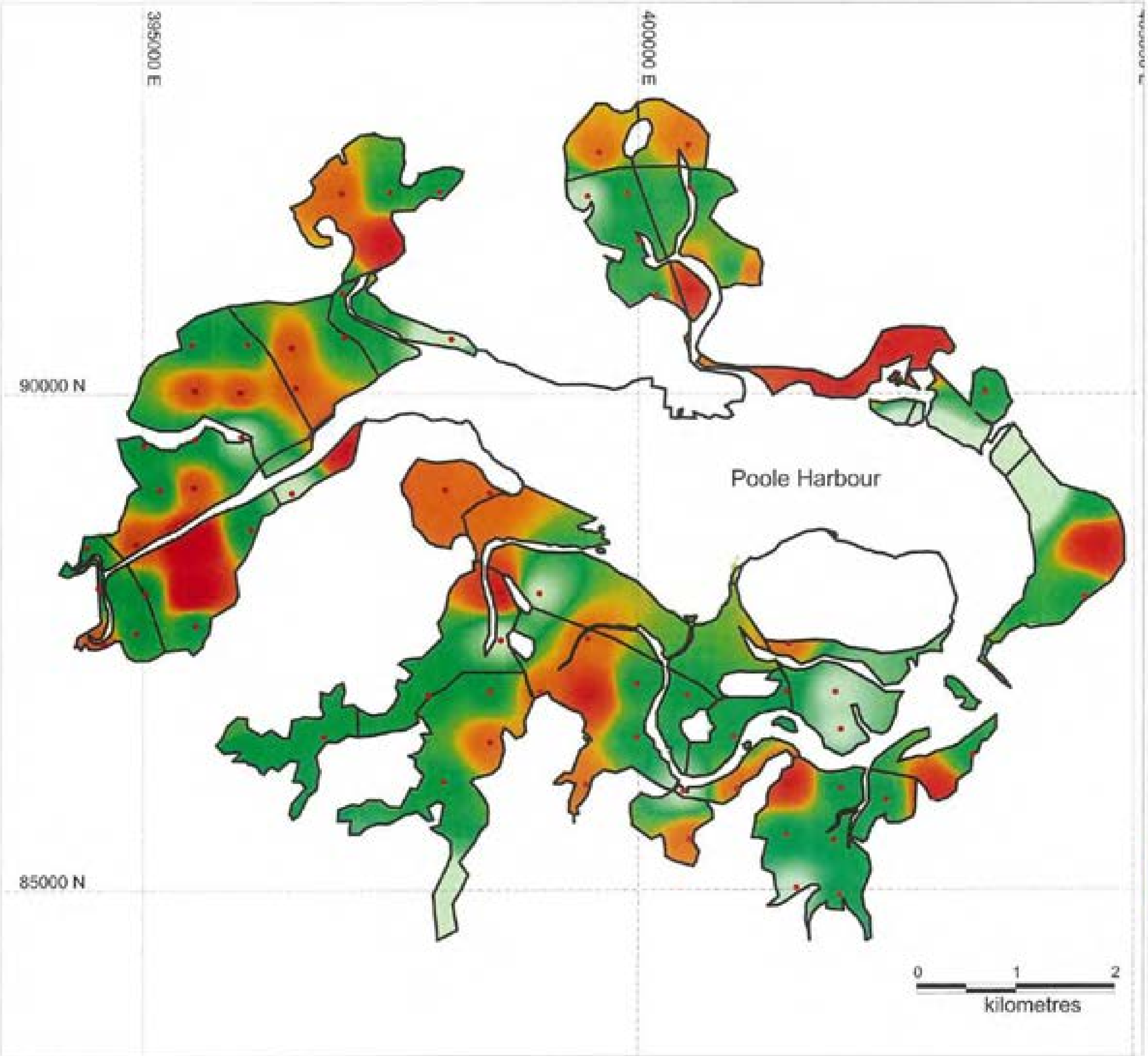
Drawing No. J/1/03/0454

Figure No. 8

Figure 9

Poole Harbour Invertebrate Study

Distribution of Biomass



Key

WeBS Count Section Boundary
Area Available to feeding birds

Biomass

- <5 mg AFDM sq m
- >5 <25 mg AFDM sq m
- >25 <50 mg AFDM sq m
- >50 mg AFDM sq m

• Data Sampling Point

Drawing No. J/1/03/0454

Figure No. 9

Revision

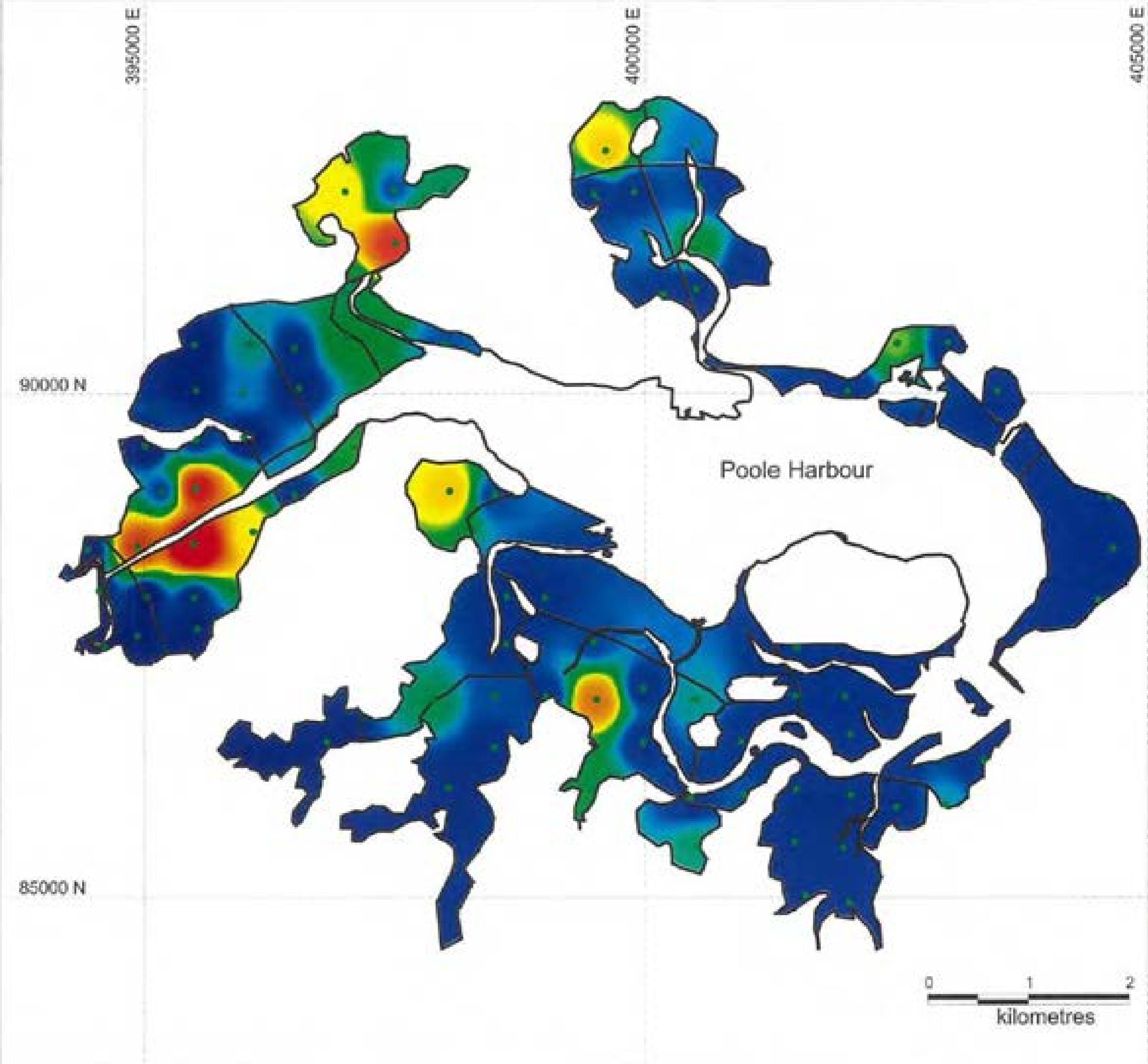


Figure 10

Poole Harbour Dominant Biomass Species

Cirratulus filiformis

Key

WeBS Count Section Boundary
Area Available to feeding birds

Cirratulus filiformis (mg / sq m)

52,700
46,800
41,000
35,100
29,300
23,400
17,600
11,700
5,900
0

Data Sampling Point

Emu

Drawing No. J/1/03/0454

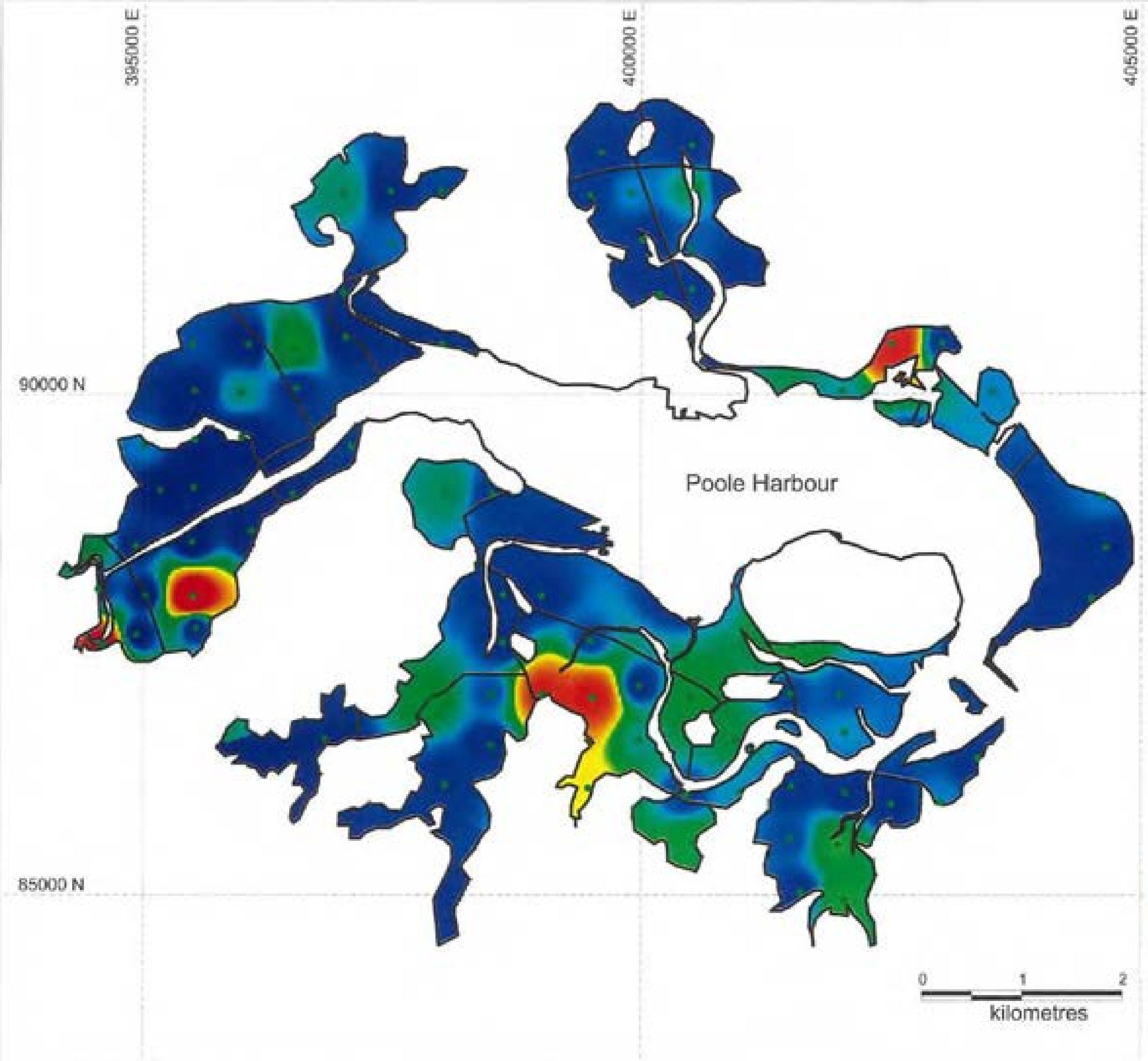
Figure No. 10

Revision

Figure 11

Poole Harbour Dominant Biomass Species

Tubificoides



Key

WeBS Count Section Boundary
Area Available to feeding birds

Tubificoides (mg/sq m)

- 22,500
- 15,000
- 12,500
- 10,000
- 7,500
- 5,000
- 2,500
- 0

• Data Sampling Point

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	11	

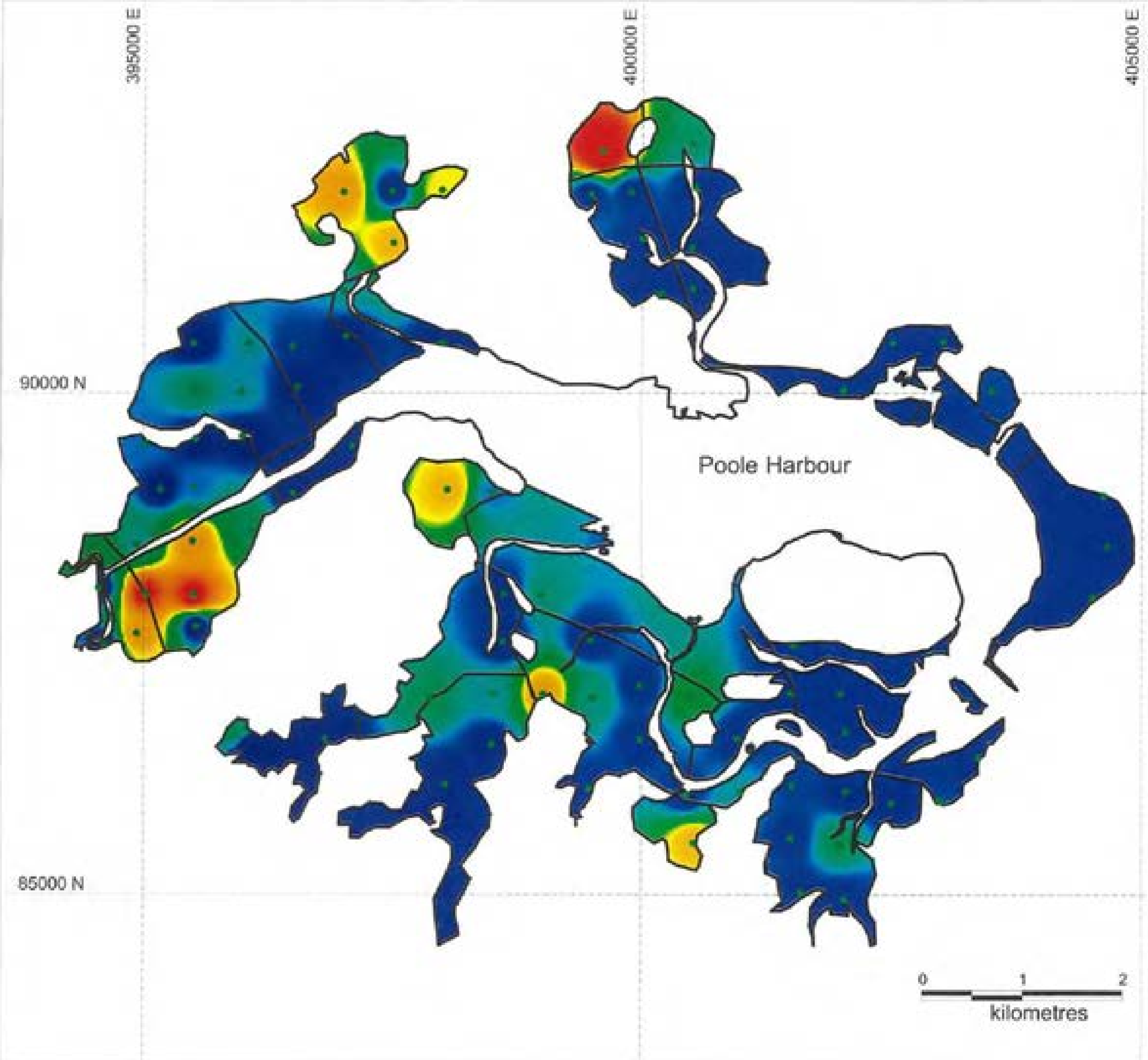


Figure 12

Poole Harbour Dominant Biomass Species

Malacoceros fuliginosus

Key

WeBS Count Section Boundary
Area Available to feeding birds

Malacoceros fuliginosus (mg/sq m)

- 5,500
- 4,000
- 3,500
- 2,500
- 2,000
- 1,500
- 500
- 0

Data Sampling Point

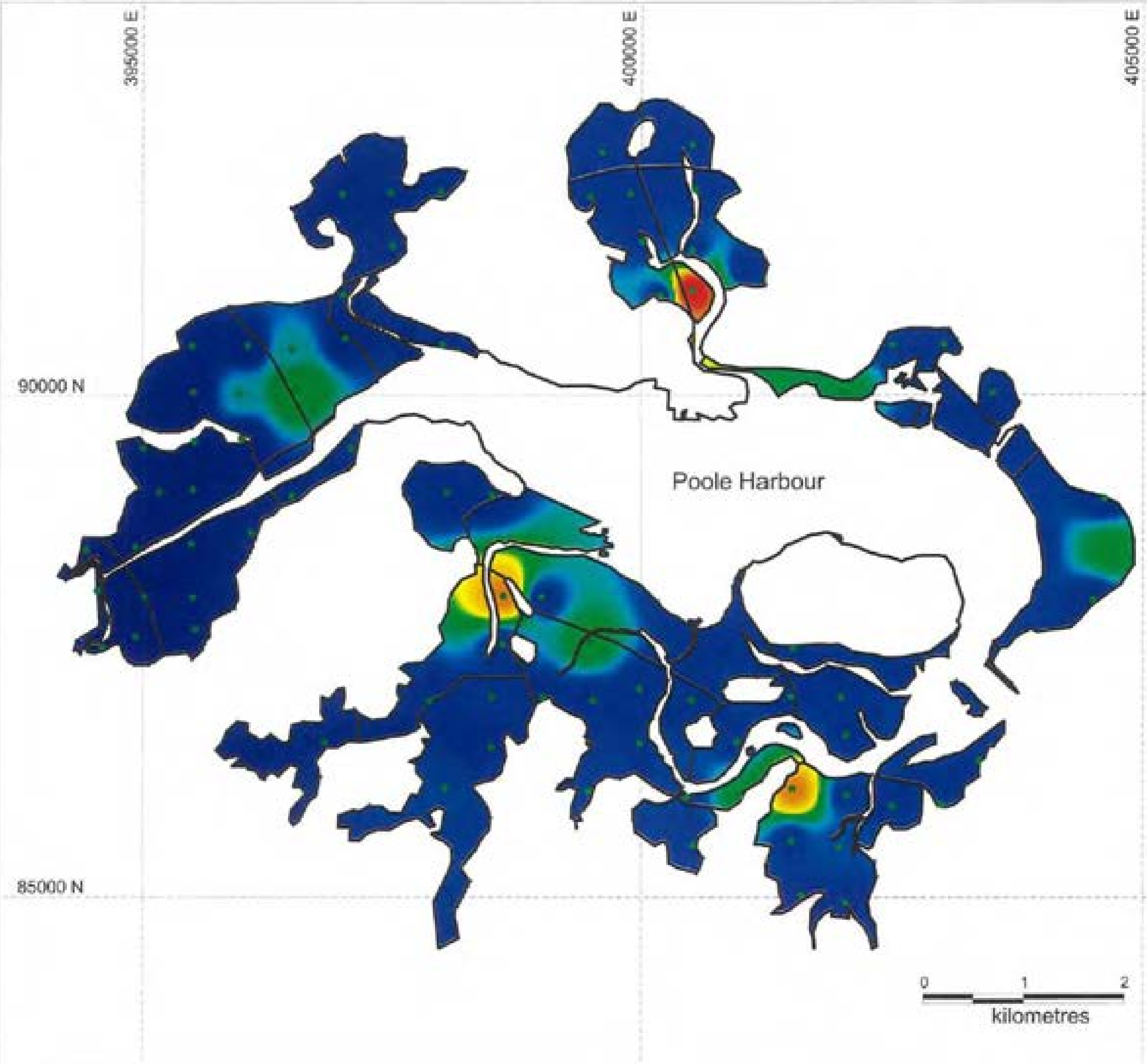
Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	12	

Figure 13

Poole Harbour Dominant Biomass Species

Nereis virens



Key

WeBS Count Section Boundary
Area Available to feeding birds

Nereis virens (mg/sq m)

100,000
80,000
65,000
55,000
35,000
22,000
10,000
0

Data Sampling Point

Drawing No. J/1/03/0454

Figure No. 13

Revision

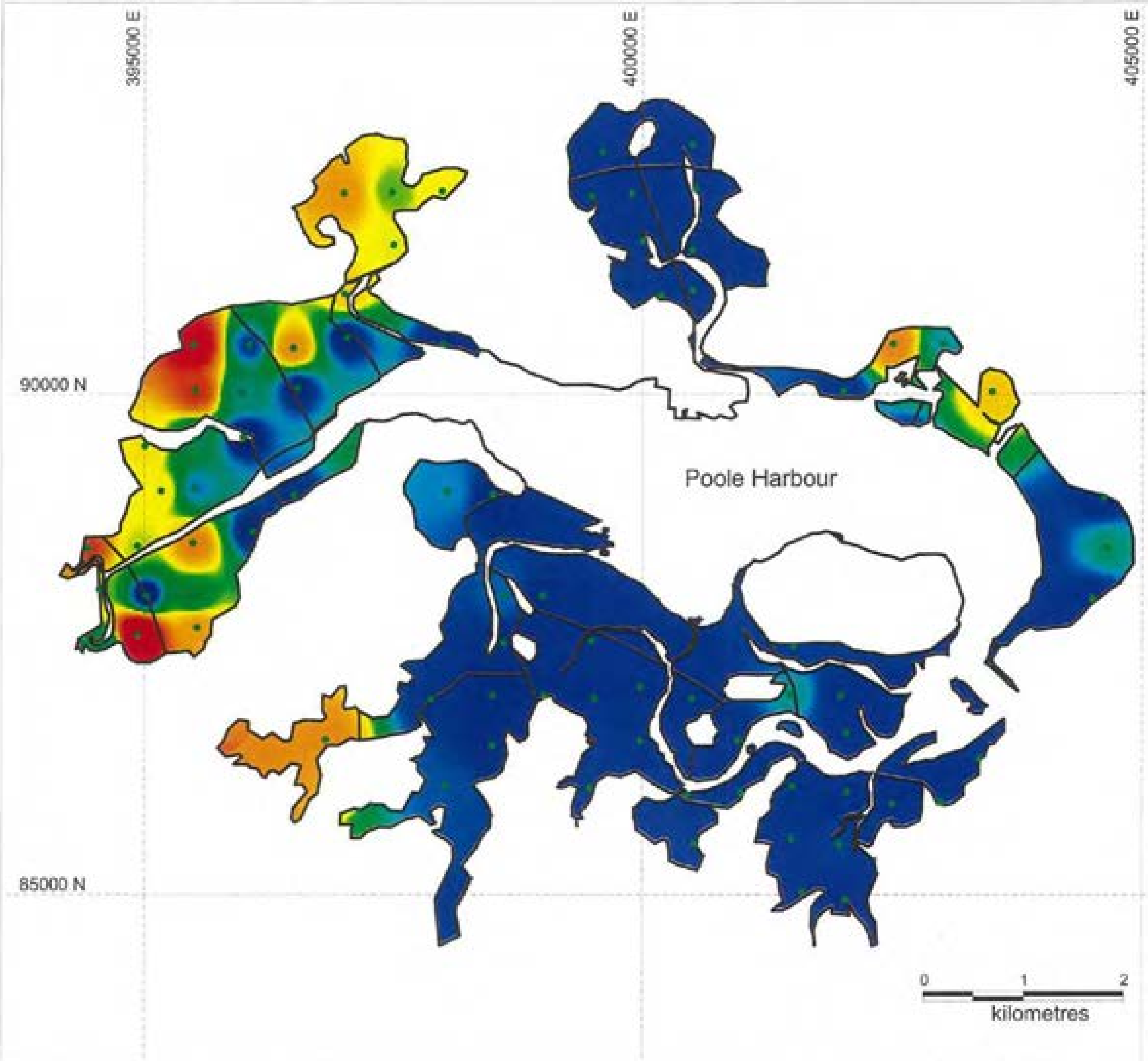


Figure 14

Poole Harbour Dominant Biomass Species

Hediste diversicolor

Key

WeBS Count Section Boundary
Area Available to feeding birds

Hediste diversicolor (mg/sq m)

17,500
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

Data Sampling Point

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	14	

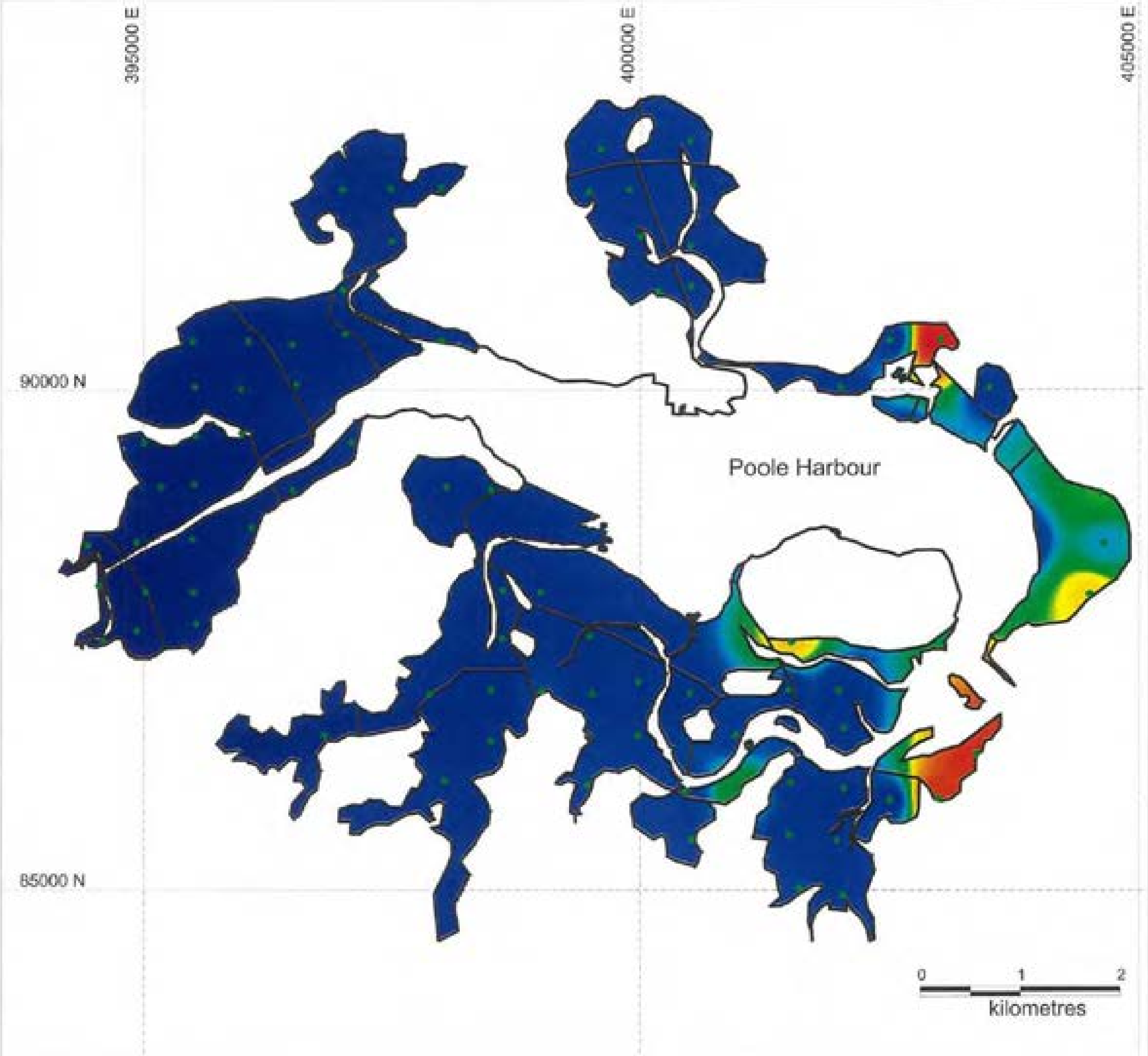


Figure 15

Poole Harbour Dominant Biomass Species

Arenicola marina

Key

WeBS Count Section Boundary
Area Available to feeding birds

Arenicola marina (mg/sq m)

- >20
- >10
- >5
- >2.5
- 0

• Data Sampling Point

Emu

Drawing No. J/1/03/0454

Figure No. 15

Revision

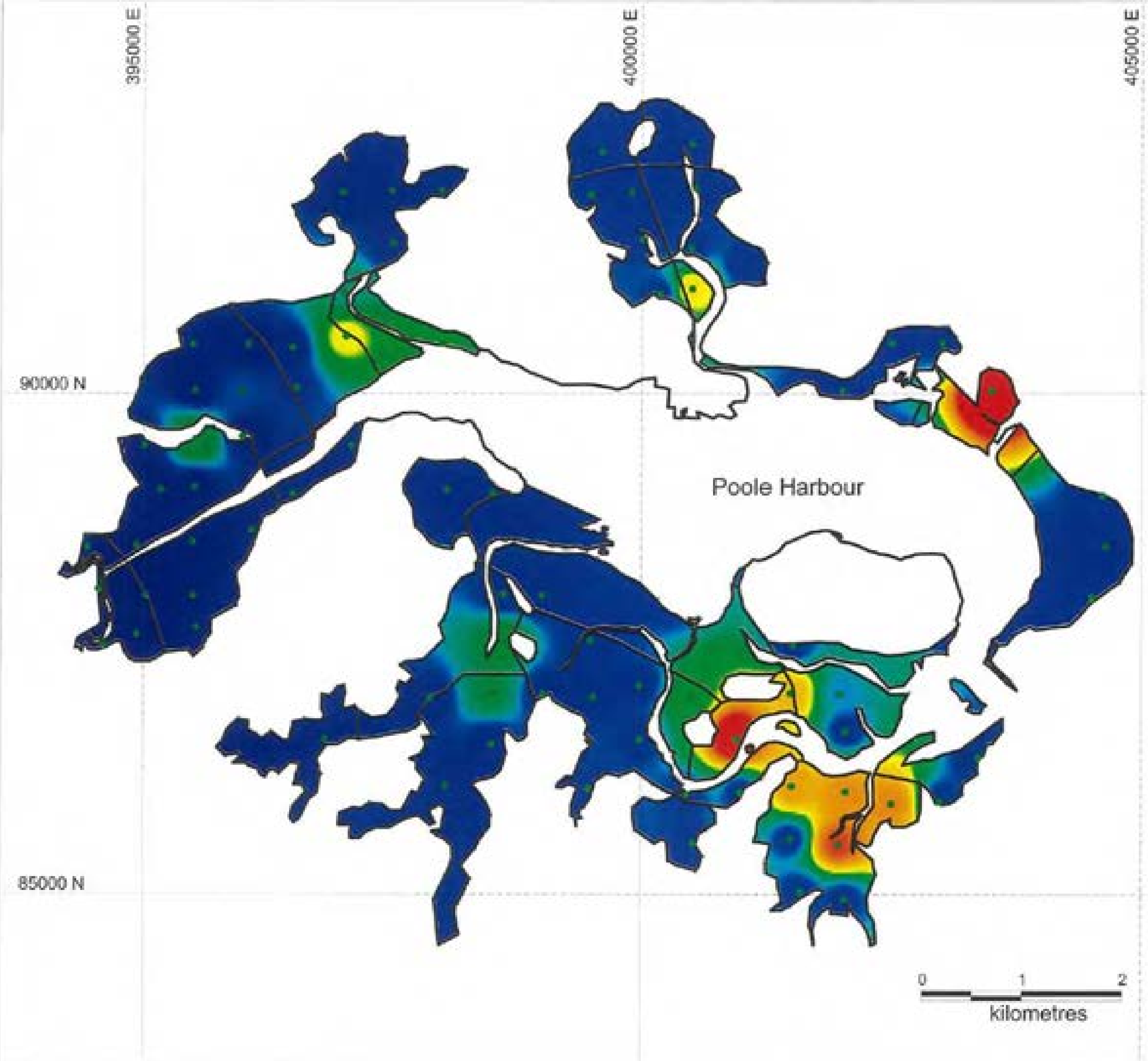


Figure 16

Poole Harbour Dominant Biomass Species

Nepthys hombergii

Key

WeBS Count Section Boundary
Area Available to feeding birds

Nepthys hombergii (mg/sq m)

5,000
4,500
4,000
3,000
2,000
1,500
500
0

Data Sampling Point

Drawing No. J/1/03/0454
Figure No. 16
Revision

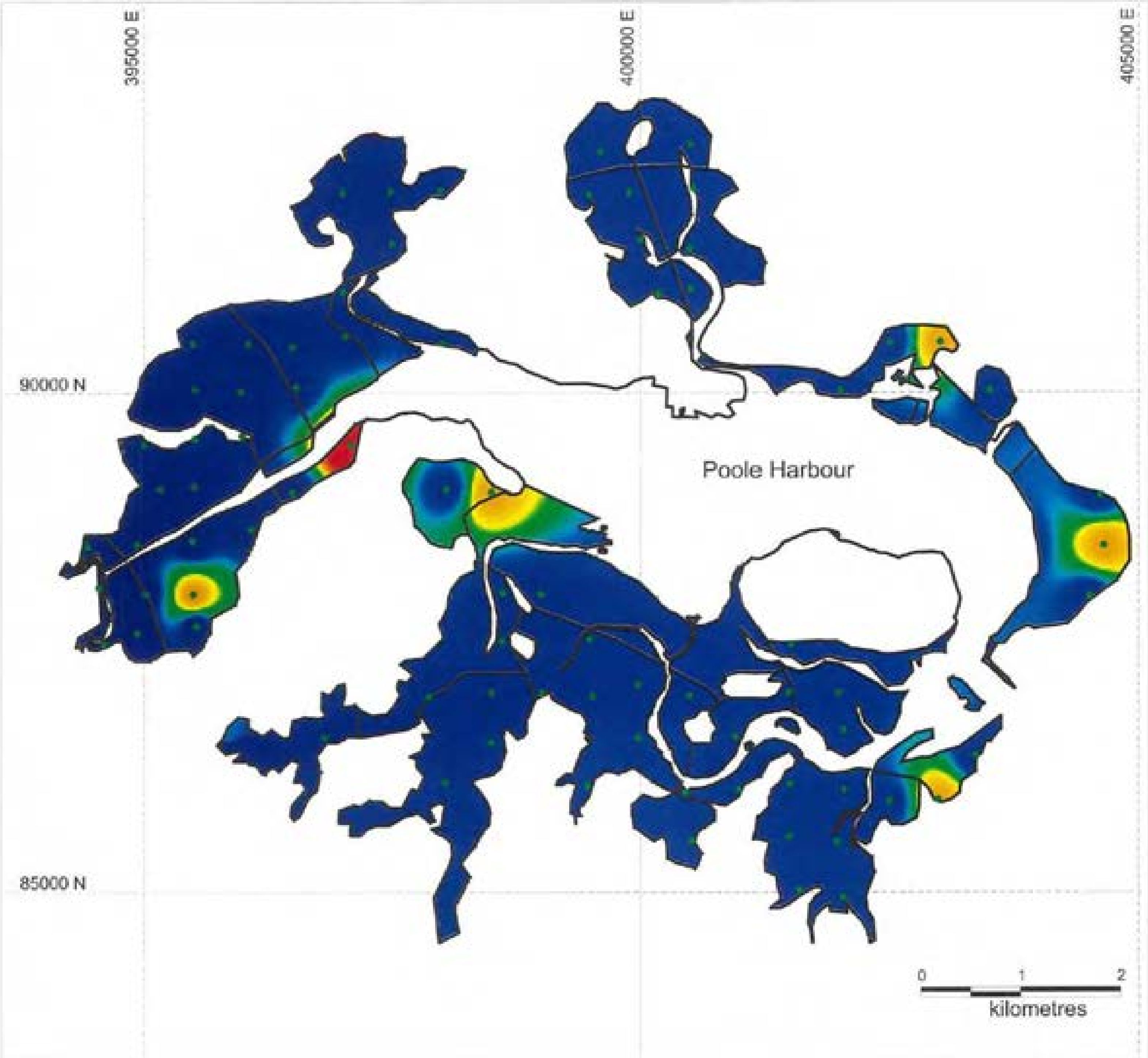


Figure 17

Poole Harbour Dominant Biomass Species

Mya arenaria

Key

WeBS Count Section Boundary
Area Available to feeding birds

Mya arenaria (mg/sq m)

- 50,000
- 35,000
- 30,000
- 25,000
- 18,000
- 12,000
- 6,000
- 0

Data Sampling Point

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	17	

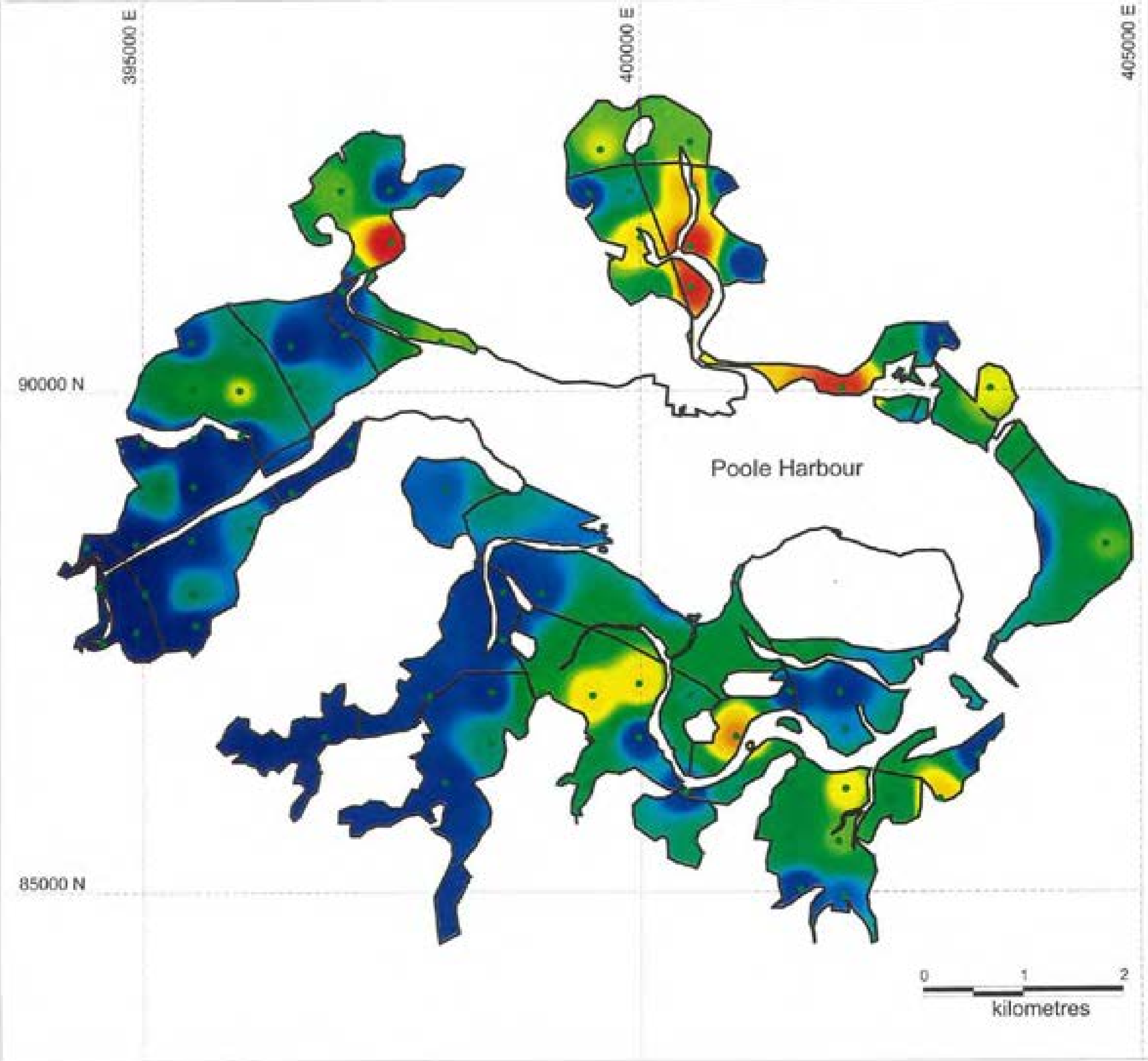


Figure 18

Poole Harbour Dominant Biomass Species

Cerastoderma edule

Key

WeBS Count Section Boundary
Area Available to feeding birds

Cerastoderma edule (mg/sq m)

- 10,000
- 7,500
- 5,000
- 2,500
- 1,000
- 0

• Data Sampling Point

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	18	

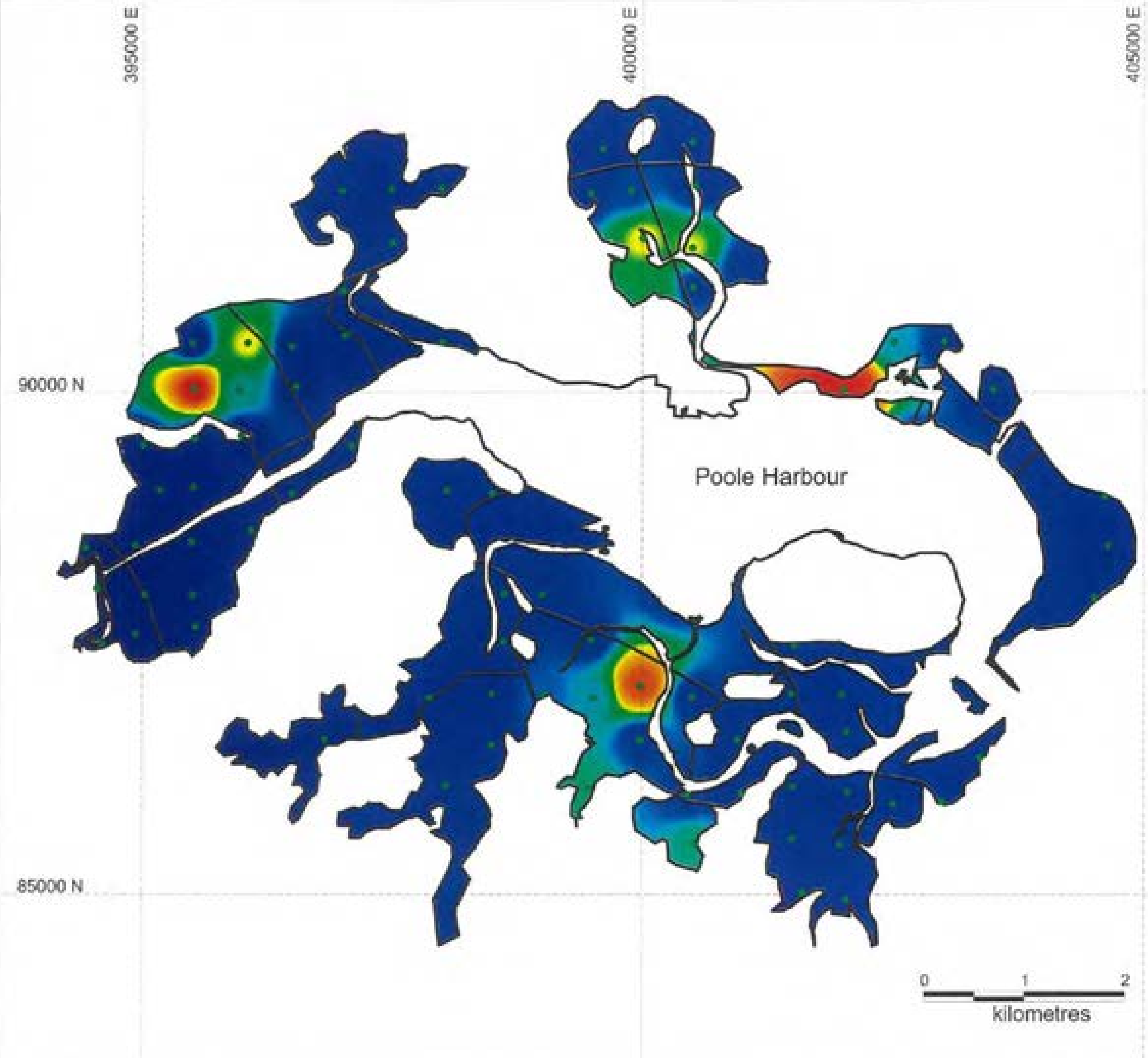


Figure 19

Poole Harbour Dominant Biomass Species

Tapes philipinarum

Key

WeBS Count Section Boundary Area Available to feeding birds

Tapes philipinarum (mg/sq m)

21,000
19,000
17,000
14,000
12,000
9,500
7,000
5,000
2,500
0

• Data Sampling Point

Drawing No. J/1/03/0454

Figure No. 19

Revision

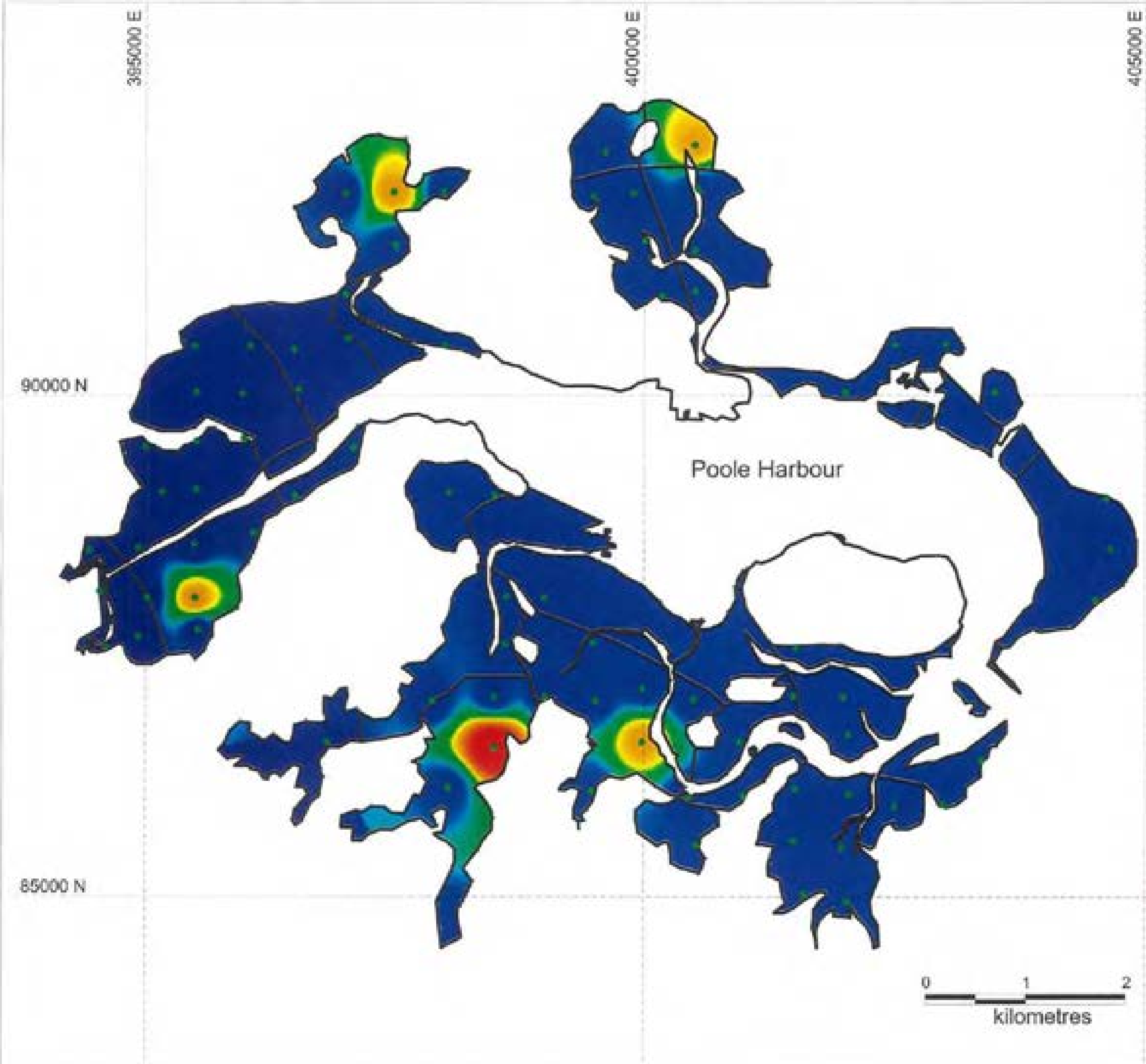


Figure 20

Poole Harbour Dominant Biomass Species

Scrobicularia plana

Key

WeBS Count Section Boundary
Area Available to feeding birds

Scrobicularia plana (mg/sq m)

30,000
25,000
22,500
20,000
16,000
13,000
10,000
6,500
3,000
0

Data Sampling Point

Emu

Drawing No.	Figure No.	Revision
J/1/03/0454	20	

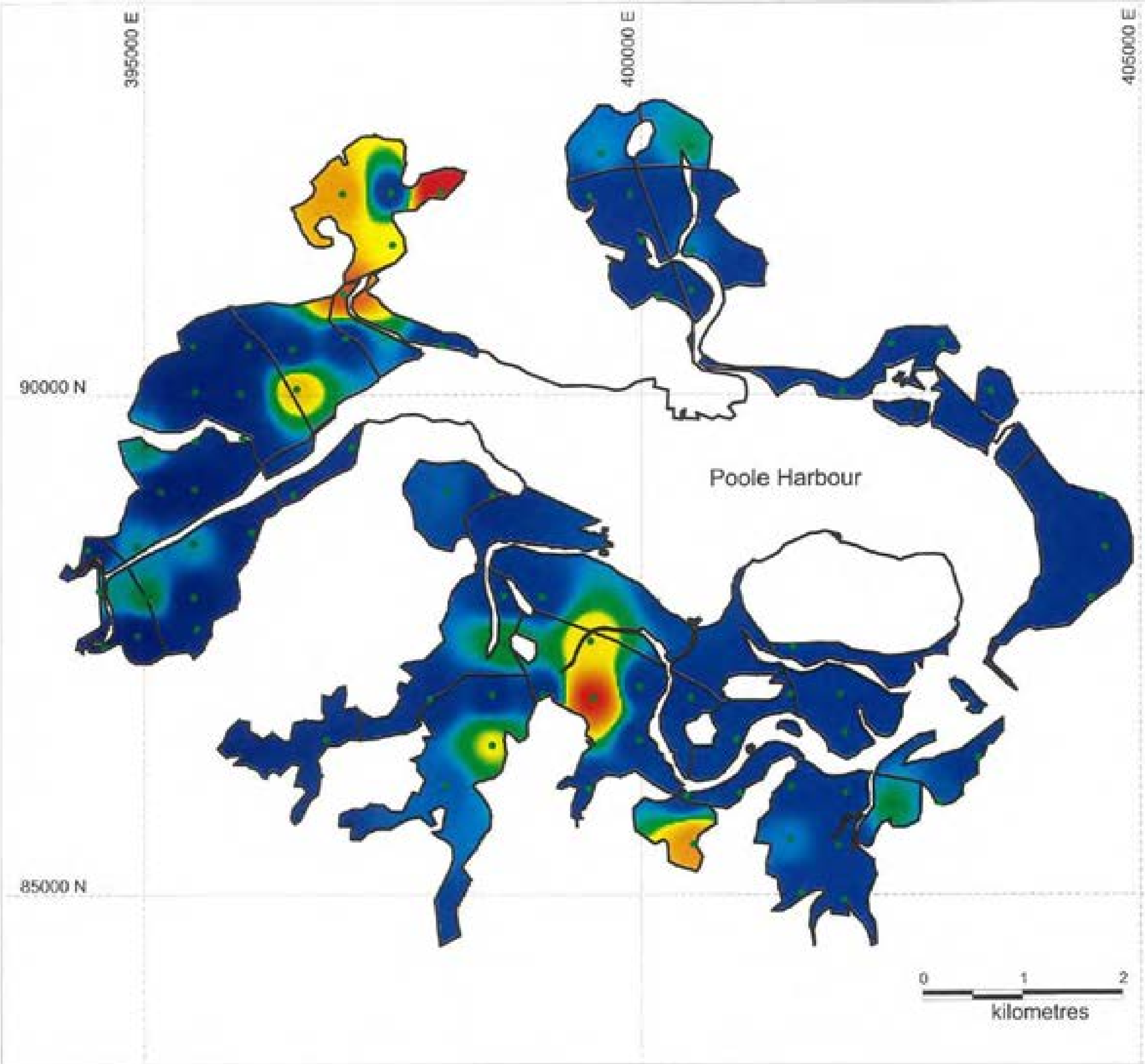


Figure 21

Poole Harbour Dominant Biomass Species

Abra tenuis

Key

WeBS Count Section Boundary
Area Available to feeding birds

Abra tenuis (mg/sq m)

3,500
3,000
2,750
2,500
2,000
1,500
1,000
750
500
0

Data Sampling Point

Drawing No. J/1/03/0454

Figure No. 21

Revision

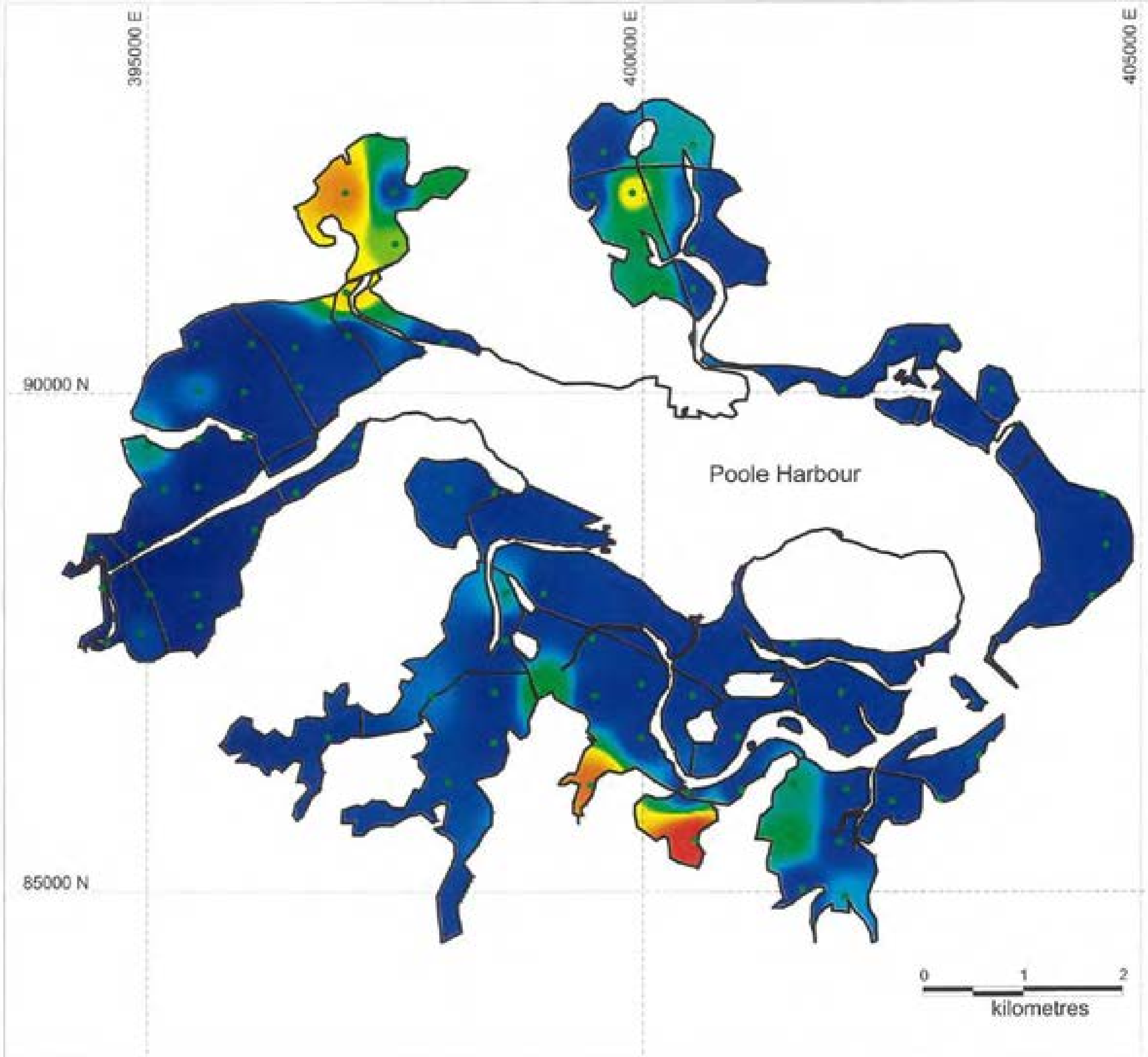


Figure 22

Poole Harbour Dominant Biomass Species

Hydrobia ulvae

Key

WeBS Count Section Boundary
Area Available to feeding birds

Hydrobia ulvae (mg/sq m)

6,500
5,500
5,000
4,000
3,500
3,000
2,000
1,500
750
0

• Data Sampling Point

Emu

Drawing No. J/1/03/0454

Figure No. 22

Revision

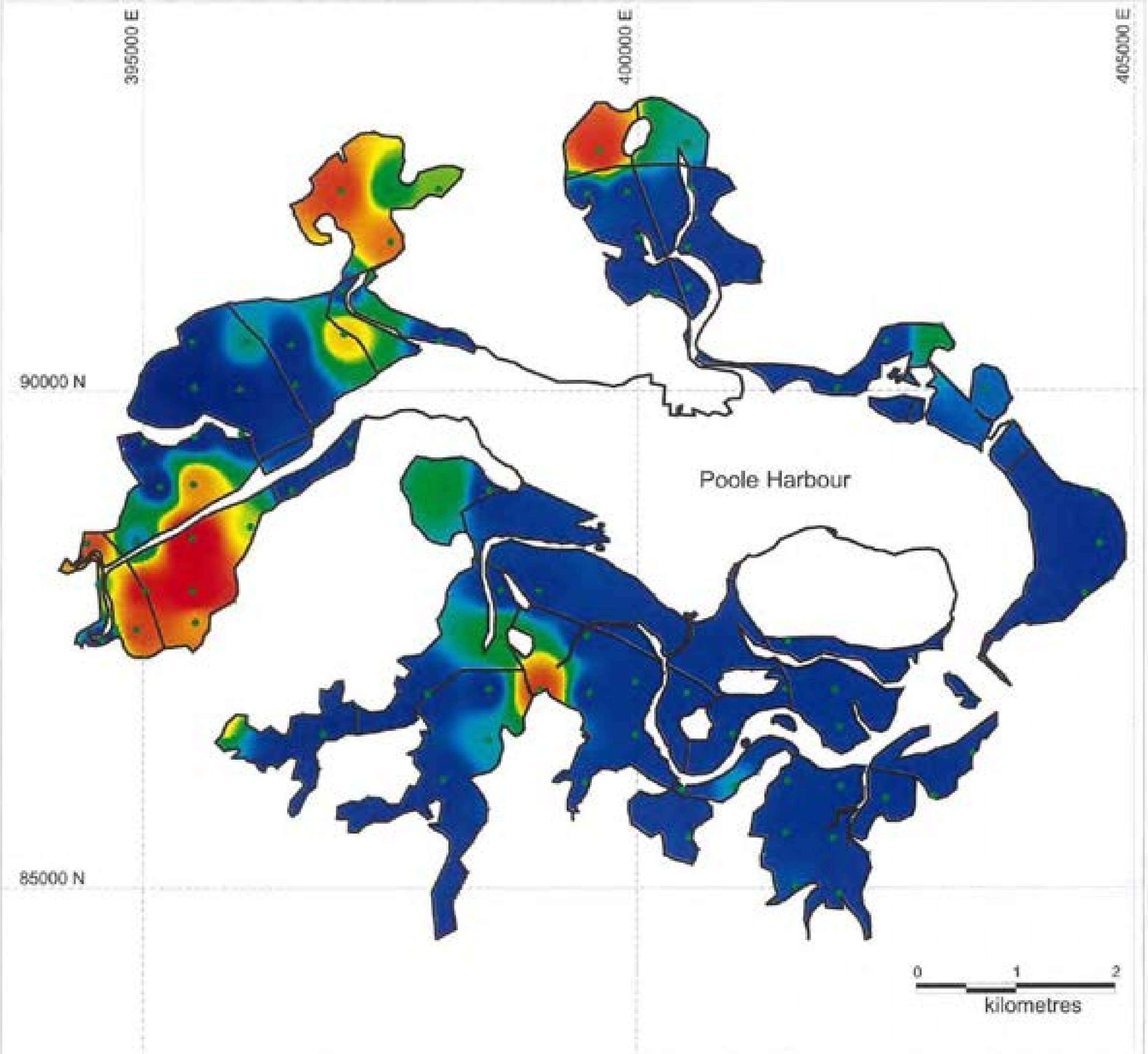


Figure 23

Poole Harbour Dominant Biomass Species

Cyathura carinata

Key

WeBS Count Section Boundary
Area Available to feeding birds

Cyathura carinata (mg/sq m)

1,900
1,690
1,480
1,270
1,060
850
630
420
210
0

Data Sampling Point

Emu

Drawing No. J/1/03/0454

Figure No. 23

Revision

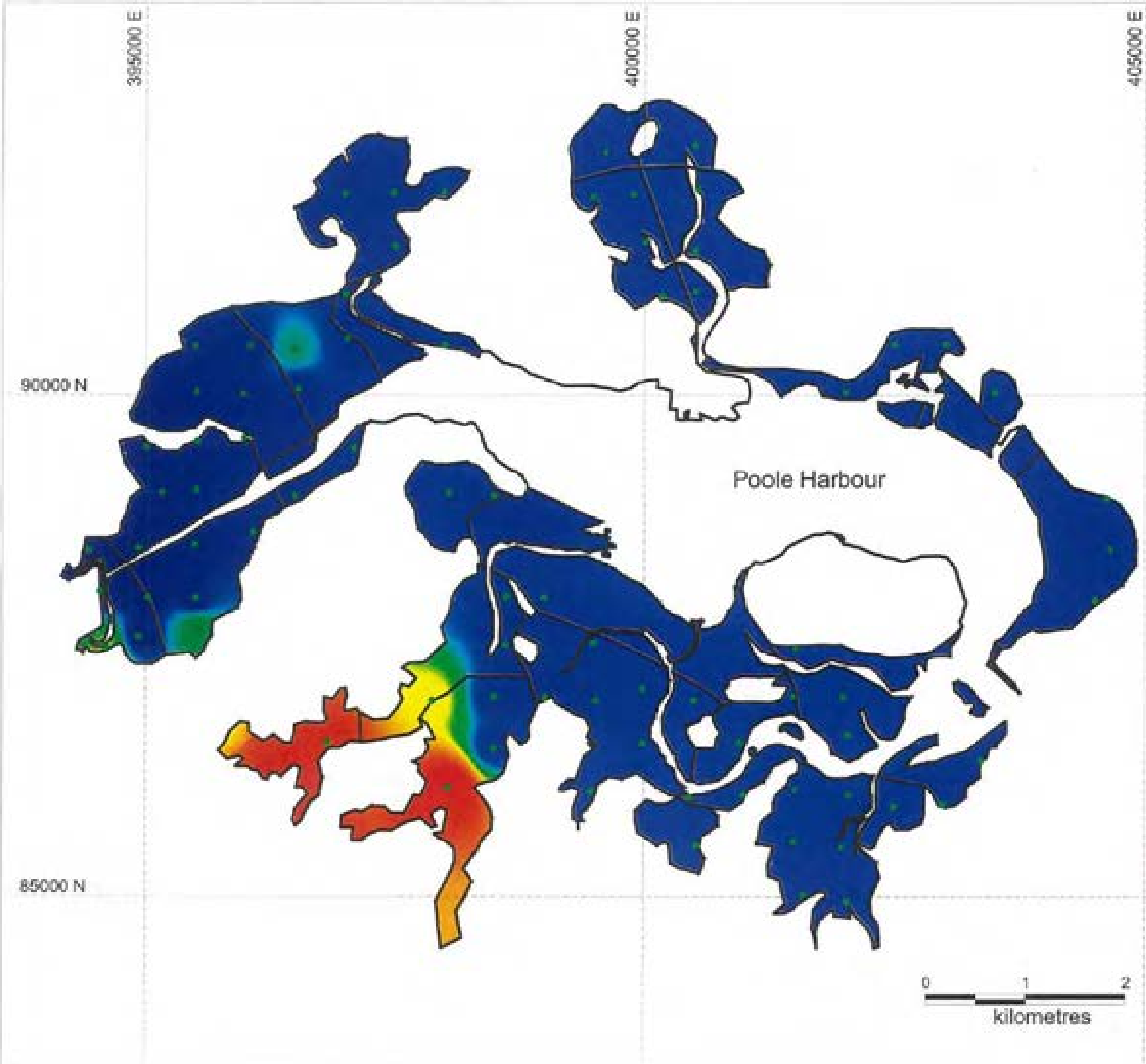


Figure 24

Poole Harbour Dominant Biomass Species

Corophium volutator

Key

WeBS Count Section Boundary
Area Available to feeding birds

Corophium volutator (mg/sq m)

4,220
3,750
3,290
2,820
2,350
1,880
1,410
940
470
0

Data Sampling Point

Drawing No. J/1/03/0454
Figure No. 24
Revision

Figure 25a. Classification of invertebrate data

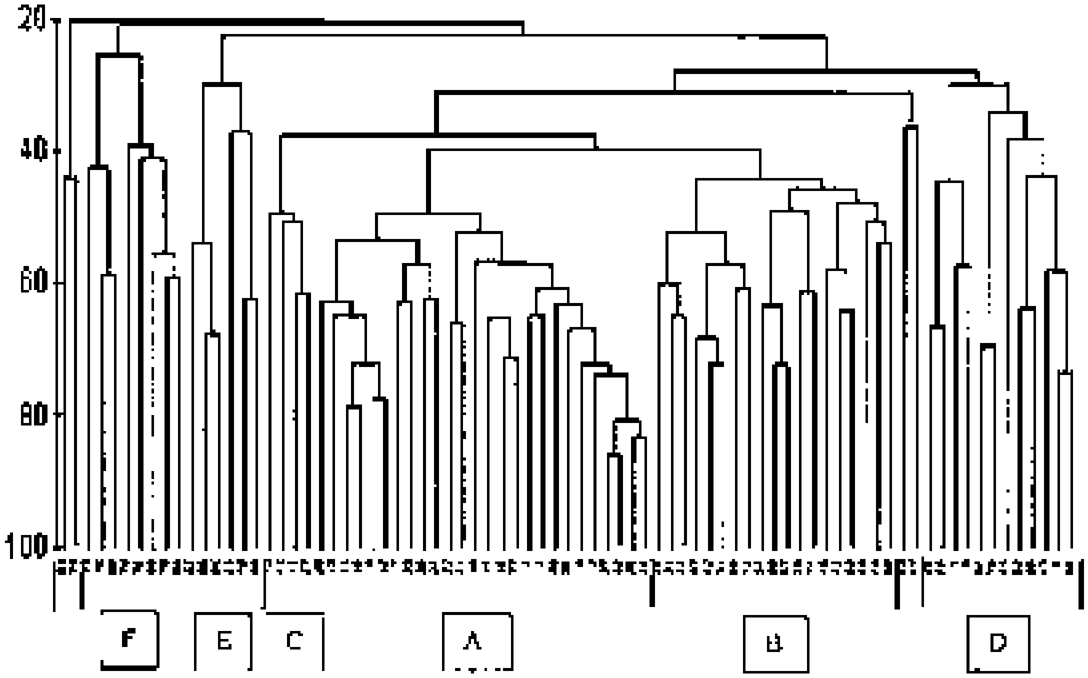
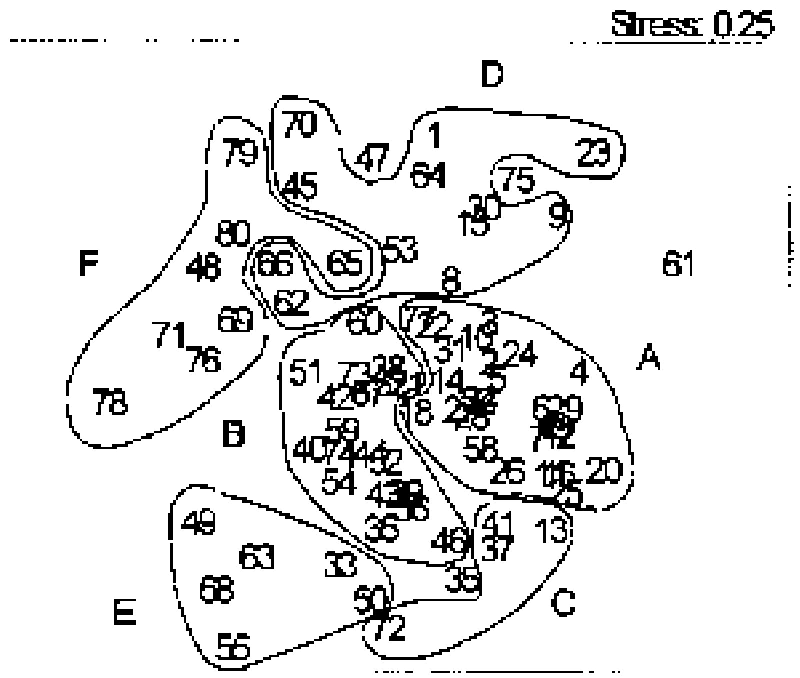


Figure 25b. Ordination of invertebrate data



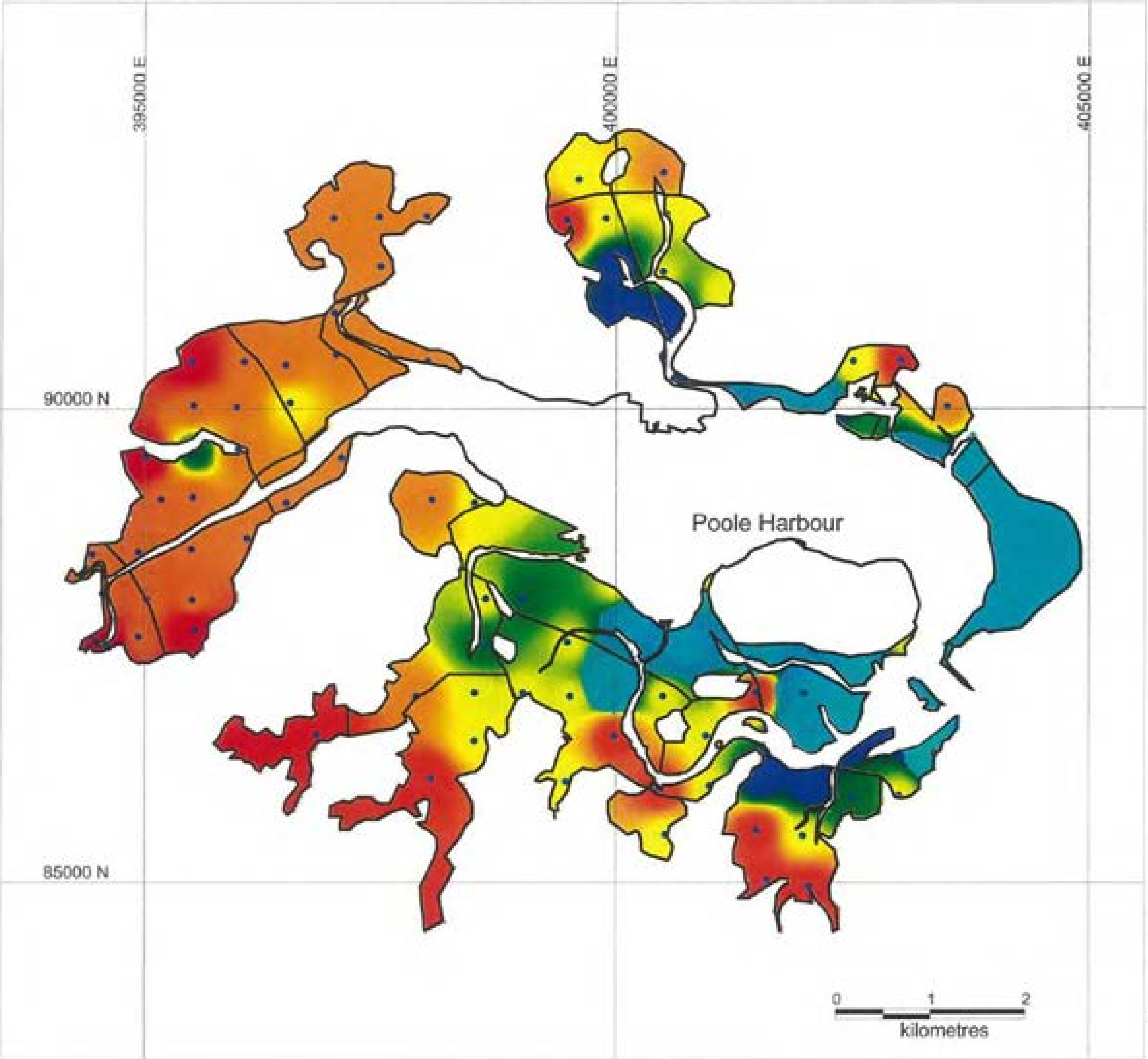


Figure 26

Distribution of Invertebrate Clusters

Key

• Actual Sample Position

Invertebrate Cluster

- 1 - D
- 2 - A
- 3 - B
- 4 - C
- 5 - E
- 6 - F

Drawing No. J/1/03/0454

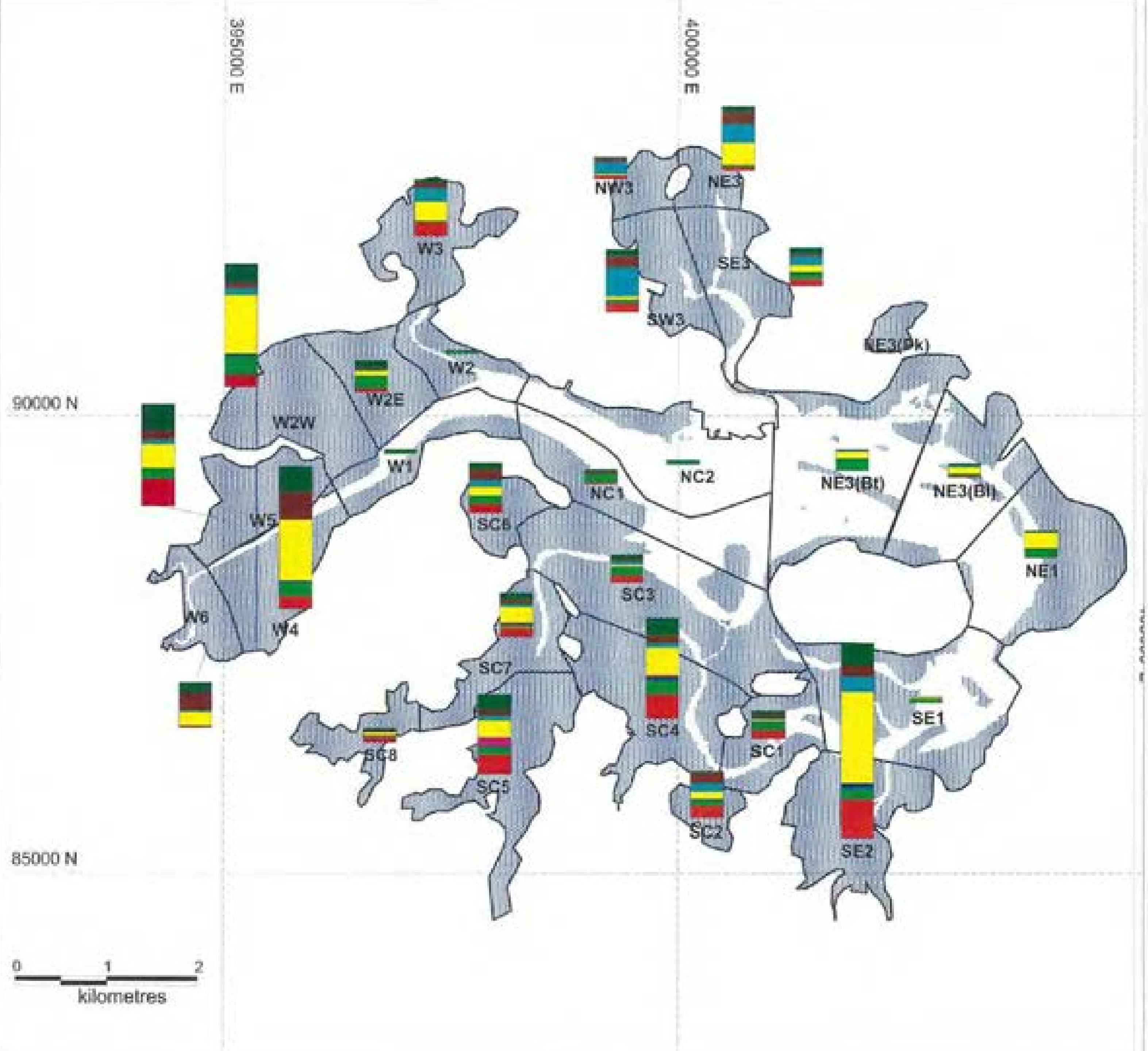
Figure No. 26

Revision

Figure 27

Poole Harbour Bird Count
Yearly Mean 1991 - 1998

Number of Individuals Per Sector
All Bird Species



Key

WeBS Count Section Boundary

Areas between MHW and MLW as shown on Admiralty Chart No. 2615_0 (excepting area W7)

Number of Individuals per Sector:

Bird Count	Species
9500	Shellduck
7000	Oyster catcher
4500	Grey Plover
2500	Avocet
0	Dunlin
	Redshank
	Black Tailed Godwit
	Curlew

Drawing No. J/1/03/0454 | Figure No. 27 | Revision

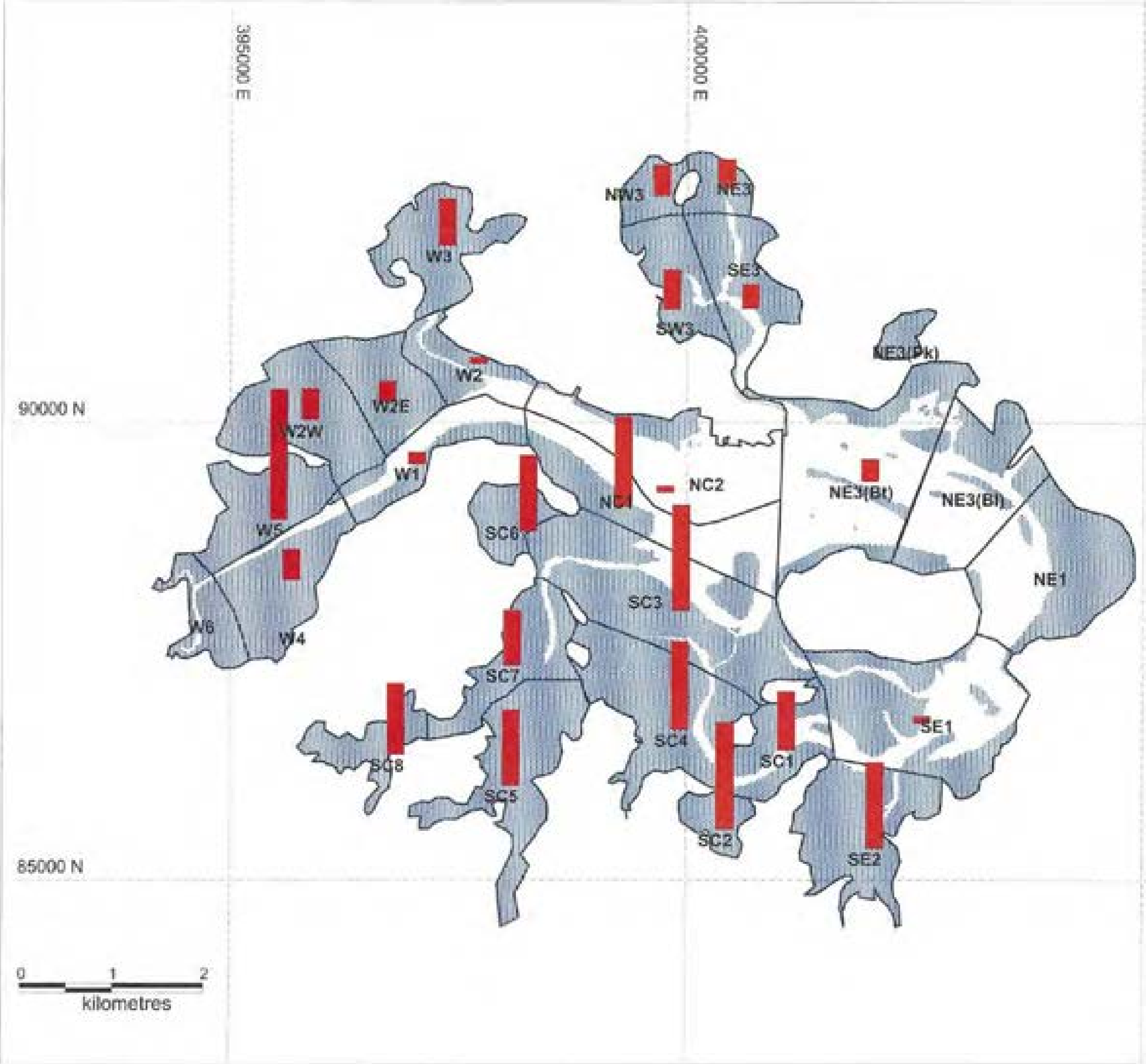


Figure 28

Poole Harbour Bird Count
1991 - 1998

Mean Number of Shellduck
Per Hectare

Key

WeBS Count Section Boundary

Areas between MHWS and CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

21
15.75
10.5
5.25

Emu

Drawing No. J/1/03/0454
Figure No. 1.0
Revision

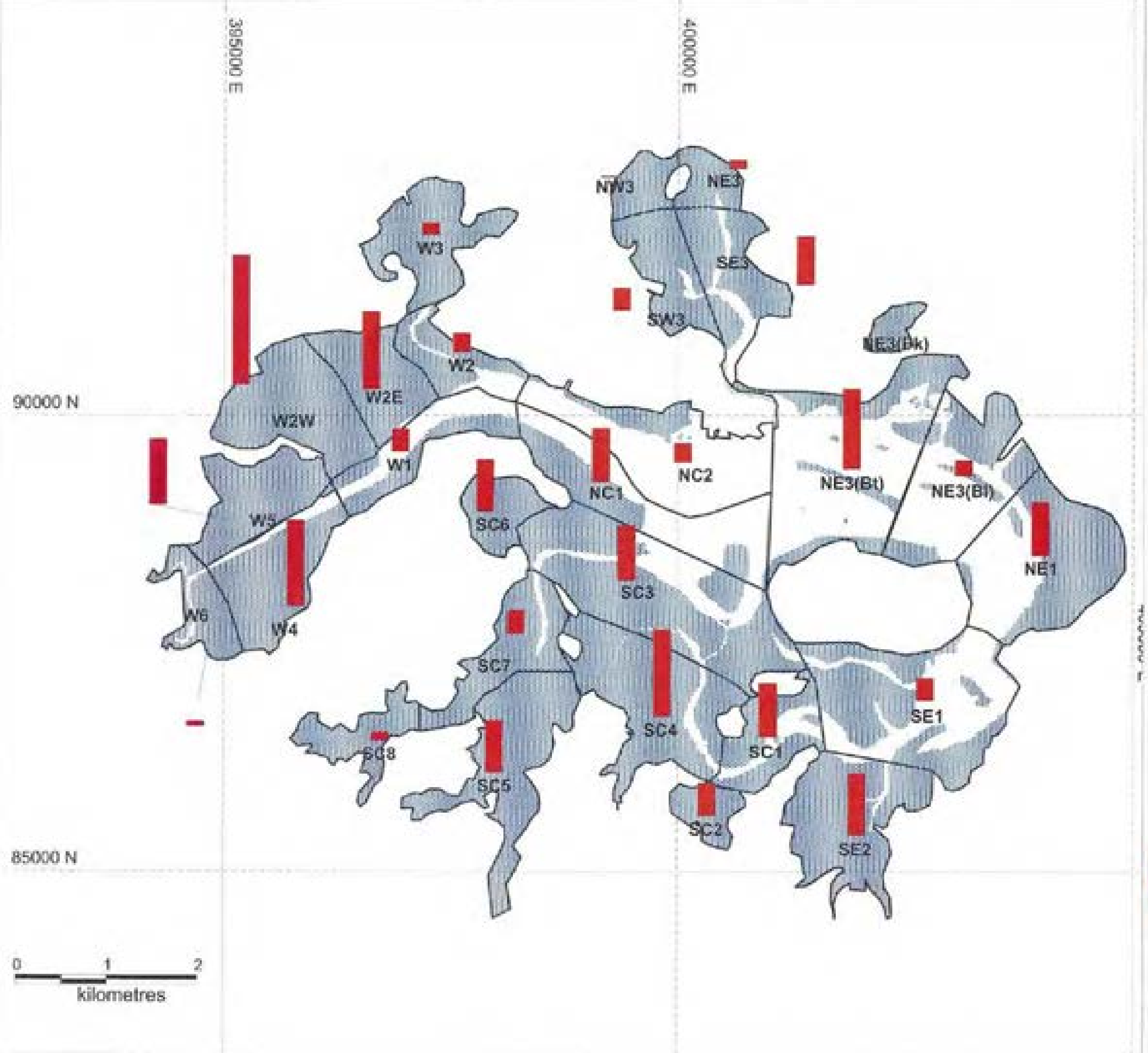


Figure 29

Poole Harbour Bird Count
1991 - 1998

Mean Number of Oystercatcher
Per Hectare

Key

WeBS Count Section Boundary

Areas between MHWS and CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

120
90
60
30

Emu

Drawing No. J/1/03/0454

Figure No. 29

Revision

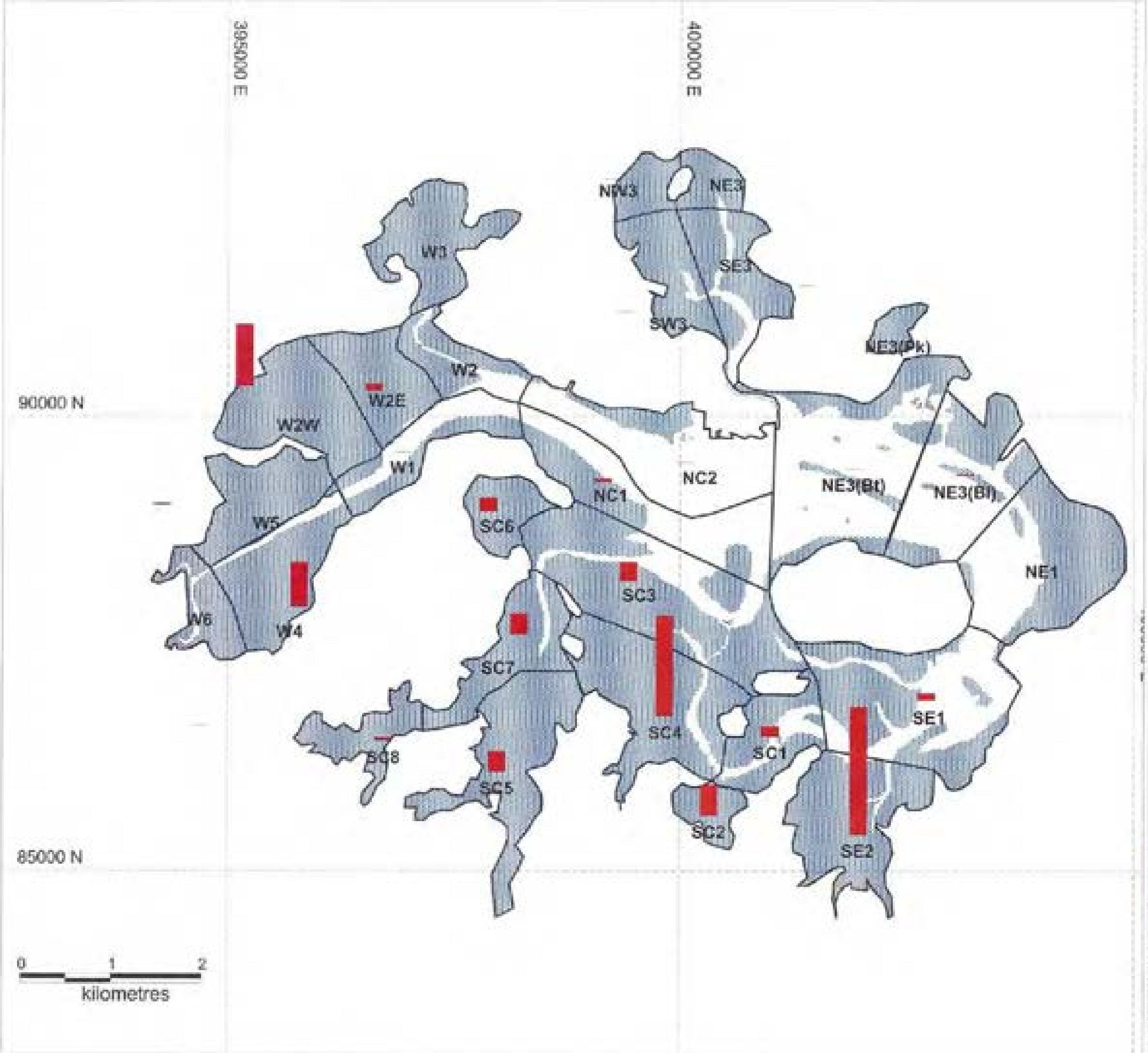


Figure 30

Poole Harbour Bird Count
1991 - 1998

Mean Number of Grey Plover
Per Hectare

Key

WeBS Count Section Boundary

Areas between MHWSand CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

31
23.25
15.5
7.75

Drawing No. J/1/03/0454
Figure No. 30
Revision

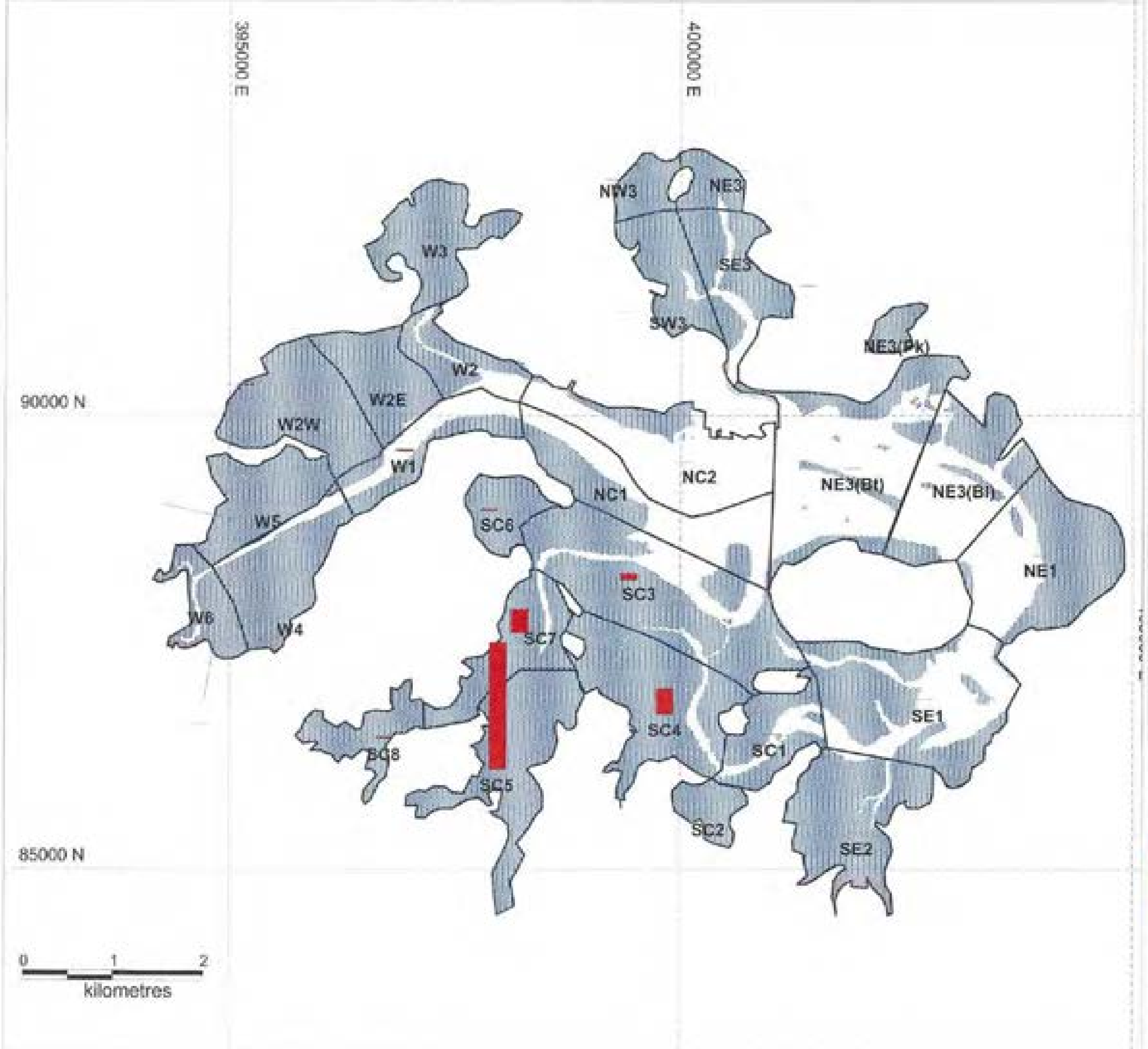


Figure 31

Poole Harbour Bird Count
1991 - 1998

Mean Number of Avocet Per Hectare

Key

WeBS Count Section Boundary

Areas between MHWS and CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

57
42.75
28.5
14.25

Drawing No: J/1/03/0454
Figure No: 31
Revision

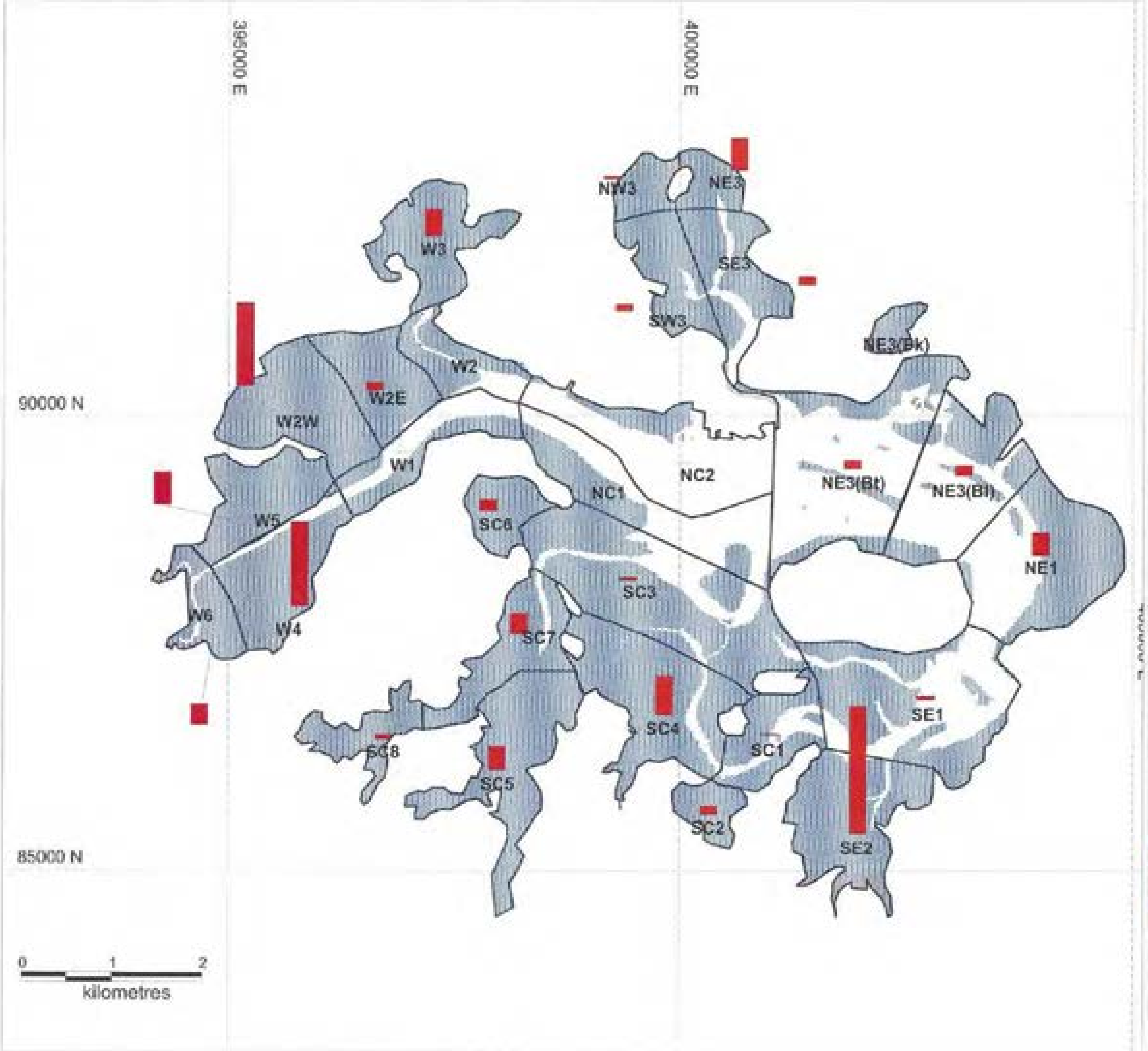


Figure 32

Poole Harbour Bird Count
1991 - 1998

Mean Number of Dunlin Per Hectare

Key

WeBS Count Section Boundary

Areas between MHWS and CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

560
420
280
140

Emu

Drawing No. J/1/03/0454

Figure No. 32

Revision

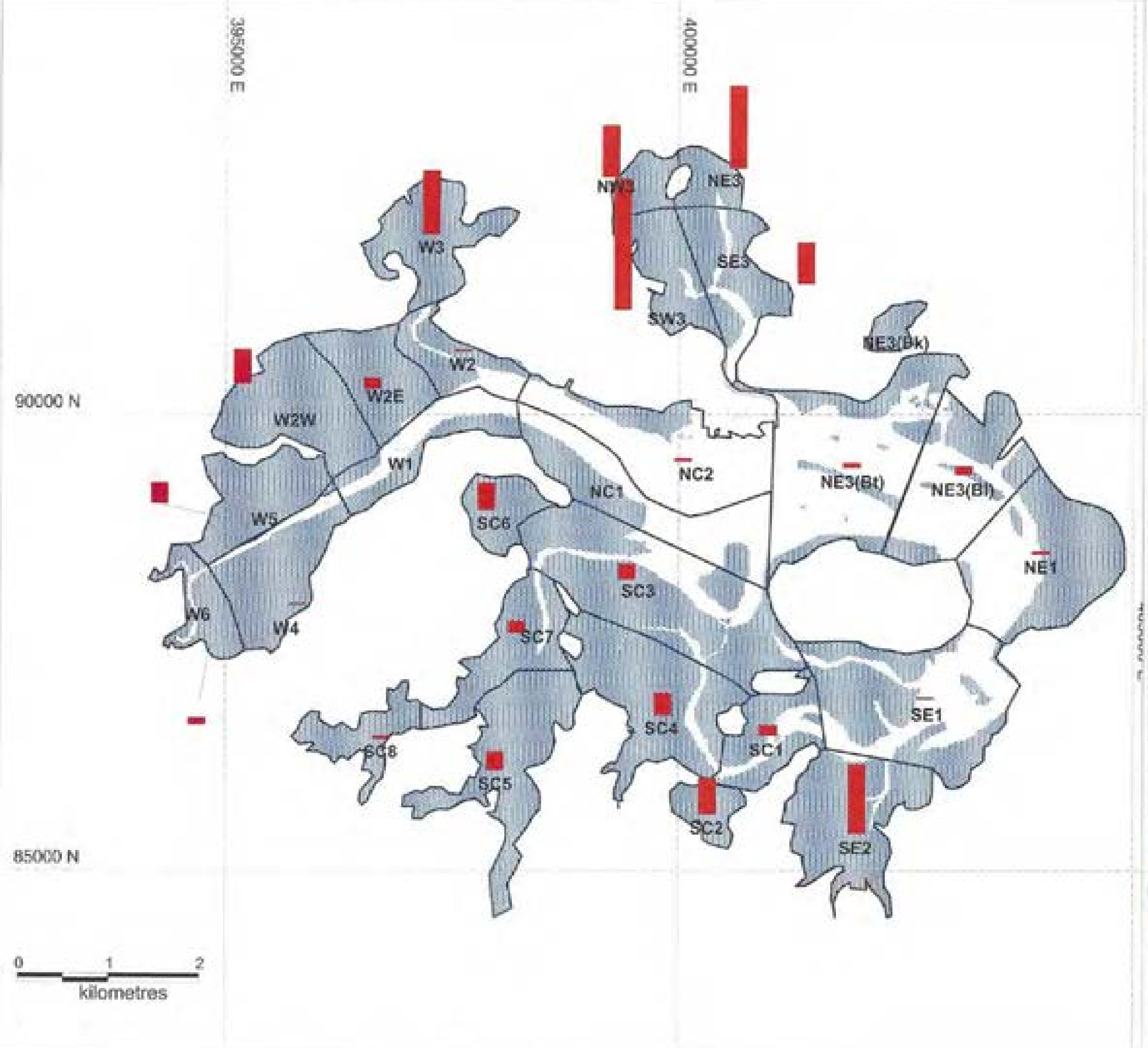


Figure 33

Poole Harbour Bird Count
1991 - 1998

Mean Number of Redshank Per Sector

Key

WeBS Count Section Boundary

Areas between MHWS and CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

180
135
90
45

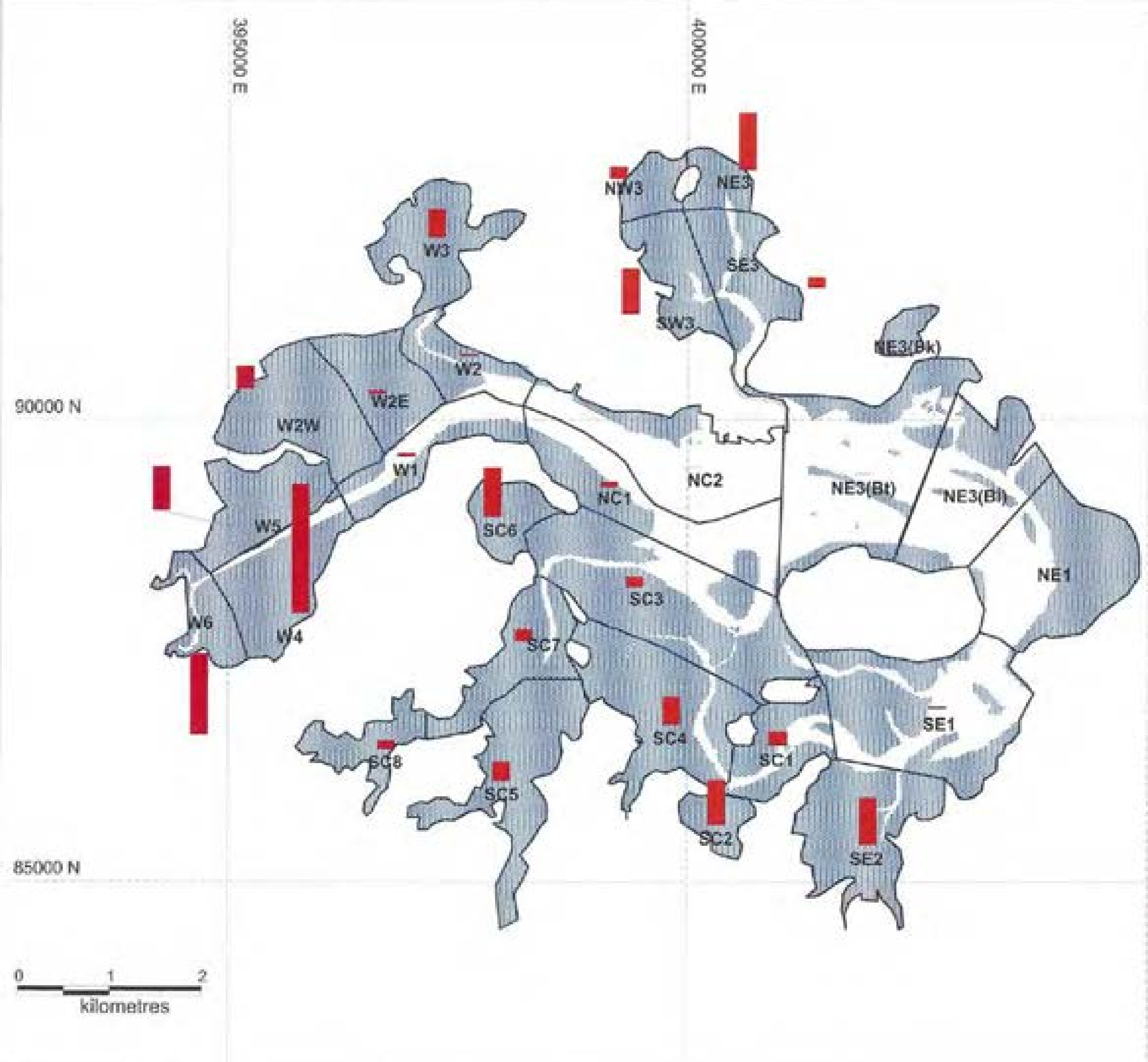
Emu

Drawing No. J/1/03/0454
Figure No. 33
Revision

Figure 34

Poole Harbour Bird Count
1991 - 1998

Mean Number of Black-tailed Godwit
Per Hectare



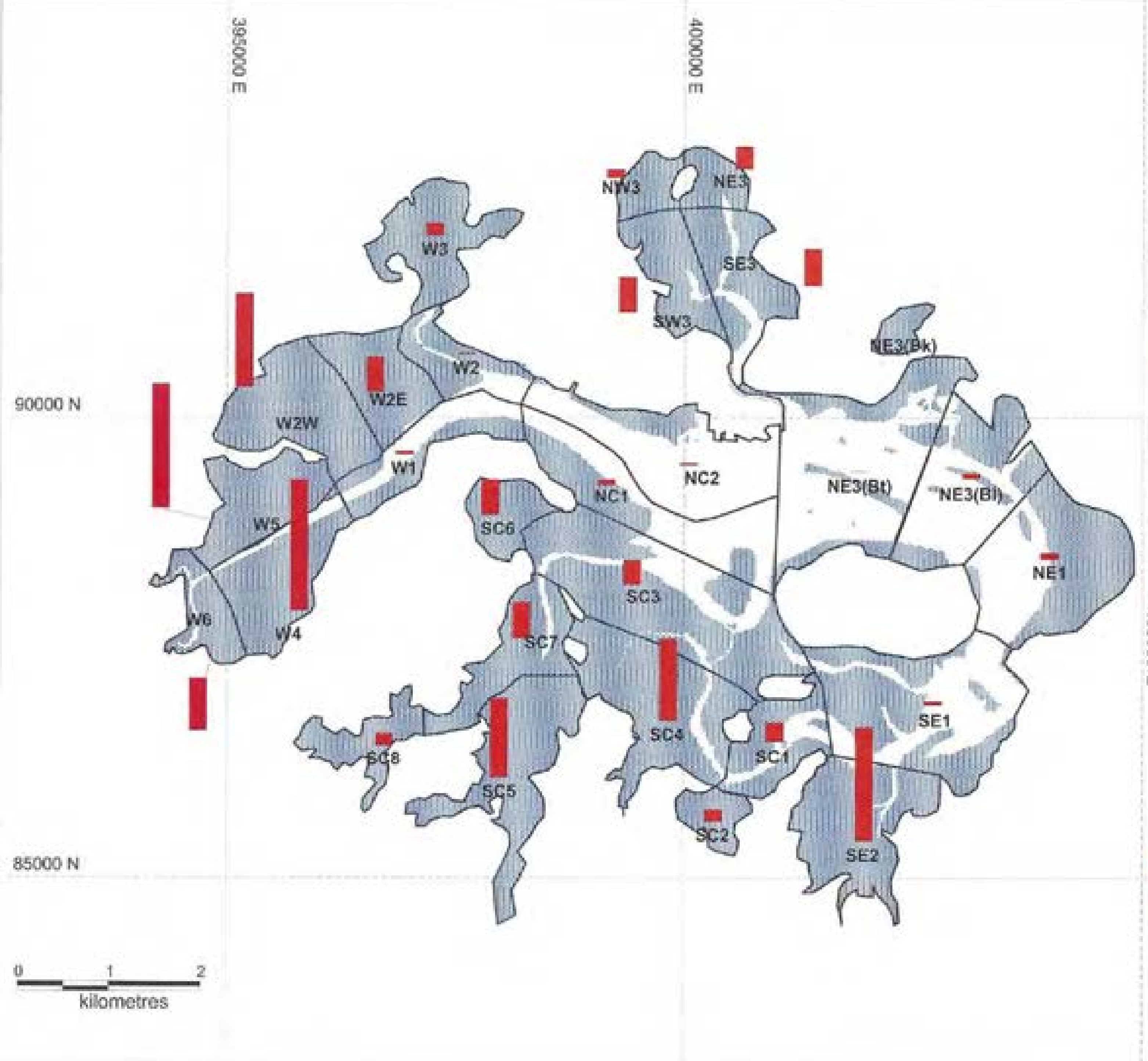


Figure 35

Poole Harbour Bird Count
1991 - 1998

Mean Number of Curlew Per Hectare

Key

WeBS Count Section Boundary

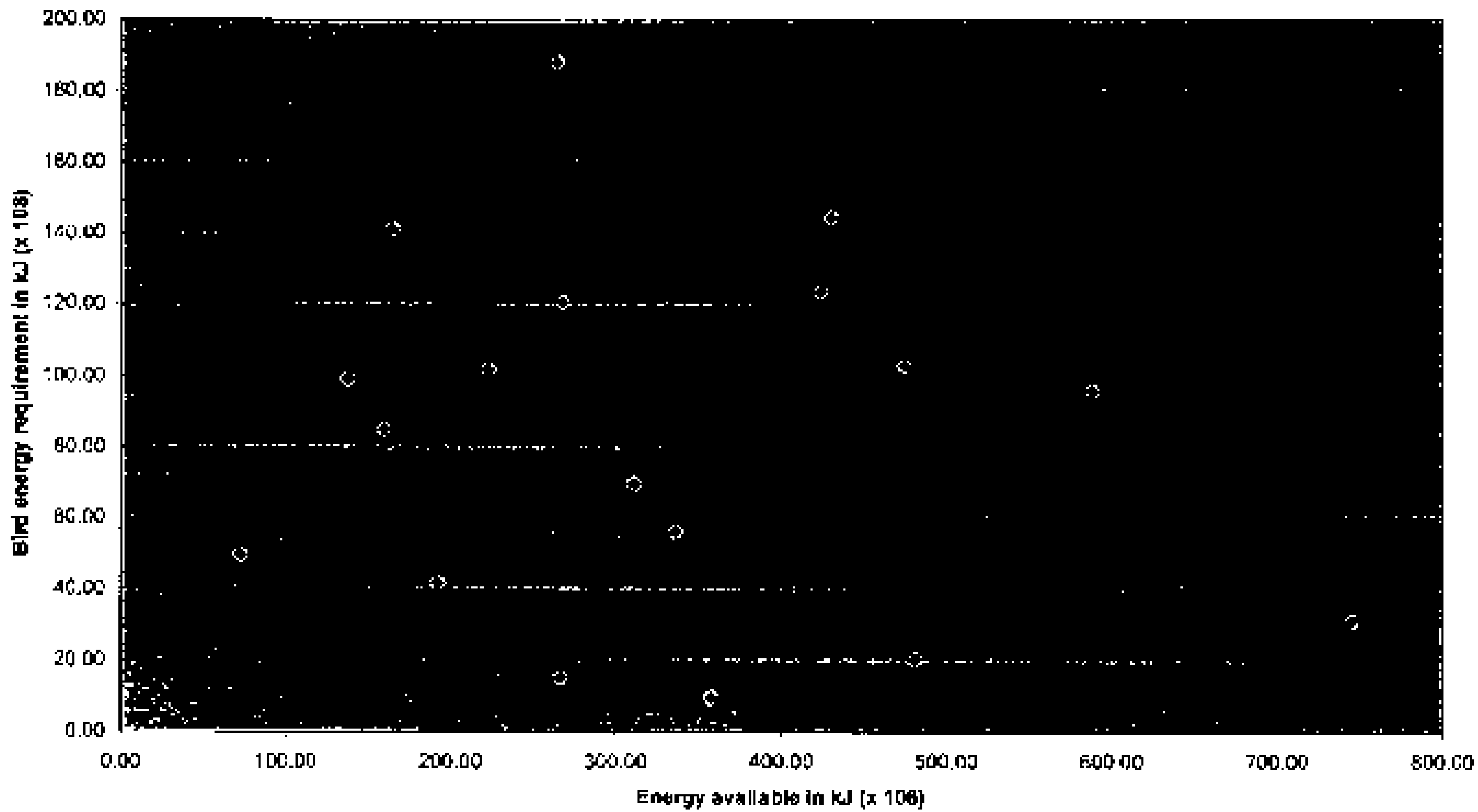
Areas between MHWS and CD as shown on Admiralty Chart No. 2611

Bird Count Data 1991-1998

170
127.5
85
42.5

Drawing No. J/1/03/0454
Figure No. 35
Revision

Fig. 36. Avifaunal energy requirement per sector compared to invertebrate prey available.



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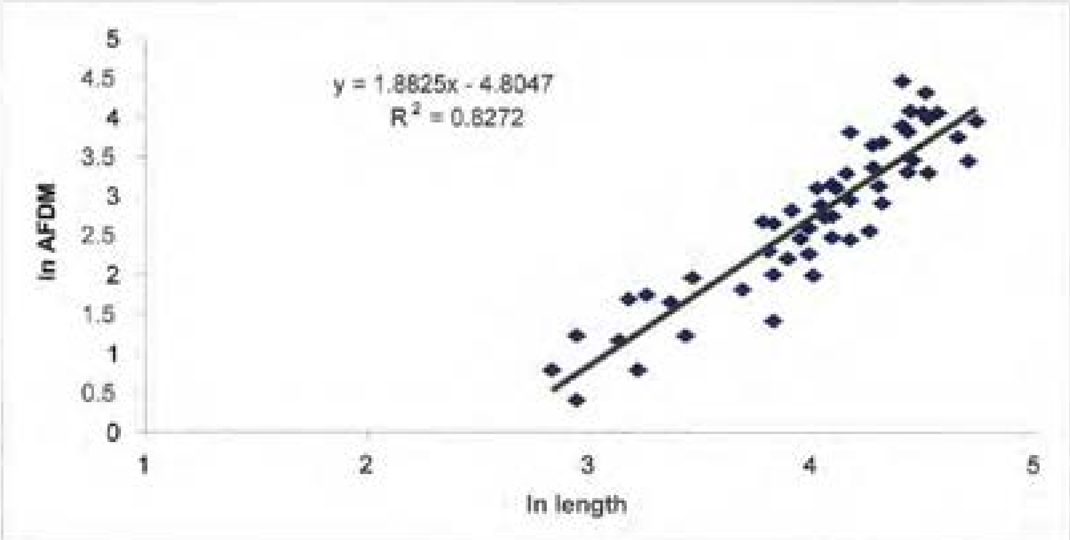
APPENDIX 1.

Weight to length ratios for invertebrate species

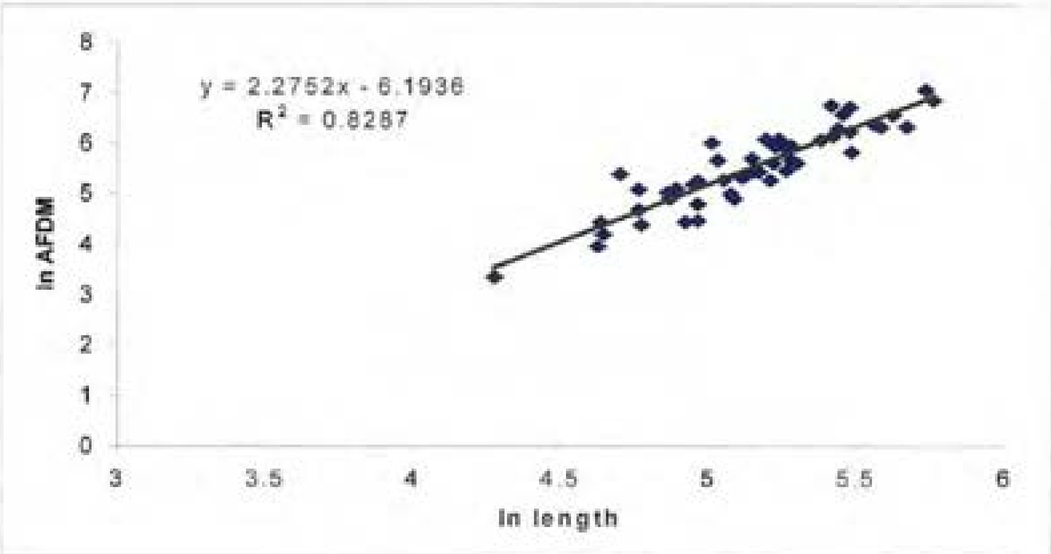
Hediste diversicolor

Slope	1.88
Intercept	-4.8
R^2	82.4%
p	<0.001
Error MS	0.175



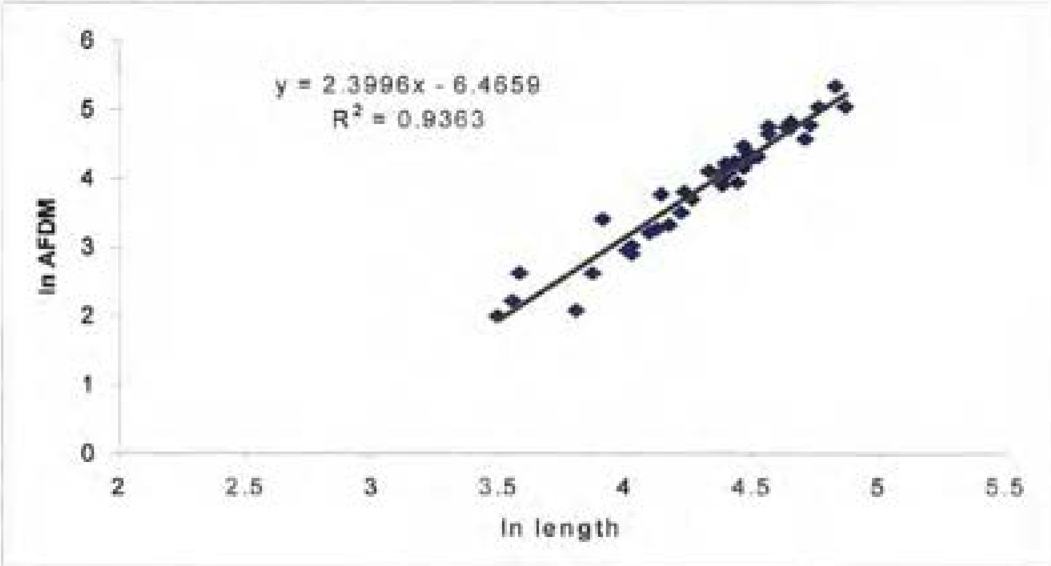
Nereis virens

Slope	1.88
Intercept	-4.8
R^2	82.4%
p	<0.001
Error MS	0.175



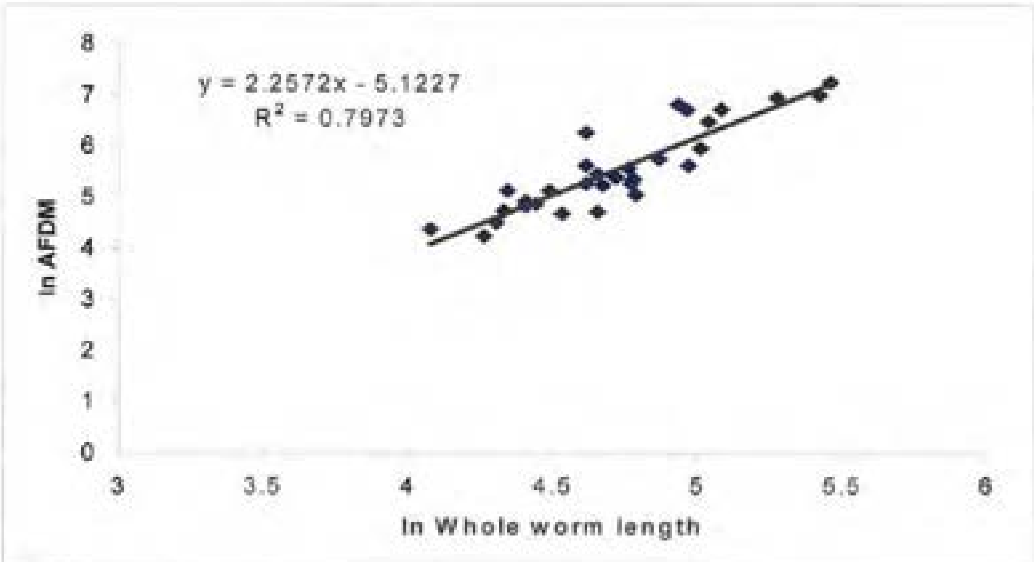
Nephtys sp

Slope	2.4
Intercept	-6.47
R^2	93.5%
p	<0.001
Error MS	0.043



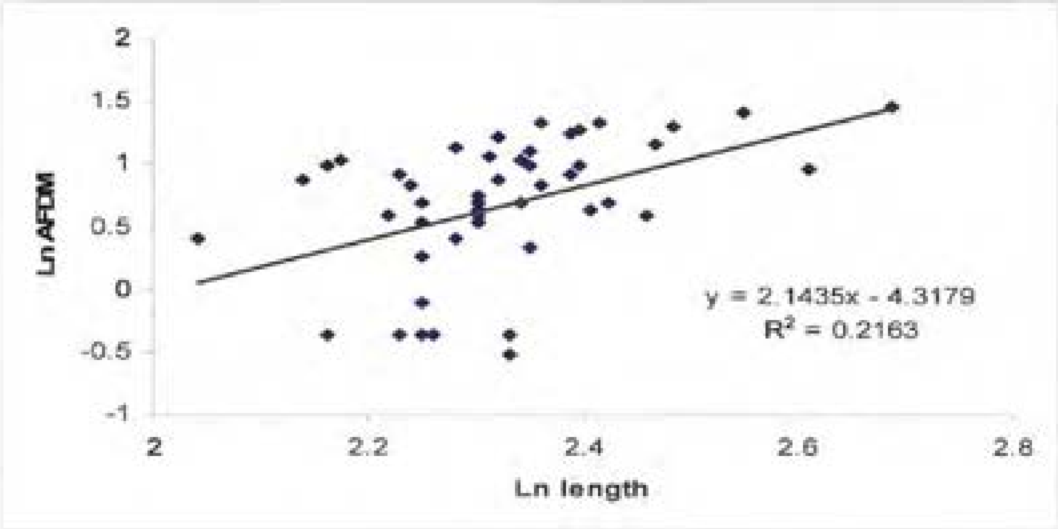
Arenicola marina

Slope	2.26
Intercept	-5.12
R^2	79.1%
p	<0.001
Error MS	0.14



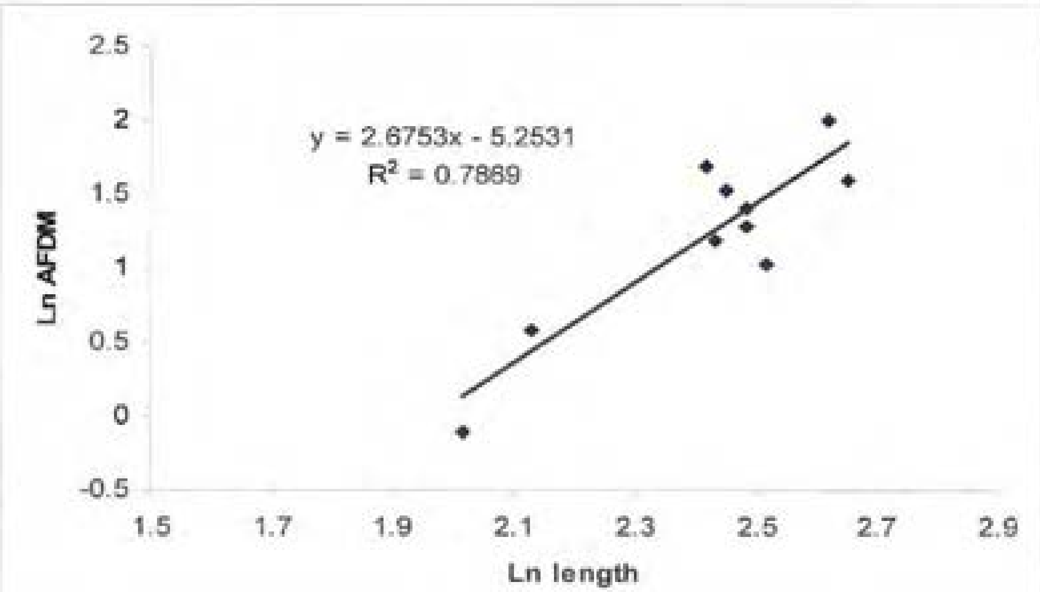
Cyathura carinata

Slope	2.1435
Intercept	-4.3179
R^2	21.60%
p	<0.001
Error MS	0.2182



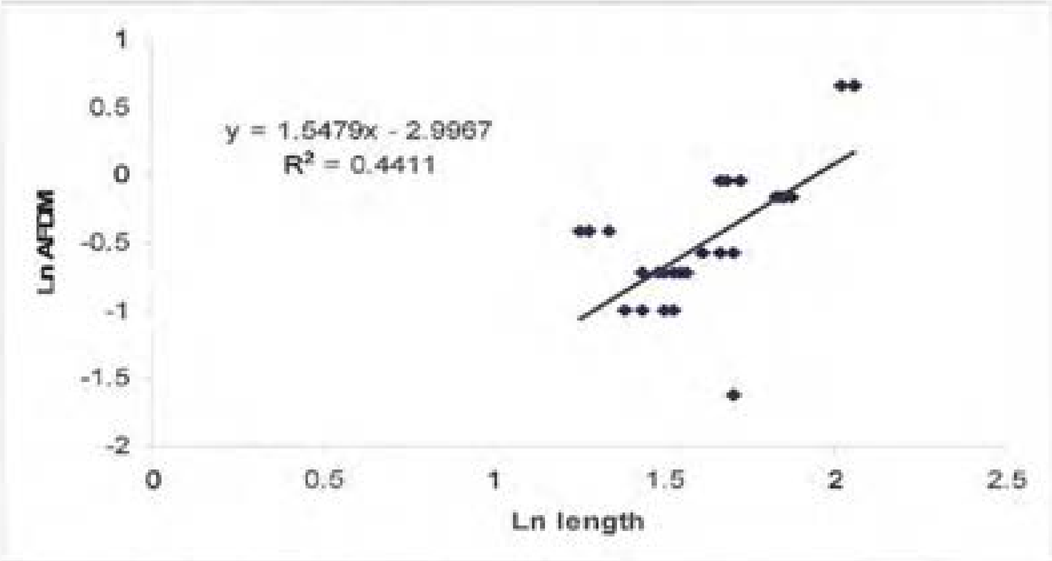
Gammarus locusta

Slope	2.6753
Intercept	-5.2531
R^2	78.70%
p	<0.001
Error MS	0.0787



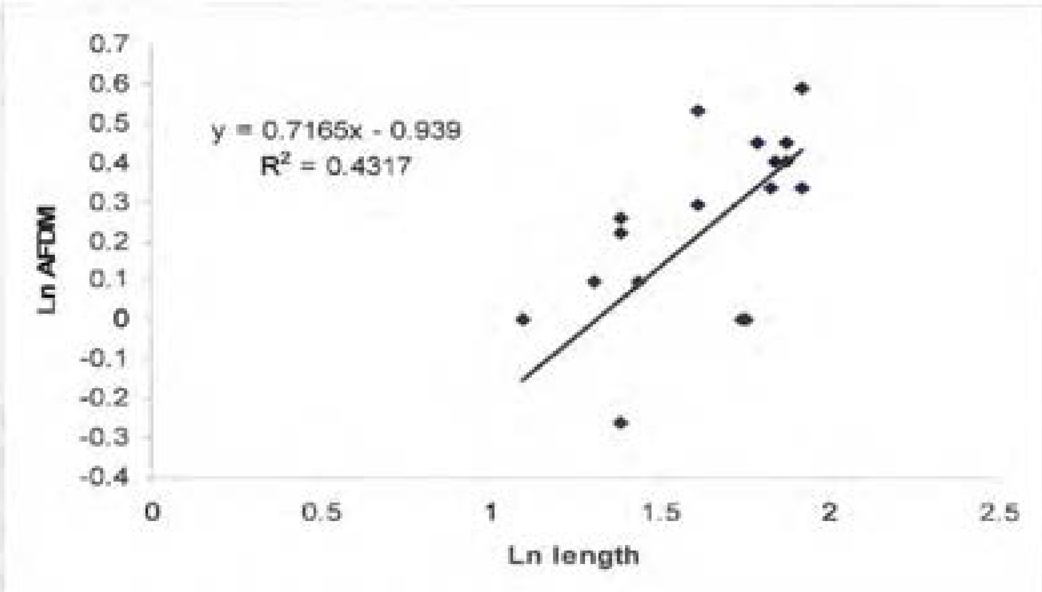
Corophium volutator

Slope	1.5479
Intercept	-2.9967
R^2	44.10%
p	<0.001
Error MS	0.129



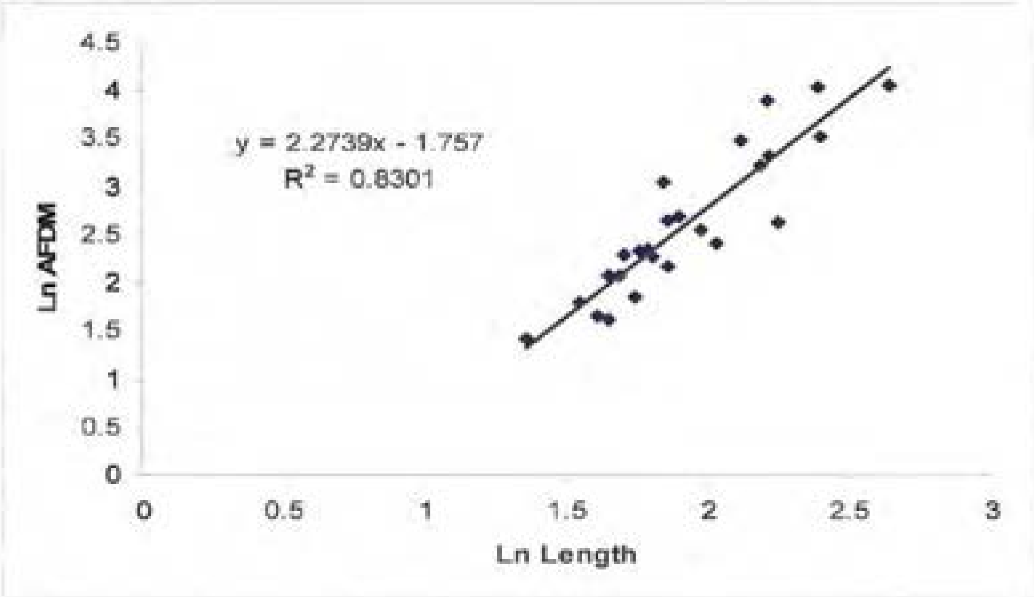
Corophium arenarium

Slope	0.7165
Intercept	-0.939
R^2	43.20%
p	0.001
Error MS	0.0374



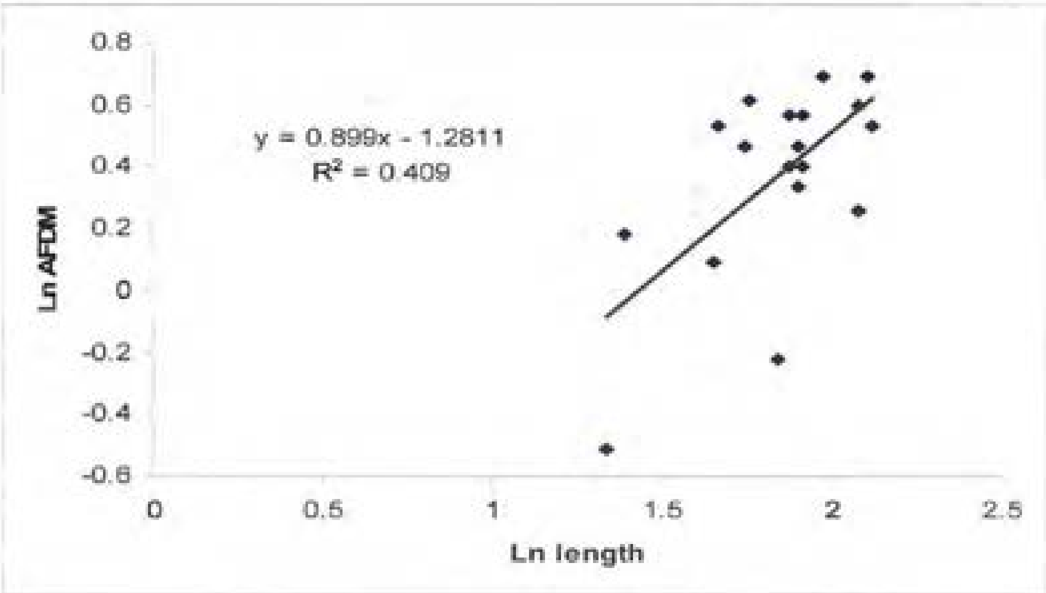
Carcinus maenas

Slope	2.2739
Intercept	-1.757
R^2	83.00%
p	<0.001
Error MS	0.104



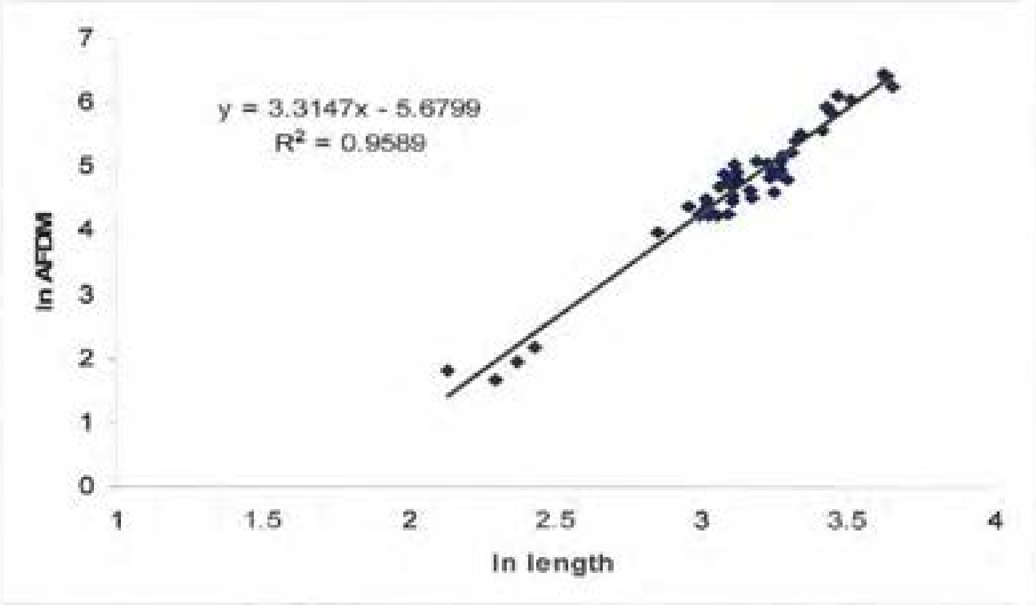
Bathyporeia

Slope	0.899
Intercept	-1.2811
R^2	40.90%
p	0.003
Error MS	0.062



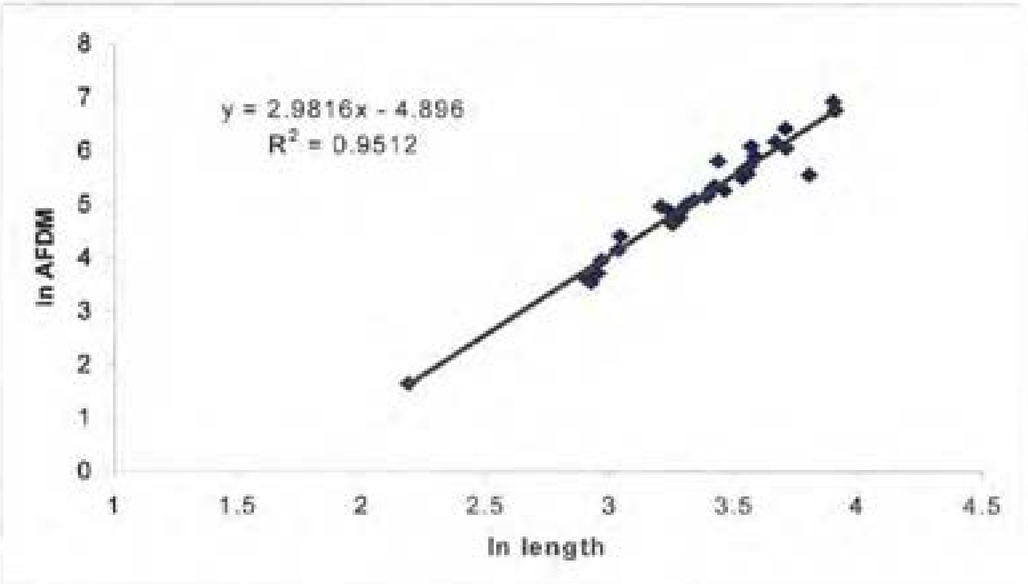
Cerastoderma edule

Slope	3.315
Intercept	-5.68
R^2	95.8%
p	<0.001
Error MS	0.046



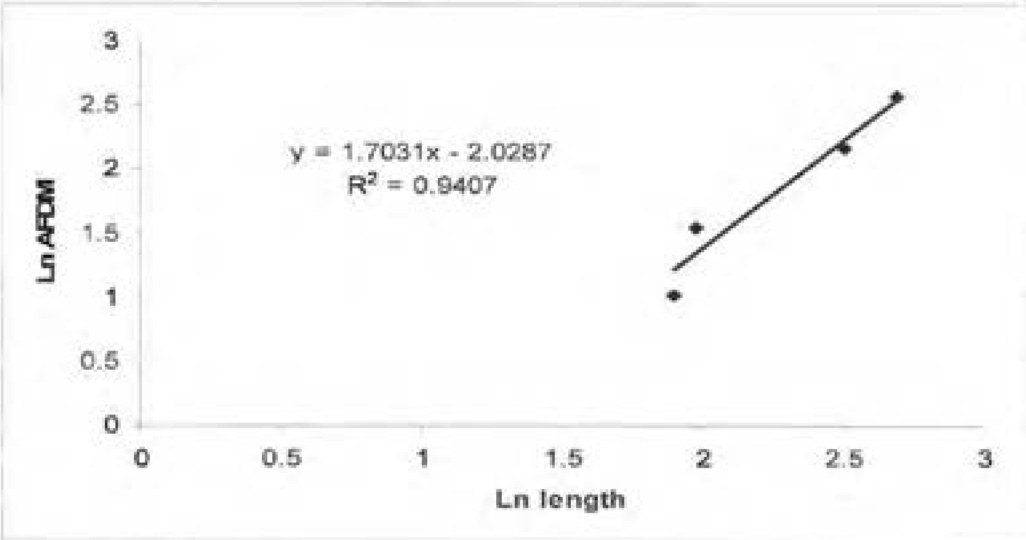
Ruditapes philippinarum

Slope	2.98
Intercept	-4.9
R^2	95.0%
p	<0.001
Error MS	0.057



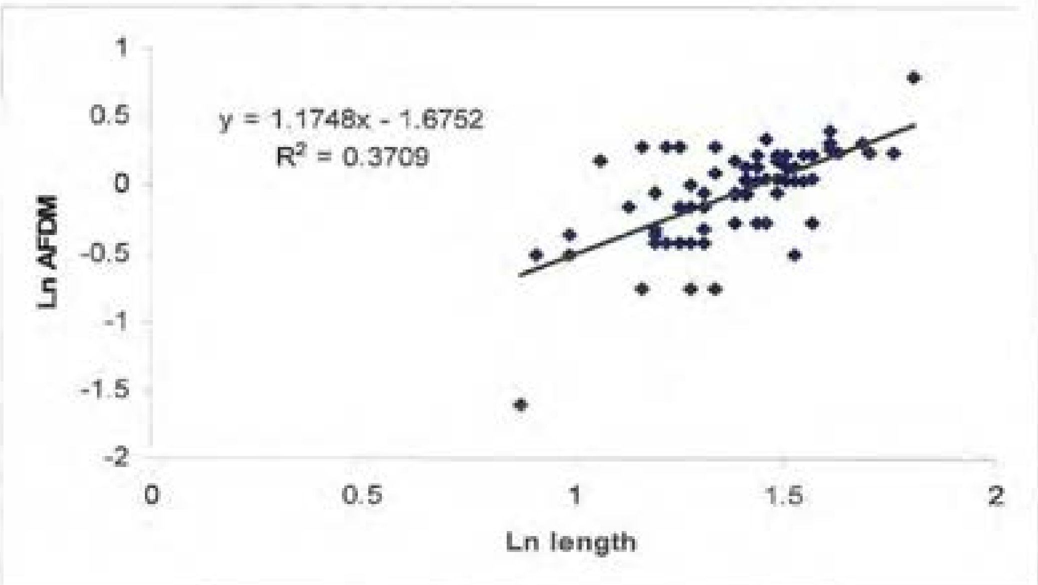
Abra tenuis

Slope	1.7031
Intercept	-2.0287
R^2	94.10%
p	0.03
Error MS	0.0412



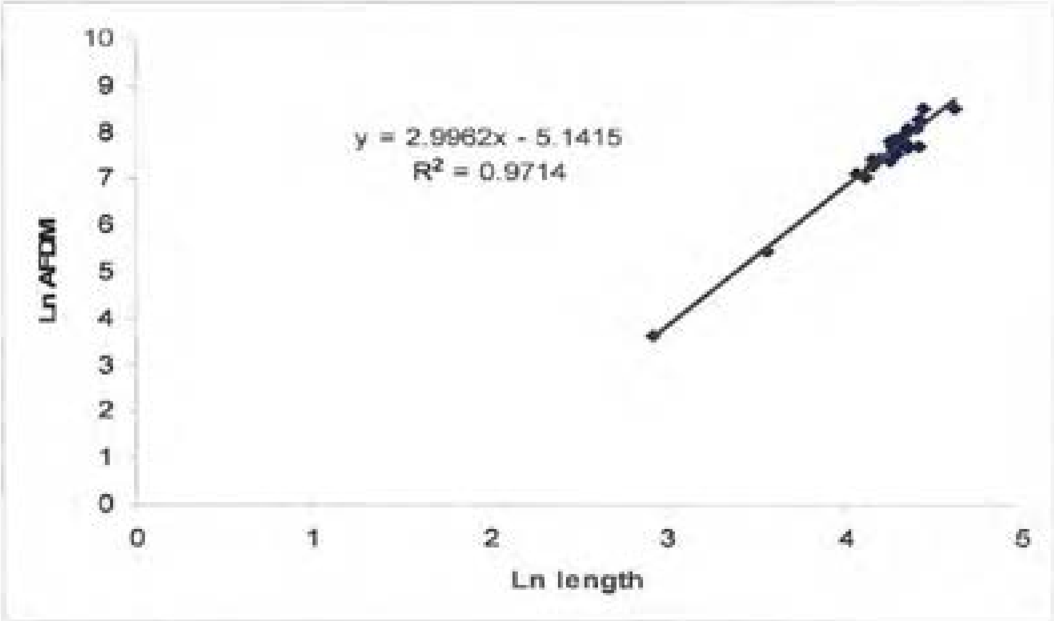
Hydrobia ulvae

Slope	1.1748
Intercept	-1.6752
R^2	37.10%
p	<0.001
Error MS	0.0762



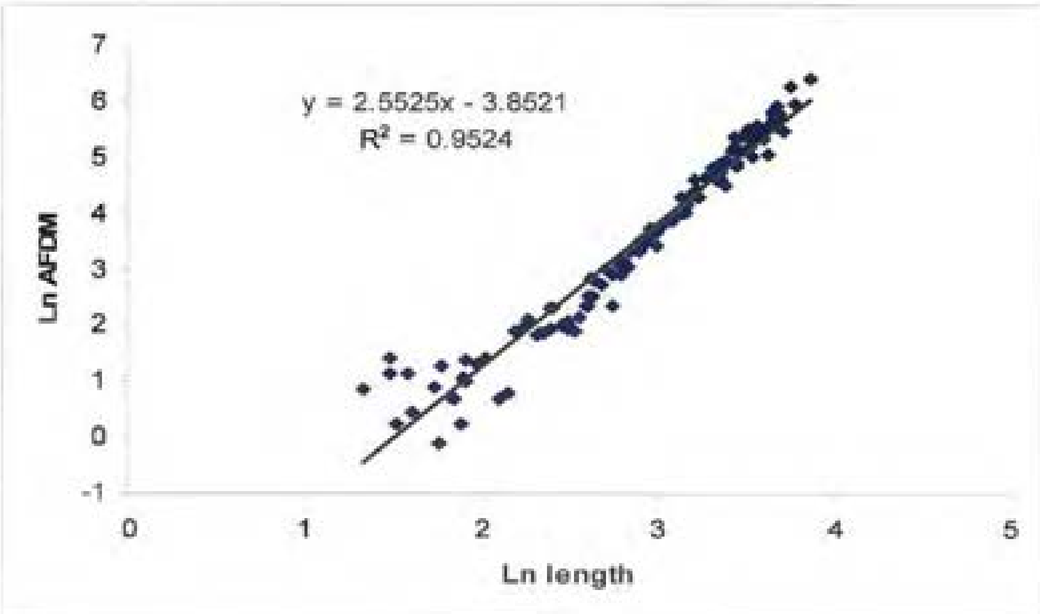
Mya arenaria

Slope	2.9962
Intercept	-5.1415
R^2	97.10%
p	<0.001
Error MS	0.03



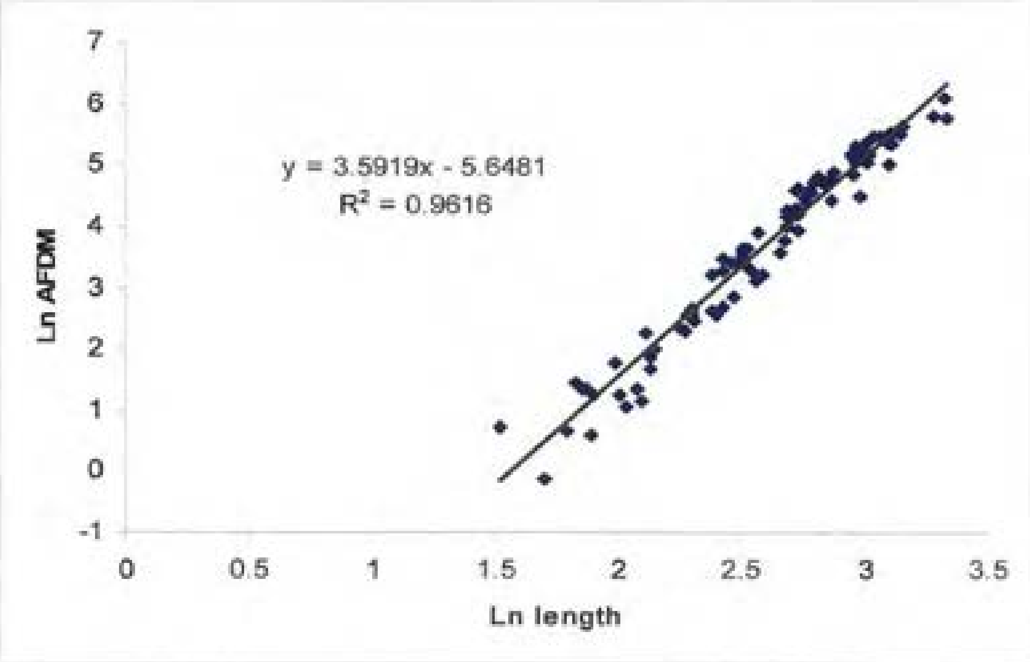
Scrobicularia plana

Slope	2.5525
Intercept	-3.8521
R^2	95.20%
p	<0.001
Error MS	0.14



Littorina spp

Slope	3.59194
Intercept	-5.6481
R^2	96.20%
p	<0.001
Error MS	0.09



APPENDIX 2.

Basic data assumptions for the calculation of available energy due to invertebrates and energy required by birds.

Basic Data Parameters

The data contained in this page sets the limits for subsequent pages. Modifications made on this page affect all others.

The data comprise the following

Energetic conversion factors to kJ from kcal is taken from SI conversion tables. 1kcal = [illegible] kJ

Bird Data

Weights of birds have been taken from RSPB web site and Wilson and Parkes, (1998)
Preferred prey species have been taken from the literature cited in the report
Basal Metabolic Rate (BMR) for the bird species have been taken from a variety of sources referenced in the report
Assimilation Efficiency (AE) has been set at 85% (Kersten & Piersma, 1988) [illegible]
The default Energy Consumption (EC) is set at 4 x the Energy Requirement (ER) or Basal Metabolic Rate (BMR) [illegible]
Feeding days based on Perkins and Urdarri-Carr (2002)

Species	Weight (kg)	Preferred Prey	BMR (kJ per day)	BMR incl AE factor (kJ per day)	EC in kJ per bird per day	Feeding days
Shelduck	1.074	Hydrobia ulvae Small annelids	345.206	406.127	[illegible]	[illegible]
Oystercatcher	0.587	Mytilus edulis Macoma balthica Ruditapes philippinarum Cerastoderma edule Scrobicularia plana Mya arenaria Hediste diversicolor	217.522	255.905	[illegible]	[illegible]
Grey Plover	0.243	Hediste diversicolor Lanice conchilega Macoma balthica Cerastoderma edule Carcinus maenas Small annelids	117.865	138.666	[illegible]	[illegible]
Avocet	0.276	Hediste diversicolor Nephtys hombergi Small Annelids Small Crustacea and Other Crustacea	128.915	151.664	[illegible]	[illegible]
Dunlin	0.052	Hydrobia ulvae Hediste diversicolor Nephtys hombergii Small annelids Gammarus sp. Crangon crangon Small Crustacea and Other Crustacea Insecta	38.507	45.490	[illegible]	[illegible]
Redshank	0.148	Corophium volutator Carcinus maenas Crangon crangon Hydrobia ulvae Macoma balthica Scrobicularia plana Hediste diversicolor Nephtys hombergii Small annelids	82.369	96.905	[illegible]	[illegible]
Black-tailed Godwit	0.314	Large Polychaetes Bivalve molluscs Crustacea	141.649	166.327	[illegible]	[illegible]
Curlew	0.863	Lanice conchilega Arenicola marina Hediste diversicolor Scrobicularia plana Cerastoderma edule Macoma balthica Carcinus maenas	294.714	346.722	[illegible]	[illegible]

Invertebrate Data

Production to biomass ratios based on annual values available in the literature quoted in the report
Some of these are based on assumptions where current data is not available
Production in the autumn-winter period is based on 25% of the total annual production [illegible]
Energetic conversion factors from kgAFDW to kcal for all invertebrate species have been taken from published values

Species parameters	P/B	kcal from kgAFDW	kJ from kgAFDW	
Hediste diversicolor	3	4700	[illegible]	
Nereis virens	1.6	4700	[illegible]	
Nephtys hombergii	1.9	4700	[illegible]	
Arenicola marina	1	4700	[illegible]	
Small annelids	3	5100	[illegible]	
Cyathura carinata	2	5600	[illegible]	
Gammarus locusta	2	5600	[illegible]	
Microdeutopus gryllotalpa	3.5	5600	[illegible]	
Corophium volutator	7	5600	[illegible]	
Corophium arenarium	7	5600	[illegible]	
Urothoe poseidonis	3.5	5600	[illegible]	
Other Crustacea	3.5	5600	[illegible]	
Carcinus maenas	1	4000	[illegible]	(note)
Crangon crangon	4	5500	[illegible]	(note)
Cerastoderma edule	2	5100	[illegible]	
Ruditapes philippinarum	1	5100	[illegible]	
Abra tenuis	4	5100	[illegible]	
Mya/Scrobicularia	1	5100	[illegible]	
Macoma balthica	0.9	5100	[illegible]	
Littorina spp	4	4000	[illegible]	
Hydrobia ulvae	1.4	4000	[illegible]	
other mollusca errns	1	5100	[illegible]	
other mollusca nets	2	4000	[illegible]	
Anemones	1	4300	[illegible]	
Other species	1	4300	[illegible]	

Sectoral Areas

Two sectoral area values are available.
One based on calculations made using Admiralty Chart 2615, extending from HWS to CD
The second on areas presented in the WeBS sectoral counts report

Sector Areas	Admiralty (m2)	WeBS m2
NC1	1742580	80000
NC2	288590	110000
NC3NW	558080	320000
NC3NE	966960	280000
NC3SW	843060	840000
NC3SE	1220080	880000
NE1	1532080	480000
NE3BL	820240	120000
NE3BT	885200	120000
SC1	690590	440000
SC2	988890	360000
SC3	1576780	200000
SC4	1588980	800000
SC5	1642580	720000
SC6	556480	320000
SC7	844000	440000
SC8	392080	240000
SE1	1608080	380000
SE2	1590000	1320000
W1	554000	120000
W2	529500	120000
W2E	859900	440000
W2W	1457000	1180000
W3	1752000	480000
W4	1784000	1200000
W5	1074000	640000
W6	516000	320000
Total	25457140	13120000

Intertidal exposure factor

In the absence of a intertidal exposure model a single default value representing the proportion of the intertidal exposed and available to be exploited by birds over time has been set at
This value is only relevant to the whole intertidal estimate of area, i.e. the Admiralty estimates #DIV/0!

Total including exposure factor (m2) 6802164.6

APPENDIX 3.

Examples of biomass calculations per sector.

[illegible]

Hediste diversicolor

Biomass per site

Sites	1	2	3	4	5
mg m^{2}	2707.59	5481.57	11192.12	17843.10	34.75

Hediste diversicolor	[illegible]		Total area [illegible] 320000.00
		mg AFDW M^{2}	Per sector (kg)
Sector Biomass Mean		**7469.85**	**2390.35**
Sector Biomass standard deviation		**7115.52**	**2276.97**
Sector Biomass Maximum		**17843.10**	**5709.79**
Production based on Mean biomass		**22409.54**	**7171.05**

Small Annelids

Biomass per site

	1	2	3	4	5
Scoloplos armiger	0.00	0.00	0.00	0.00	0.00
Harmothoe sp	0.00	0.00	0.00	0.00	0.00
Polycirrus caliendrum	0.00	0.00	0.00	0.00	0.00
Ampharete grubei	0.00	0.00	634.51	0.00	0.00
Glycera tridactyla	0.00	0.00	0.00	0.00	0.00
Anaitides mucosa	0.00	0.00	0.00	0.00	0.00
Eteone longa	0.00	0.00	158.63	0.00	158.63
Malacoceros fuliginosus	0.00	0.00	1269.02	2696.66	3965.68
Scolelepis squamata	0.00	0.00	0.00	0.00	0.00
Scolelepis foliosa	0.00	0.00	0.00	0.00	0.00
Pygospio elegans	0.00	0.00	0.00	0.00	0.00
Spionid spp	3172.04	0.00	0.00	0.00	0.00
Cirriformia tentaculata	0.00	0.00	0.00	0.00	0.00
Cirratulus filiformis	0.00	1744.90	158.63	317.25	158.63
Capitella capitata	0.00	0.00	0.00	0.00	0.00
Heteromastus filiformis	0.00	0.00	0.00	0.00	0.00
Tubificoides	17766.72	951.79	3807.05	0.00	158.63
Nemerteans	0.00	0.00	0.00	0.00	0.00
Nematodes	0.00	0.00	0.00	0.00	0.00
Total	20938.76	2696.69	6027.82	3013.91	4441.56

Small Annelids [illegible]

Total area m² 320000.00

	mg AFDW M²	Per sector (kg)
Sector Biomass Mean	**7423.74**	**2376.60**
Sector Biomass standard deviation	**7669.58**	**2454.27**
Sector Biomass Maximum	**20938.76**	**6700.40**
Production based on Mean biomass	**22271.23**	**7126.79**

Abra tenuis

Biomass per site

Site	1	2	3	4	5
Total	0.70	575.07	0.00	0.00	624.07

Abra tenuis Plot No ... 3

	mg AFDW M^2	Total Area (m^2) 320,000.00 Per sector (kg)
Sector Biomass Mean	**229.82**	**73.54**
Sector Biomass standard deviation	**316.63**	**101.32**
Sector Biomass Maximum	**624.07**	**199.70**
Production based on Mean biomass	**919.27**	**294.17**

APPENDIX 4.

Summary abundance values for each species at each site
Summary biomass values for contributors >1% total.

No. individuals per square metre at each site

species	method	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Hediste diversicolor	core	1013.3	1248.9	3066.7	4475.4	2564.4	4133	1991.6	3235.4	4642.6	3399.7	1471.6	4613	2246.6	3746.4	3667.7	2786.6	0	6066.4	1303.6	1190	613.3
Nereis virens	fork	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	113.3	0	0	113.3
Nephtys hombergii	core	0	0	0	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	113.3	0	0	113.3
Arenicola marina	cast count	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lanice conchilega	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible] sp.	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.3
Polydora cf. ciliata	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampharete grubei	core	0	0	333.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera tridactyla	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea minuta	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone longa	core	0	0	133.3	0	133.3	466.7	0	[illegible]	0	0	266.6	0	0	0	133.3	233.3	0	0	0	0	0
Malacoceros fuliginosus	core	0	0	1066.4	2266.5	2266.6	266.5	0	266.6	0	3466.6	2133.3	266.6	0	266.5	0	1066.5	0	233.3	233.3	0	0
Scolelepis squamata	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scolelepis foliosa	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pygospio elegans	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio sp.	core	2666	0	0	0	0	0	0	0	399.9	0	0	0	0	0	0	0	0	0	0	0	0
Cirriformia tentaculata	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulus filiformis	core	0	1466.1	113.3	2666.6	113.3	4773.4	2266.1	0	0	14066.6	4423.0	3066.6	1466.5	533.3	0	[illegible]	0	3066.1	3333.2	533.1	266.6
Capitella capitata	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubificidae	core	14056.6	733.4	3199.7	0	133.3	1453.3	0	1496.5	2666.6	11373.2	0	266.6	0	3666.7	2266.4	0	0	2133.6	0	0	266.6
Enchytraeidae	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyathura carinata	core	0	746.1	3033.4	2266.6	1373.4	113.3	0	0	1013.3	2266.6	3066.6	453.3	0	0	0	1333.1	0	0	113.3	0	0
Gammarus [illegible]	core	0	0	0	0	0	0	0	0	0	0	0	0	2266.6	0	0	0	0	0	0	0	0
Microdeutopus gryllotalpa	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium volutator	core	3066.1	0	0	0	0	0	0	0	266.1	0	0	0	0	0	2266.6	0	0	0	113.3	0	0
Corophium arenarium	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urothoe poseidonis	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idotea neglecta	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idotea balthica	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idotea chelipes	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bathyporeia sarsi	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Talitrus saltator	core	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neomysis integer	core	0	0	0	0	0	0	0	0	2036.4	666.6	113.3	0	0	0	0	0	0	0	0	0	0
Praunus flexuosus	core	226.6	0	0	0	0	113.3	266.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesopodopsis slabberi	core	0	0	2266	0	0	266.6	113.3	0	0	0	0	113.3	0	0	0	2266	0	0	0	0	0
[illegible] palmata	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palaemon longirostris	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palaemon serratus	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carcinus maenas	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crangon crangon	0.25sqm net	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0
Mysidae spp.	0.25sqm net	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastoderma edule	cores and net	0	0	4	0	4	0	24	0	0	0	0	0	0	40	0	0	0	30	0	0	12
Tapes philippinarum	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	24	16	0	0
Abra tenuis	core	0	113.3	0	0	266.1	113.3	0	1226.6	113.3	0	113.3	0	113.3	0	1466.6	0	0	0	0	0	113.3
Crepidula fornicata	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Hydrobia ulvae	core	0	226.6	333.3	333.3	113.3	0	453.3	906.6	0	0	0	0	0	6793	0	0	0	113.3	0	0	226.6
Mya arenaria	core	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0	0
Scrobicularia plana	core	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0	0
[illegible]	core	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0	0
[illegible]	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible] spp.	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anemones (undiff)	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133.3	0	0	0
Ascidians (undiff)	0.25sqm net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha linum	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chaetomorpha [illegible]	core	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total No. of species per site		7	6	10	8	9	8	8	6	7	11	8	7	6	7	6	6	4	11	3	4	9

Numbers per square metre at each site

Site no.	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Hediste diversicolor	793.1	1133	566.5	226.6	113.3	3852.2	7989.5	339.9	1472.6	113.3	3847.3	0	1699.5	0	0	339.9	113.3	0	0	113.3	0	0
Nereis virens	113.3	0	0	0	0	0	0	0	1019.7	0	0	0	0	226.6	566.5	0	113.3	0	0	0	0	0
Alkmaria romijni	0	0	0	113.3	113.3	0	0	0	0	0	0	113.3	0	0	113.3	113.3	0	0	0	0	0	0
Arenicola marina	0	0		0				0	0	0	0	0	0	0					0	0	0	0
Scoloplos armiger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harmothoe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora cornuta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0
Ampharete grubei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	453.2	0	2446.6	2266	0	0	0
Glycera tridactyla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea minuta	113.3	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	0	0
Eteone longa	113.3	0	0	0	0	226.6	0	0	0	2446.6	566.5	0	0	113.3	0	0	0	0	113.3	0	0	0
Malacoceros fuliginosus	113.3	0	0	0	339.9	2379.4	3172.4	0	0	865.1	3172.4	0	1586.5	0	339.9	0	0	793.1	2379.4	680.2	0	5552.2
Scolelepis squamata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scolelepis foliosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pygospio elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spio spp.	0	0	0	0	0	0	0	0	0	0	0	2152.4	0	0	0	0	0	0	679.8	0	0	0
Cirriformia tentaculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Streblospio shrubsolii	1019.4	0	17110.7	14727.5	4758.1	15226	31275.4	23902.4	0	8666	14178.9	23902.4	5099.4	113.3	2379.1	453.2	113.3	1779.8	906.3	339.9	8009.4	23082.9
Capitella capitata	0	0	0	0	0	0	0	0	0	1133.1	0	0	0	0	0	0	0	0	133.3	0	7466.6	0
Heteromastus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tubificoides	5062.4	0	533.2	0		2583.7	4156.7	0	2886	3465.8	2958	0	2388.6	0	933.1	0	2669.8	5553.2	15328.5	0	18074.6	17585.8
Nemertea	0	0	0	0			133.3	0	0	0		0	0	0	0	0	0	0	133.3	0	0	113.3
Nematoda	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyathura carinata	0	0	0	1359.6	113.3	3625.4	1586.2	113.3	0	0	566.5	0	4644.4	453.2	0	339.9	0	0	2266	0	0	0
Gammarus locusta	0	0	0	0	0	113.3	0	0	0	566.5	339.9	0	0	0	226.6	113.3	113.3	0	13974.1	0	113.3	453.2
Microprotopus maculatus	0	0	0	0			0	0	0	0	0	0	0	0	113.3	0	0	0	20458	0	0	4079.8
Corophium volutator	1246.3	8610.8	0	0			0	0	11691.6	3738.9	0	0	113.3	0	0	0	0	0	0	0	0	0
Corophium arenarium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urothoe poseidonis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idotea linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idotea baltica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idotea granulosa	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	226.4	0	0	113.3
Bathyporeia sarsi	0	0	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0
Talitrus saltator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neomysis integer	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0	0	0	0	0	0	0	0	0
Praunus flexuosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesopodopsis slabberi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schistomysis spiritus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palaemon longirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pagurus bernhardus	0	113.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carcinus maenas	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crangon crangon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mytilus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastoderma edule	0	0	0	0	0	566.5	793.1	0	0	0	0	113.3	0	0	0	113.3	0	0	24	4	38	103
Tapes philippinarum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	34	20
Abra tenuis	0	0	0	0	4758.1	7929.6	3281.9	0	2266.4	0	2379.4	0	7250.4	4758.3	0	453.2	0	0	113.3	339.9	0	5551.7
Angulus tenuis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma balthica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobia ulvae	113.3	113.3	113.3	0	13029.8	15409.8	5325.1	453.2	566.5	6798	339.9	339.9	3059.2	793.1	0	0	1586.2	0	2379.4	0	2719.3	0
Mya arenaria	0	0	3456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	113.3	0	0	0	0
Scrobicularia plana	0	0	0	0	0	0	0	2719.3	0	0	0	0	0	226.6	0	0	0	0	0	0	0	0
Venerupis senegalensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nassarius reticulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Retusa spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Lymnaea peregra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Littorina obtusata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Littorina littorea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Littorina saxatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gibbula umbilicalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hinia reticulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthozoa (indent.)	113.3	0	0	0	0	0	0	0	0	0	0	113.3	0	0	0	453.2	113.3	226.6	226.6	226.6	0	906.4
Actiniaria (indent.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomid larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1359.6	0	453.2	1359.6
Chironomid pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	226.6	113.3	0	0
Total no. species per site	12	4	6	5	9	11	8	6	7	11	11	7	9	8	9	10	7	7	21	8	11	17

Numbers per square metre at each site

Species	[illegible]
[illegible]	[illegible]
Total No. species per site	[illegible]

Numbers per square metre in each site

Species	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Average numbers sq m	Average mg ash-free wt
[illegible]	0	[illegible]	0	0	0	0	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]	0		[illegible]	[illegible]
[illegible]	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	0	0	[illegible]	0	0	[illegible]	0		[illegible]	[illegible]
[illegible]	0	[illegible]	[illegible]	0	[illegible]	0	[illegible]	0	0	0	0	[illegible]	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	[illegible]	0	0	0	[illegible]	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0		[illegible]	[illegible]
[illegible]	0	[illegible]	0	0	0	0	0	0	[illegible]	0	0	[illegible]	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	[illegible]	0	0	[illegible]	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]	[illegible]	0	[illegible]	0	0	0	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	[illegible]	0	0	0	0	[illegible]	[illegible]	[illegible]	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	[illegible]	0	[illegible]	0	[illegible]	[illegible]	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	[illegible]	0	[illegible]	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	[illegible]	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	[illegible]	0	[illegible]	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	0	0	[illegible]	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	[illegible]	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	[illegible]	0	0	0	0	[illegible]	0	[illegible]	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	[illegible]	0	0	[illegible]	0	[illegible]	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0		[illegible]	
[illegible]	[illegible]	0	[illegible]	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	0	[illegible]		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	[illegible]	[illegible]	0	0	0	[illegible]	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	[illegible]
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	[illegible]	[illegible]	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	[illegible]	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	[illegible]	0	[illegible]	0	0	[illegible]	0	[illegible]	0	0	[illegible]	0	0	0		[illegible]	
[illegible]	0	0	[illegible]	0	0	[illegible]	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	[illegible]	[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
[illegible]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		[illegible]	
Total no. species per site	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Dominant biomass species individual site values mg AFDW per sq metre

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Cirratulus filiformis	0	1745	159	317	159	32526	2697	0	0	1239	52667	30496	1745	434	0	19528	0	4285	8545
Nereis virens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5316	0
Tubificoides	17790	952	3967	0	159	636	0	1745	317	22540	0	317	0	317	1269	0	0	2323	0
Hediste diversicolor	2758	5452	11192	17840	35	5732	8536	6779	8354	4147	8909	1397	2606	11617	14760	130	0	2127	794
Mya arenaria	0	0	0	0	0	0	0	0	0	26551	0	0	0	0	0	0	0	0	0
Cerastoderma edule	0	0	141	0	188	0	1549	0	0	1211	297	0	0	3601	292	1023	0	4870	1570
Tapes philippinarum	0	0	0	0	0	0	0	0	0	0	0	0	0	14741	0	0	0	3543	7023
Scrobicularia plana	0	0	0	0	0	0	0	0	0	14538	0	0	0	0	0	0	0	0	0
Arenicola marina	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0
Malacoceros fuliginosus	0	0	1269	2597	3956	476	0	317	0	4125	3556	317	0	793	0	793	0	476	476
Nephtys hombergii	0	0	0	0	0	0	0	0	0	0	0	0	1411	0	0	0	0	238	0
Littorina spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobia ulvae	0	130	152	371	132	0	332	857	0	146	0	0	0	504	0	0	0	80	0
Abra tenuis	0	626	0	0	524	413	0	540	99	0	413	0	154	0	95	0	0	0	0
Cyathura carinata	0	551	1167	1157	1521	145	0	0	921	1287	1024	254	0	0	0	801	0	0	254
Corophium volutator	1312	0	0	0	0	0	0	0	511	0	0	0	0	0	45	0	0	0	16

Species	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
Cirratulus filiformis	1110	317	1269	0	16482	11422	9592	19048	37755	2846	0	7692	21574	2855	7615	159	2697	635	159
Nereis virens	0	28740	9525	0	0	0	0	0	0	0	2892	0	0	0	0	10	1946	0	63536
Tubificoides	0	476	8070	0	535	0	0	3016	1458	0	317	4756	3173	0	987	0	1110	0	317
Hediste diversicolor	340	106	8026	9069	2964	18	7250	8868	1485	2412	844	415	1468	0	6365	0	0	167	4146
Mya arenaria	0	0	0	0	53101	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastoderma edule	0	1585	0	0	0	709	0	4321	7302	0	0	242	528	4523	456	1787	0	0	0
Tapes philippinarum	0	0	0	0	0	0	0	794	0	0	0	0	0	0	0	0	0	0	0
Scrobicularia plana	0	0	0	0	0	0	0	0	0	14508	0	0	0	0	0	28136	0	0	0
Arenicola marina	0	0	0	0		0	992	0	0	0	0	0	0	359	0	0		0	
Malacoceros fuliginosus	0	0	159	0	0	0	476	2856	7539	0	0	793	2236	0	2003	0	476	0	0
Nephtys hombergii	0	115	0	0	0	2144	629	0	0	0	0	0	0	1665	0	0	975	1255	0
Littorina spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrobia ulvae	0	135	80	112	149	0	2635	3498	1885	174	501	457	276	44	1534	44	0	0	716
Abra tenuis	0	1362	0	0	0	0	2532	1498	1352	0	251	0	260	0	3038	1031	0	764	0
Cyathura carinata	0	0	0	0	0	780	53	1322	1109	411	0	0	346	0	571	187	0	486	0
Corophium volutator	0	0	546	4254	0	0	0	0	0	0	4274	1509	0	0	15	0	0	0	0

Species	39	40	41	42	43	44	45	46	47	48	59	60	61	62	63	64	65	66	67
Cirratulus filiformis	2562	793	476	10787	30455	7092	0	72750	1179	0	0	2549	159	8690	0	8028	0	11263	1504
Nereis virens	0	0	0	0	0	20137	0	0	0	0	0	0	0	0	0	208	105262	0	0
Tubificoides	635	14242	0	8249	20309	793	317	159	1587	159	0	0	3745	5711	476	5235	0	1269	3248
Hediste diversicolor	0	0	126	0	0	0	0	0	0	0	0	0	0	0	14	0	0	14	237
Mya arenaria	26551	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastoderma edule	1307	3086	207	2110	6901	3127	0	4879	0	6382	1656	6260	8347	7655	0	1384	9435	10000	7000
Tapes philippinarum	0	1831	0	3244	2111	0	0	0	0	15075	4151	7334	373	3136	0	0	0	6929	0
Scrobicularia plana	0	0	0	0	0	0	0	0	14586	0	0	0	0	0	0	0	0	0	0
Arenicola marina		716	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
Malacoceros fuliginosus	317	2856	635	0	635	0	0	5870	0	0	0	0	0	2539	0	1269	0	0	0
Nephtys hombergii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1403	2451	0	0
Littorina spp	0	0	0	696	0	0	0	947	0	1145	0	103	7555	197	0	0	0	0	0
Hydrobia ulvae	0	1490	0	3925	0	122	50	0	0	0	1459	1176	2196	6389	122	0	0	0	250
Abra tenuis	0	15	80	0	7685	1700	0	472	0	0	0	0	0	1495	0	0	0	322	0
Cyathura carinata	0	1096	0	0	0	0	0	1050	0	0	0	0	0	0	0	0	0	0	0
Corophium volutator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Dominant biomass species individual site values (cont.)

Species	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
Cirratulus filiformis	3046	2537	317	0	0	0	0	317	0	159	0	0	0	0	317	15984	4759	0	0
Nereis virens	0	17626	0	0	0	66133	0	0	0	3484	1041	15	0	10179	43	1315	0	0	141
Tubificoides	0	1934	3907	0	467	0	723	6545	6545	6654	0	1004	1170	9534	0	21574	1746	159	159
Hediste diversicolor	45	0	0	218	0	0	2097	302	0	485	0	0	0	0	0	9839	0	1981	0
Mya arenaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23651	26521	0
Cerastoderma edule	4259	1510	7994	0	5887	2100	0	5841	420	4330	5513	665	0	2158	2733	2894	8772	4	0
Tapes philippinarum	0	0	0	0	0	159	0	0	162	0	0	0	0	21276	0	2407	0	0	0
Scrobicularia plana	14685	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arenicola marina	0	5017	358	308	0	0	0	8950	0	0	0	0	0	0	0	0	15456	21122	17184
Malacoceros fuliginosus	793	476	0	0	0	125	0	0	0	852	0	0	0	0	0	0	150	0	0
Nephtys hombergii	0	0	6058	0	0	3779	7984	0	0	4645	3725	0	257	0	3815	0	0	0	0
Littorina spp	0	0	0	0	0	0	0	0	16	0	0	0	0	37810	0	0	0	0	0
Hydrobia ulvae	801	0	0	0	1245	1000	0	68	590	0	22	0	0	0	0	0	0	0	216
Abra tenuis	584	0	51	0	335	0	0	0	0	50	0	0	0	0	682	0	236	0	0
Cyathura carinata	201	175	0	78	0	0	0	0	0	0	0	0	0	0	0	0	0	347	0
Corophium volutator	0	0	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	77	78	79	80	Max value	Total value	% contribution
C. filiformis	0	0	0	0	63507	427880	21%
Nereis virens	0	0	15130	0	100596	365381	18%
Tubificoides	1745	0	0	1596	22843	203690	10%
Hediste diversicolor	7564	0	2338	0	17543	109292	10%
Mya arenaria	0	0	23551	0	53101	182858	9%
Cerastoderma edule	4321	1668	4225	1283	10892	172438	8%
Tapes philippinarum	0	0	0	0	21276	92437	5%
Scrobicularia plana	0	0	0	0	29638	87428	4%
Arenicola marina	0	8224	1730	8086	21122	82694	4%
Malacoceros fuliginosus	159	0	0	0	9676	47290	2%
Nephtys hombergii	6858	0	0	0	9635	44128	2%
Littorina spp	0	0	0	0	37810	42070	2%
Hydrobia ulvae	117	60	0	50	6069	35957	2%
Abra tenuis	0	0	0	0	3696	24120	1%
Cyathura carinata	169	0	0	0	1994	24181	1%
Corophium volutator	0	0	0	0	4224	11819	1%

APPENDIX 5.

Physical environmental data

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	34500	87462	50.0	31.9	14	9.9	0	0	652.5	1.9
2	34550	88048	45.8	38.6	13.5	5.2	0	0	102.5	[illegible]
3	34436	88424	64.0	34	7.5	4.2	0	0	102.5	1.1
4	34632	87548	47.8	37.7	9.8	5.2	0	0	120	1.3
5	35021	87049	42.8	36.9	11.7	5.5	0	0	145	1.4
6	34530	89445	39.8	33.2	12	15.2	0	0	102.5	1.1
7	35789	89033	40.2	36.6	11.3	9.9	90	90	120	1.3
8	35036	89461	52.1	33	0.0	5.1	50	50	110	1.2
9	35532	87864	45	38.3	9.7	7.3	70	70	120	1.3
10	35502	87863	45.8	37.7	9.4	7.1	10	10	120	1.3
11	35482	89515	35.0	30.4	13.5	15.6	0	0	95	1
12	35510	89059	35.8	38.1	15.5	10.2	3 poles/m	5	95	1
13	36021	89644	67.8	22.8	8.7	5.8	0	0	85	0.9
14	36618	89025	65.8	32.8	10.5	5.1	100	100	102.5	1.1
15	35484	89494	53.2	34	8.4	7.3	100	100	102.5	1.1
16	36005	89627	29.7	21.9	5	42.4	0	0	95	1
17	35621	89579	53.4	28.1	9.3	9.2	100	100	85	0.9
18	35078	90019	47.2	32.5	11.9	4.9	5	5	102.5	1.1
19	36054	89465	33.7	33.5	10.3	15	5	5	102.5	1.1
20	36530	89060	27.1	34.4	11.9	16.6	45	5	110	1.2
21	36504	89061	31.0	25	14.3	28.1	0	0	102.5	1.1
22	36495	89467	47.9	34.8	13.8	4.1	0	0	102.5	1.1
23	36824	88547	44.8	37.3	8.8	9	0	0	155	1.4
24	37088	89475	42.2	34.8	11.5	11.5	0	0	70	0.7
25	37030	89579	21.5	12.8	3.8	62.4	0	0	85	0.9
26	37037	91013	41	36.8	9.4	12	0	0	110	1.2
27	37030	92014	65.4	26.8	5.5	2.7	0	0	102.5	1.1
28	37402	91503	43.5	34.2	10.8	11.5	0	0	102.5	1.1
29	37487	92026	43.6	32.3	11.7	12	0	0	102.5	1.1
30	36036	89549	55.6	34.3	6.7	3.8	0	0	102.5	1.1
31	37690	85957	60.5	27.2	8.5	4	1 ...	100	165	1.4
32	38047	89022	59.4	24.7	7.6	5.3	lots	100	615	1.8
33	38030	89503	13.4	5	3.2	78.4	scattered pieces	25	62.5	0.6
34	37688	82033	61.3	33.3	5.2	10.2	95	95	102.5	1.1
35	36530	89489	63.8	27.6	6.6	3.1	patches	25	95	1
36	38602	88567	57.3	27.5	6.4	8.2			120	1.3
37	38810	87504	45.3	22.5	6.2	25	0	0	70	0.7
38	38817	87954	54.4	33.1	6.6	3.9	0	0	95	1
39	98500	89003	33.4	12.4	4.1	49.1			165	1.4
40	99012	86915	43.1	25.0	6.7	22.4	100	100	165	1.4
41	99031	87985	12.8	7.4	2.0	77.4	30	30	285	1.5
42	99471	88059	60.4	28.5	5.9	7.2	100	100	165	1.4
43	99517	89003	50.3	30.4	5.1	7.2	present	5	205	1.5
44	99420	87502	50.4	32.3	11.5	5.8	if there, rare	50	205	1.5
45	99485	91987	33.4	25.8	10.1	31	100	100	850	2
46	99932	90425	48.8	30.6	6.2	11.1	50	50	75	0.8
47	99952	88538	44.5	35.4	12.2	8.1	0	0	102.5	1.1
48	99582	87677	39.8	38.8	13.7	7.9	70	70	102.5	1.1
49	186	90954	46.7	35.1	5.5	8.0	100	100	335	1.6
50	3	91897	42.4	35.3	13.7	8.8	present	5	420	1.7
51	99891	92010	54.2	29.2	7.8	8.8	100	100	687.5	1.9
52	521	85510	54.3	25.7	5.8	14.2	75	75	872.5	2.1
53	456	85992	42.9	32.1	13.8	11.2	80	80	120	1.3
54	500	85962	40.9	30.8	14.5	13.7	100	100	102.5	1.1
55	507	91042	43.4	33	12.7	13.8	0	0	75	0.8
56	500	91448	38.7	30.3	18.2	10.8	0	0	95	1
57	530	87087	40.1	32.2	10.9	19.8	70	70	0	0.2
58	500	93530	50.9	31.8	5	8.3	0	0	70	0.7
59	995	88016	15.8	5.4	3.3	77.5	0	0	672.5	2.1
60	336	98645	23.1	17.5	13.3	46	thick	100	95	0.9
61	1580	95623	50.8	32.9	9.2	7.2	5	5	615	1.8
62	1490	95553	45	28	11.6	5.4	90	90	615	1.8
63	1500	90076	35.3	32.5	12.7	19.4	thin	50	335	1.6
64	1495	97030	35.1	29.1	10	25.8	50	50	55	0.9
65	1511	97479	6	3.3	3.5	86.1	patchy	50	622.5	1.9
66	2327	94050	47.4	24.9	7.8	25.1	100	100	620	2
67	1970	35409	41.6	30.8	13	14.5	90	90	55	0.9
68	2342	90021	30	29.7	14.7	16.1	...	25	420	1.7
69	2307	90019	32.6	21.7	12.8	33.2	95	95	95	1
70	1445	90045	22.6	12.5	16.6	48.1	70	70	52.5	0.5
71	2307	90028	4.6	1.8	1	92.5	m. some redd.	0	95	1
72	2495	85031	34.9	25.1	18.4	20.6	90	90	120	1.3
73	2500	90030	15.0	7.7	7.6	69.3	0	0	70	0.7
74	2368	85519	5.8	2.6	5.8	85.8	0	0	650	2
75	3008	90506	21.3	11.5	6.2	61	0	0	110	1.2
76	3370	88300	6.4	3.1	3.7	86.8	0	0	615	1.8
77	3400	90021	52.9	37	10	0.1	0	0	335	1.6
78	4505	87058	7	4.3	2.0	85.9	0	0	95	1
79	4650	88452	5.5	5.7	2.4	34	7	7	95	1
80	4645	88908	3.1	2.2	1.3	93.4	0	0	120	1.3

Interpolation Settings - Poole Harbour Project

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Average

* includes subjective modification due to lack of continuity between clusters

APPENDIX 6.

Primer analysis outputs

Species causing Cluster separation

	A	B	C	D	E	F
A		*Tubificoides*	*Anemones (unident)* *Nepthys hombergii*	*Tubificoides* *Corophium volutator*	*Nepthys hombergii* *Anemones (unident)* *Gammarus locusta*	*Scoloplos armiger* *Spionid spp.* *Nereis virens*
B	*Hediste diversicolor* *Cirratulus filiformis* *Cyathura carinata*		*Nepthys hombergii* *Hediste diversicolor* *Anemones (unident)*	*Hediste diversicolor* *Corophium volutator*	*Nepthys hombergii* *Spionid spp.*	*Scoloplos armiger* *Spionid spp.* *Capitella capitata*
C	*Cirratulus filiformis* *Hydrobia ulvae* *Malacoceros fuliginosu*	*Tubificoides* *Cirratulus filiformis* *Malacoceros fuliginosus*		*Tubificoides* *Hediste diversicolor* *Hydrobia ulvae*	*Cirratulus filiformis* *Hydrobia ulvae*	*Scoloplos armiger* *Tubificoides* *Spionid spp.*
D	*Cirratulus filiformis* *Malacoceros fuliginosu* *Cyathura carinata*	*Cirratulus filiformis* *Hydrobia ulvae* *Anemones (unident)*	*Cirratulus filiformis* *Abra tenuis*		*Hydrobia ulvae* *Nepthys hombergii*	*Scoloplos armiger* *Spionid spp.* *Nereis virens*
E	*Cirratulus filiformis* *Hediste diversicolor* *Cyathura carinata*	*Tubificoides* *Cirratulus filiformis* *Microdeutopus gryllotalpa*	*Abra tenuis* *Hediste diversicolor*	*Tubificoides* *Hediste diversicolor* *Corophium volutator*		*Scoloplos armiger* *Tubificoides* *Nereis virens*
F	*Cirratulus filiformis* *Hediste diversicolor* *Malacoceros fuliginosu*	*Cirratulus filiformis* *Tubificoides* *Hydrobia ulvae*	*Cirratulus filiformis* *Abra tenuis* *Nepthys hombergii*	*Tubificoides* *Hediste diversicolor* *Corophium volutator*	*Spionid spp.* *Hydrobia ulvae* *Nepthys hombergii*	

The table should be read as follows:

The species that caused Cluster B to separate from A was *Tubificoides* in B

The species that caused Cluster A to separate from B were *Hediste diversicolor*, *Cirratulus filiformis* and *Cyathura carinata* in Cluster A

Correlation Coefficient: HARMONIC (WEIGHTED SPEARMAN)

TRANSFORMATIONS

(2) <63
none

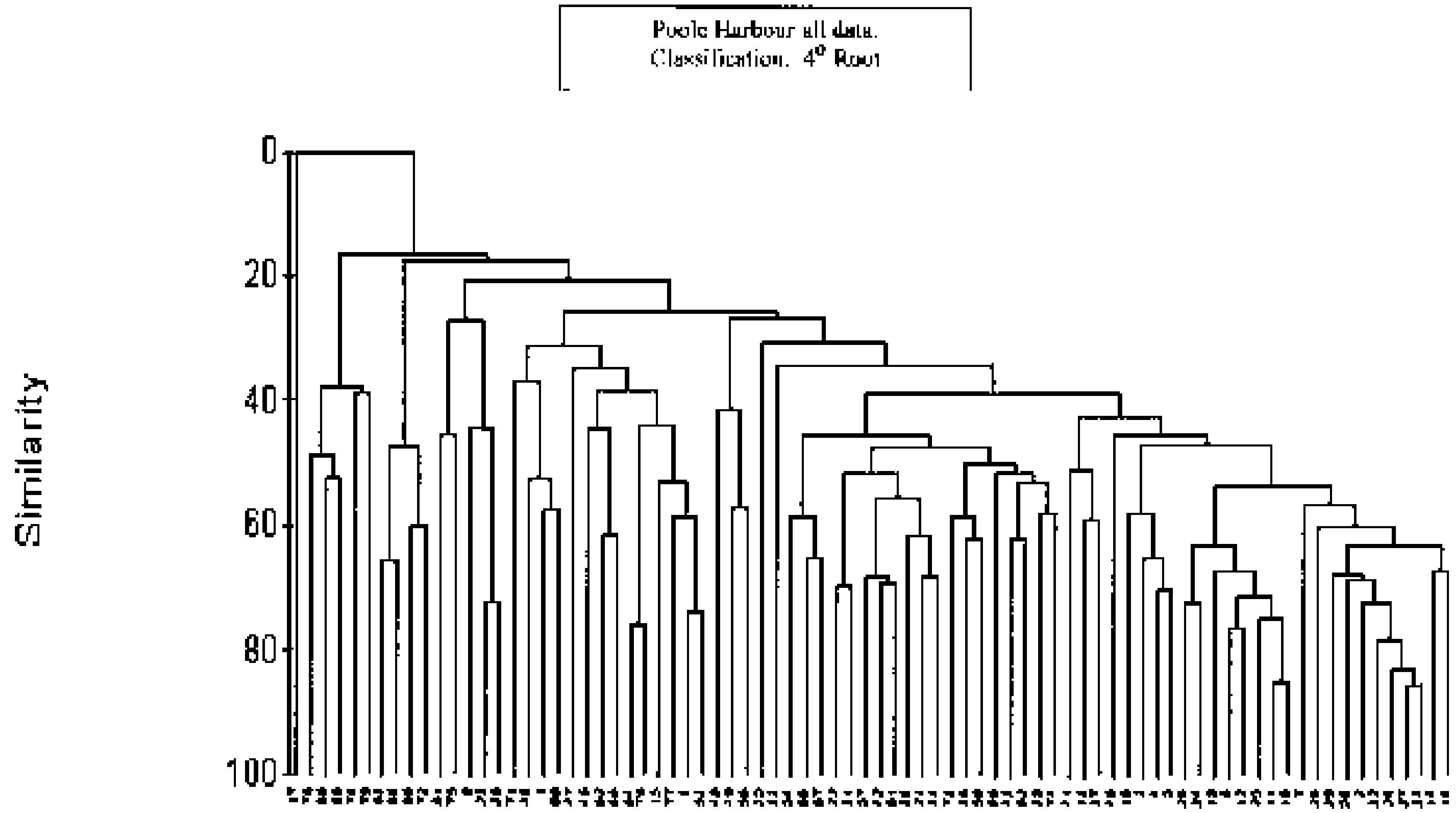
(3) Fine san
none

(4) Coarse s
none

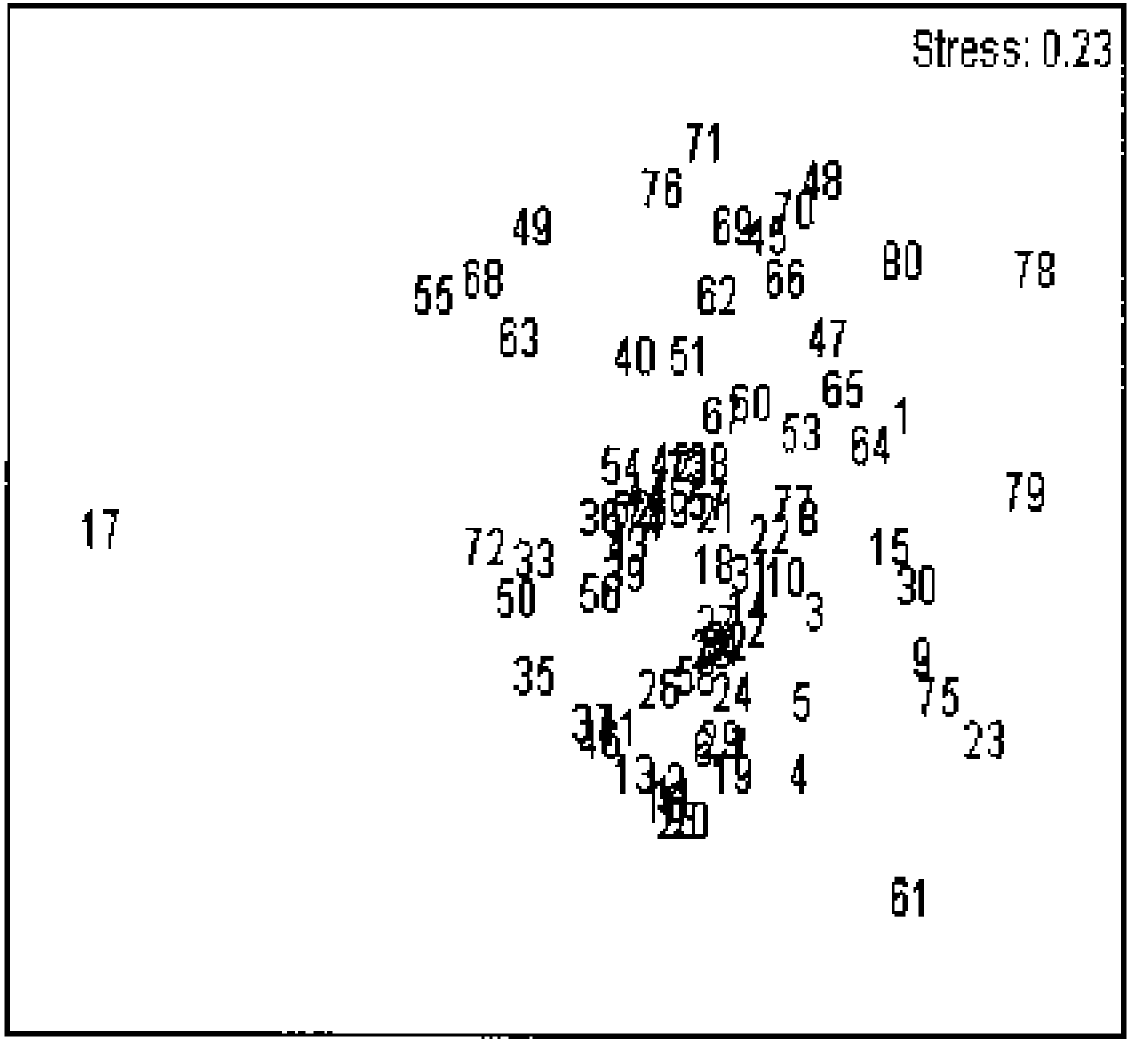
(5) % cover
none

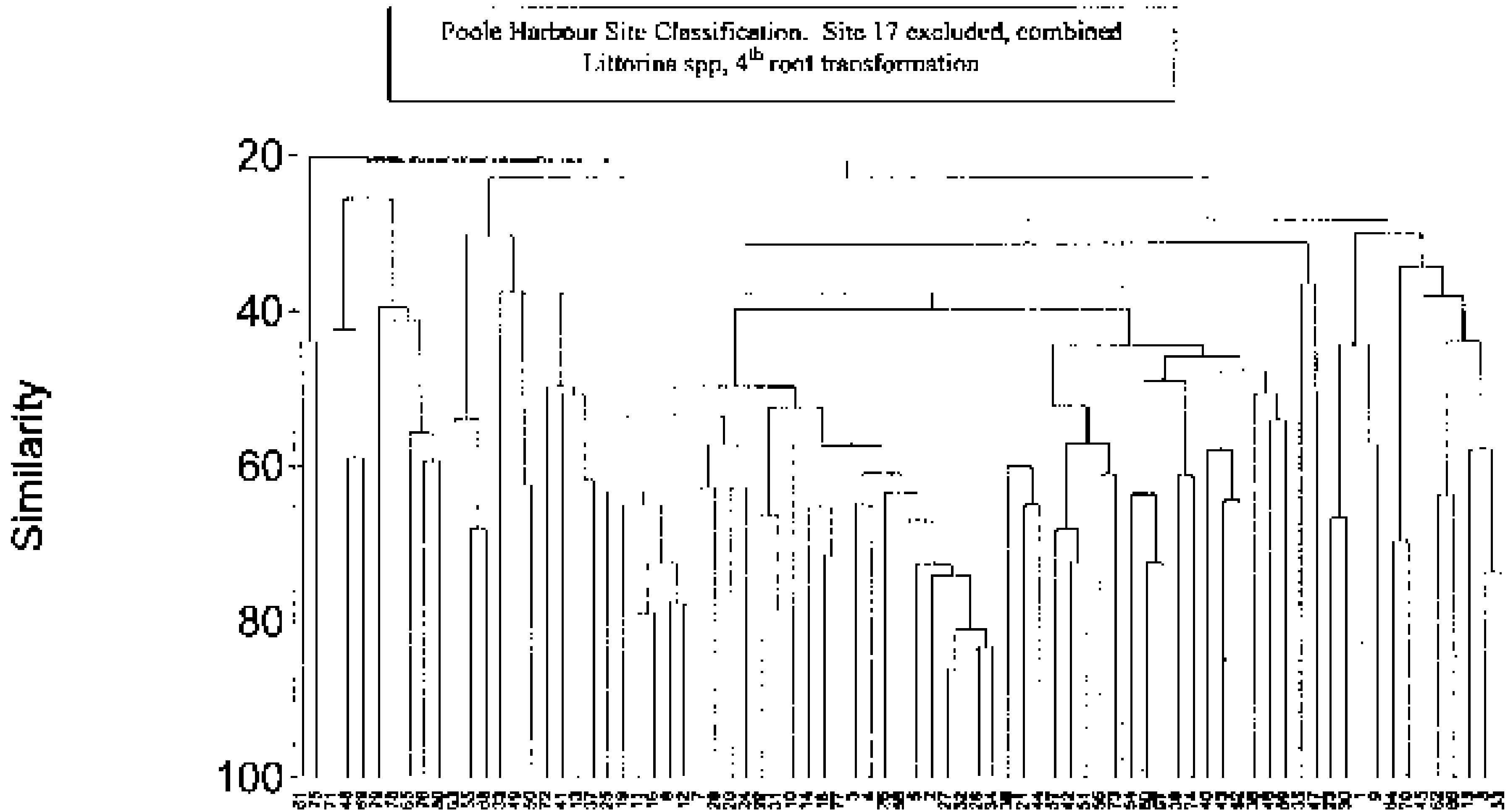
(6) mean exp
none

n	r	<63	Fine san	Coarse s	% cover	mean.exp
1	0.182			4		
1	0.158	2				
1	0.075		3			
1	0.054					6
1	0.036				5	
2	0.211			4		6
2	0.199	2				6
2	0.172	2		4		
2	0.159			4	5	
2	0.151	2			5	
2	0.138	2	3			
2	0.135		3	4		
2	0.128		3			6
2	0.064		3		5	
2	0.036				5	6
3	0.222	2		4		6
3	0.179	2	3			6
3	0.179		3	4		6
3	0.174			4	5	6
3	0.170	2			5	6
3	0.166	2		4	5	
3	0.149	2	3	4		
3	0.142	2	3		5	
3	0.140		3	4	5	
3	0.091		3		5	6
4	0.192	2		4	5	6
4	0.186	2	3	4		6
4	0.165	2	3		5	6
4	0.163		3	4	5	6
4	0.152	2	3	4	5	
5	0.177	2	3	4	5	6


Poole Harbour all data.
Classification. 4° Root
Similarity
0
20
40
60
80
100

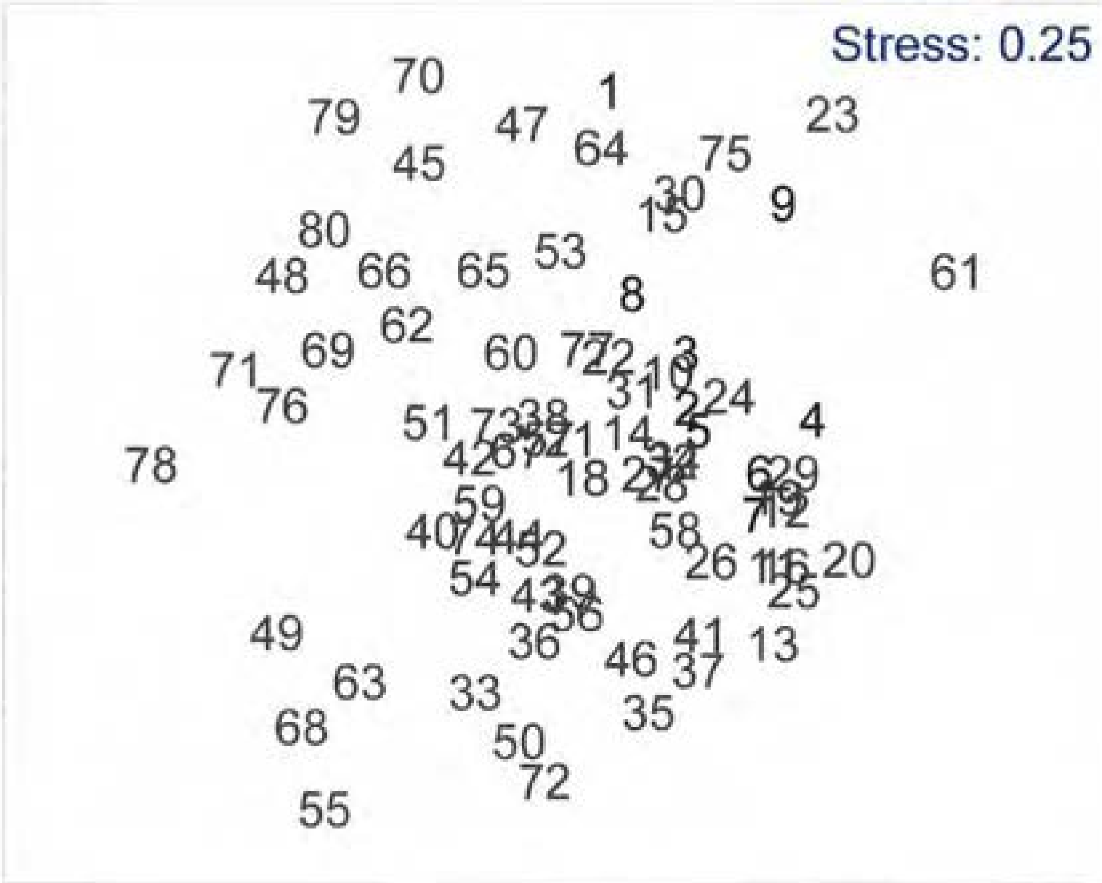
Poole Harbour all sites
MDS Ordination, 4th root





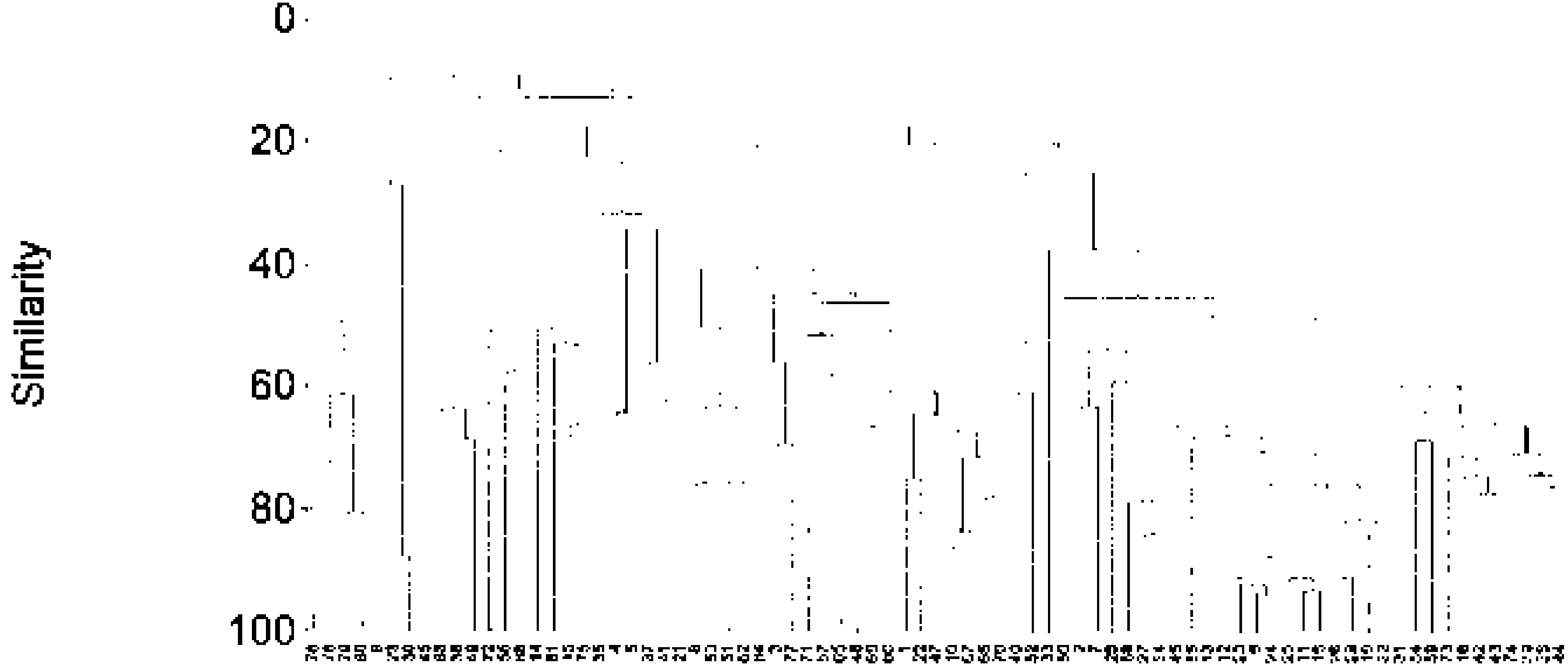
4th root trans

Poole Harbour Site Ordination. Site 17 excluded, combined Littorina spp, 4th root transformation



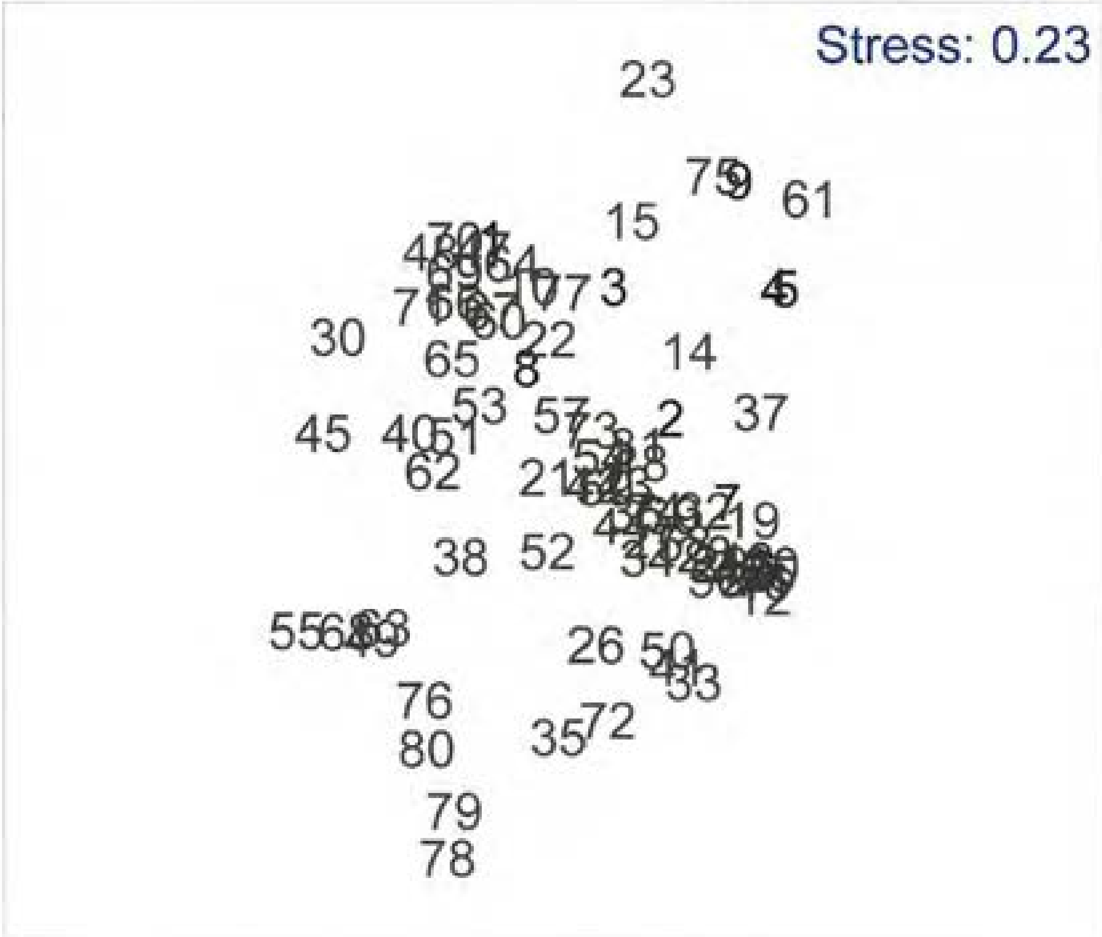
4th root trans

Poole Harbour Site Classification. Site 17 excluded, combined Littorina spp. No transformation



no transformation

Poole Harbour Site Ordination. Site 17 excluded, combined Littorina spp,
No transformation



APPENDIX 7.

Sectoral energy balance calculations.

Energy requirements and availability table for sector W8

Bird data is based on a 8 year mean 1991 - 1998

Bird Species	Mean no birds per month	Over-winter energy requirement kJ x 10^8	Preferred Prey Species	Biomass (benthic) over winter in kJ x 10^8	Energy (net product) available over winter in kJ x 10^8
Shelduck	14.7	6.034	Hydrobia ulvae	0.62	0.71
Tadorna tadorna			Small annelids	33.69	58.97
			Total	34.32	59.67
Oystercatcher	5.0	1.25	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	0.25	0.35
			Scrobicularia plana	0	0
			Hediste diversicolor	31.24	54.67
			Total	31.50	55.05
Grey Plover	0.1	0.02	Hediste diversicolor	31.24	54.68
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	0.25	0.34
			Carcinus maenas	0.00	0
			Small annelids	33.69	58.97
			Total	65.19	114.02
Avocet	0	0.00	Hediste diversicolor	31.24	54.60
Recurvirostra avosetta			Nephtys hombergii	0.00	0
			Small Annelids	33.69	58.97
			Small Crustacea and Other	6.65	11.16
			Total	70.69	124.80
Dunlin	65.2	3.83	Hydrobia ulvae	0.62	0.71
Calidris alpina			Hediste diversicolor	31.24	54.65
			Nephtys hombergii	0.00	0
			Small annelids	33.69	58.97
			Gammarus sp	included below	
			Crangon crangon	0.00	0.115
			Small Crustacea and Other	6.65	11.15
			Insecta	0	0
			Total	71.47	125.62
Redshank	9.1	0.65	Corophium volutator	1.28	0.53
Tringa totanus			Carcinus maenas	0.00	0
			Crangon crangon	0.00	0.00
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0	0.00
			Hydrobia ulvae	0.52	0.71
			Hediste diversicolor	31.24	54.64
			Nephtys hombergii	0.00	0
			Small annelids	33.69	58.97
			Total	66.69	117.94
Black-tailed Godwit	105.3	17.03	Large Polychaetes	31.24	49.[illegible]
Limosa limosa islandica			Bivalve molluscs	4.30	1.94
			Crustacea	8.01	11.27
			Total	38.55	57.[illegible]
Curlew	0.4	21.38	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	31.24	54.56
			Scrobicularia plana	0	0
			Cerastoderma edule	0.25	0.34
			Macoma balthica	0.00	0.00
			Carcinus maenas	0.00	0
			Total	31.53	55.[illegible]
			Other sources of invertebrate energy		
			Nereis virens	0.00	0.00
			other Crustacea only	0.56	1.05
			Abra tenuis	1.24	2.09
			Littorina spp	0.00	0.00
Total Energy Requirement		49.39	Total Available	72.77	128.09

Energy requirements and availability table for sector WS

Bird data is based on a 5 year mean [illegible] - [illegible]

Bird Species	Mean no birds per month	Overwinter energy requirement kJ x 10^8	Preferred Prey Species	Baseline Biomass overwinter in kJ x 10^8	Energy (inc. productivity) available overwinter in kJ x 10^8
Shelduck	164.8	64.739	Hydrobia ulvae	3.24	4.38
Tadorna tadorna			Small annelids	117.96	205.43
			Total	121.19	210.30
Oystercatcher	59.3	14.76	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	2.32	3.46
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	31.79	55.64
			Total	34.11	59.12
Grey Plover	0.5	0.09	Hediste diversicolor	31.79	55.64
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	2.32	3.46
			Carcinus maenas	1.64	2.06
			Small annelids	117.95	206.43
			Total	153.71	267.60
Avocet	0	0.00	Hediste diversicolor	31.79	55.64
Recurvirostra avosetta			Nephtys hombergi	1.95	2.87
			Small Annelids	117.53	206.43
			Small Crustacea and Othe	4.21	7.06
			Total	155.51	272.04
Dunlin	142.3	6.28	Hydrobia ulvae	3.23	4.38
Calidris alpina			Hediste diversicolor	31.79	55.64
			Nephtys hombergi	1.95	2.07
			Small annelids	117.53	206.43
			Gammarus sp	included below	
			Crangon crangon	0.00	0
			Small Crustacea and Othe	4.21	7.06
			Insecta	0	0
			Total	[illegible]	274.70
Redshank	28.0	2.04	Corophium volutator	0.00	0.00
Tringa totanus			Carcinus maenas	1.64	2.06
			Crangon crangon	0.00	0
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hydrobia ulvae	3.23	4.35
			Hediste diversicolor	31.76	55.64
			Nephtys hombergi	1.55	2.87
			Small annelids	117.96	205.43
			Total	156.57	271.35
Black-tailed Godwit	25.0	8.19	Large Polychaetes	33.74	49.78
Limosa limosa islandica			Bivalve molluscs	3.99	5.99
			Crustacea	6.47	12.12
			Total	44.20	67.88
Curlew	172.0	64.49	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	31.79	55.04
			Scrobicularia plana	0.00	0
			Cerastoderma edule	2.32	3.46
			Macoma balthica	0.00	0.00
			Carcinus maenas	1.64	2.06
			Total	34.75	61.16
			Other sources of invertebrate energy		
			Nereis virens	0.00	0.00
			other Crustacea only	2.41	4.51
			Abra tenuis	1.89	3.35
			Littorina spp	0.00	0.00
Total Energy Requirement		161.57	Total Available	164.78	286.06

Energy requirements and availability table for sector W4

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Overwinter energy requirement kJ x 10^8	Preferred Prey Species	Standing Biomass over winter in kJ x 10^8	Energy (incl. productivity) available over winter in kJ x 10^8
Shelduck	73.4	26.274	Hydrobia ulvae	0.27	0.37
Tadorna tadorna			Small annelids	250.31	438.04
			Total	250.58	438.42
Oystercatcher	79.6	18.80	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	5.97	8.96
			Scrobicularia/Mya	87.42	140.1[illegible]
			Hediste diversicolor	47.23	82.65
			Total	140.62	[illegible]
Grey Plover	12.0	1.42	Hediste diversicolor	47.23	82.65
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	5.97	8.55
			Carcinus maenas	1.08	1.33
			Small annelids	250.31	438.04
			Total	304.59	530.99
Avocet	5	0.03	Hediste diversicolor	47.23	82.65
Recurvirostra avosetta			Nephtys hombergi	0.00	0.00
			Small Annelids	250.31	438.04
			Small Crustacea and Other	26.65	46.80
			Total	324.19	570.56
Dunlin	364.1	16.10	Hydrobia ulvae	0.27	0.37
Calidris alpina			Hediste diversicolor	47.23	82.65
			Nephtys hombergi	0.00	0.00
			Small annelids	250.31	438.04
			Gammarus sp.	included below	
			Crangon crangon	0.05	0.10
			Small Crustacea and Other	26.69	48.95
			Insects	0	0
			Total	324.51	571.13
Redshank	7.2	5.20	Corophium volutator	2.07	3.70
Tringa totanus			Carcinus maenas	1.08	1.35
			Crangon crangon	0.05	0.10
			Macoma balthica	0.00	0.00
			Scrobicularia plana	34.52	51.77
			Hydrobia ulvae	0.27	0.37
			Hediste diversicolor	47.23	82.65
			Nephtys hombergi	0.00	0.00
			Small annelids	250.31	438.04
			Total	335.53	579.98
Black-tailed Godwit	109.6	27.55	Large Polychaetes	47.23	69.50
Limosa limosa islandica			Bivalve molluscs	104.67	156.93
			Crustacea	28.19	47.55
			Total	180.04	273.45
Curlew	160.2	63.89	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	47.23	82.65
			Scrobicularia plana	34.62	43.15
			Cerastoderma edule	5.97	6.96
			Macoma balthica	0.00	0.00
			Carcinus maenas	1.08	1.35
			Total	88.90	136.10
			Other sources of invertebrate energy		
			Nereis virens	0.00	0.00
			other Crustacea only	11.23	21.06
			Abra tenuis	1.22	2.15
			Littorina spp	0.00	0.00
Total Energy Requirement		144.83	Total Available	490.21	[illegible]

Energy requirements and availability table for sector W3

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Overwinter energy requirement kJ x 10^7	Preferred Prey Species	Useable Biomass overwinter in kJ x 10^7	Energy (inc. productivity) available over winter in kJ x 10^7
Shelduck *Tadorna tadorna*	83.1	24.632	Hydrobia ulvae	13.32	17.98
			Small annelids	168.64	294.95
			Total	181.96	312.93
Oystercatcher *Haematopus ostralegus*	11.0	2.69	Mytilus edulis	0	0
			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.95	1.19
			Cerastoderma edule	35.42	53.14
			Scrobicularia/Mya	34.94	43.85
			Hediste diversicolor	58.59	103.06
			Total	130.21	201.07
Grey Plover *Pluvialis squatarola*	0.0	0.03	Hediste diversicolor	58.59	103.06
			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	35.42	53.14
			Carcinus maenas	0.00	0.00
			Small annelids	168.64	294.95
			Total	262.65	451.15
Avocet *Recurvirostra avosetta*	0	0.03	Hediste diversicolor	58.59	103.06
			Nephtys hombergii	0.00	0.00
			Small Annelids	168.64	294.95
			Small Crustacea and Other	9.39	17.03
			Total	236.62	415.04
Dunlin *Calidris alpina*	113.6	5.74	Hydrobia ulvae	13.32	17.98
			Hediste diversicolor	58.59	103.06
			Nephtys hombergii	0.00	0.00
			Small annelids	168.64	294.95
			Gammarus sp	included below	
			Crangon crangon	0.00	0.00
			Small Crustacea and Other	9.39	17.03
			Insects	0	0
			Total	249.94	433.02
Redshank *Tringa totanus*	65.1	5.01	Corophium volutator	0.25	0.73
			Carcinus maenas	0.00	0.00
			Crangon crangon	0.00	0.00
			Macoma balthica	0.00	0.00
			Scrobicularia plana	34.94	43.56
			Hydrobia ulvae	13.32	17.98
			Hediste diversicolor	58.59	103.06
			Nephtys hombergii	0.00	0.00
			Small annelids	168.64	294.95
			Total	275.74	459.79
Black-tailed Godwit *Limosa limosa islandica*	30.0	3.60	Large Polychaetes	58.59	85.57
			Bivalve molluscs	96.66	129.65
			Crustacea	9.39	17.03
			Total	164.64	232.25
Curlew *Numenius arquata*	15.9	6.35	Lanice conchilega	0	0
			Arenicola marina	0.00	0
			Hediste diversicolor	58.59	103.06
			Scrobicularia plana	34.54	43.85
			Cerastoderma edule	35.42	53.14
			Macoma balthica	0.00	0.00
			Carcinus maenas	0.00	0.00
			Total	129.28	199.84
			Other sources of invertebrate energy		
			Nereis virens	0.00	0.00
			other Crustacea only	0.00	0.00
			Abra tenuis	15.34	33.09
			Littorina spp	0.00	0.00
Total Energy Requirement		65.96	**Total Available**	556.20	681.72

Energy requirements and availability table for sector W2W

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Overwinter energy requirement in kJ x 10^6	Preferred Prey Species	Absolute Biomass over winter in kJ x 10^6	Energy (inc. productivity) available over winter in kJ x 10^6
Shelduck	72.6	15.005	Hydrobia ulvae	1.35	1.57
Tadorna tadorna			Small annelids	52.23	91.41
			Total	63.62	93.28
Oystercatcher	149.3	29.64	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.08	0.10
			Tapes philippinarum	13.70	22.12
			Cerastoderma edule	31.57	47.36
			Scrobicularia/Mya	0.00	0.00
			Hediste diversicolor	81.60	142.81
			Total	126.95	212.39
Grey Plover	17.0	1.93	Hediste diversicolor	81.60	142.81
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.08	0.10
			Cerastoderma edule	31.57	47.38
			Carcinus maenas	0.00	0.00
			Small annelids	52.23	91.41
			Total	165.49	281.68
Avocet	0.424	0.05	Hediste diversicolor	81.60	142.81
Recurvirostra avosetta			Nephtys hombergi	0.68	0.98
			Small Annelids	52.23	91.41
			Small Crustacea and Other	1.04	1.94
			Total	135.54	237.14
Dunlin	351.8	16.55	Hydrobia ulvae	1.35	1.57
Calidris alpina			Hediste diversicolor	81.60	142.81
			Nephtys hombergi	0.68	0.98
			Small annelids	52.23	91.41
			Gammarus sp	included below	
			Crangon crangon	0.00	0.00
			Small Crustacea and Other	1.04	1.94
			Insects	0	0
			Total	136.92	238.70
Redshank	45.7	4.31	Corophium volutator	0.27	0.75
Tringa totanus			Carcinus maenas	0.00	0.00
			Crangon crangon	0.00	0.00
			Hydrobia ulvae	1.35	1.57
			Macoma balthica	0.08	0.10
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	81.60	142.81
			Nephtys hombergi	0.68	0.98
			Small annelids	52.23	91.41
			Total	136.24	237.61
Black-tailed Godwit	23.7	4.35	Large Polychaetes	108.20	159.60
Limosa limosa islandica			Small molluscs	106.64	158.43
			Crustacea	1.04	1.94
			Total	214.88	320.01
Curlew	115.4	28.83	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	81.60	142.81
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	31.57	47.36
			Macoma balthica	0.08	0.10
			Carcinus maenas	0.00	0.00
			Total	113.25	190.27
			Other sources of invertebrate energy		
			Nereis virens	25.94	36.31
			other Crustacea only	0.00	0.00
			Abra tenuis	0.29	0.57
			Littorina spp	0.00	0.00
Total Energy Requirement		120.26	Total Available	288.30	415.47

Energy requirements and availability table for sector W2E

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Over-winter energy requirement kJ x 10^9	Preferred Prey Species	Resource Biomass over winter in kg x 10^6	Energy (inc. productivity) available over winter in kJ x 10^9
Shelduck	49.5	6.544	Hydrobia ulvae	0.44	0.80
Tadorna tadorna			Small annelids	53.98	94.43
			Total	**54.46**	**96.00**
Oystercatcher	71.6	17.61	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	4.11	6.17
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	22.24	38.93
			Total	**26.35**	**45.10**
Grey Plover	1.8	0.21	Hediste diversicolor	22.24	38.93
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	4.11	6.17
			Carcinus maenas	9.08	11.35
			Small annelids	53.98	94.43
			Total	**89.38**	**150.87**
Avocet	0.29	0.04	Hediste diversicolor	22.24	38.93
Recurvirostra avosetta			Nephtys hombergii	5.59	8.24
			Small Annelids	53.98	94.43
			Small Crustacea and Other	2.84	7.19
			Total	**84.62**	**146.79**
Dunlin	34.4	1.57	Hydrobia ulvae	0.44	0.80
Calidris alpina			Hediste diversicolor	22.24	38.93
			Nephtys hombergii	5.59	8.24
			Small annelids	53.98	94.43
			Gammarus sp	included below	
			Crangon crangon	0.04	0.06
			Small Crustacea and Other	2.93	7.19
			Insects	0	0
			Total	**85.18**	**149.65**
Redshank	14.4	1.35	Corophium volutator	1.56	4.35
Tringa totanus			Carcinus maenas	9.08	11.35
			Crangon crangon	0.04	0.06
			Hydrobia ulvae	0.44	0.80
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	22.24	38.93
			Nephtys hombergii	5.59	8.24
			Small annelids	53.98	94.43
			Total	**92.93**	**167.97**
Black-tailed Godwit	0.0	5.30	Large Polychaetes	117.57	175.12
Limosa limosa islandica			Bivalve molluscs	7.76	11.54
			Crustacea	16.25	50.96
			Total	**141.45**	**215.43**
Curlew	42.3	14.74	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	22.24	38.93
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	4.11	6.17
			Macoma balthica	0.00	0.00
			Carcinus maenas	9.08	11.35
			Total	**35.43**	**56.44**
			Other sources of invertebrate energy		
			Nereis virens	69.54	125.33
			other Crustacea only	0.00	0.00
			Abra tenuis	3.65	7.25
			Littorina spp	0.00	0.00
Total Energy Requirement		41.65	Total Available	192.48	299.43

Energy requirements and availability table for sector W1W2

Bird data is based on a 8 year mean 1991 - 1998

Bird Species	Mean no birds per month	Over-winter energy requirement kJ x 10⁸	Preferred Prey Species	Standing Biomass over winter in kJ x 10⁸	Energy (inc. productivity) available over winter in kJ x 10⁸
Shelduck	4.2	1.434	Hydrobia ulvae	5.29	7.14
Tadorna tadorna			Small annelids	76.44	133.76
			Total	81.73	140.90
Oystercatcher	30.3	9.62	Mytilus adults	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma adults	10.60	15.01
			Scrobicularia/Mya	124.21	156.25
			Hediste diversicolor	23.46	41.06
			Total	168.28	212.23
Grey Plover	0.0	0.00	Hediste diversicolor	23.46	41.06
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma adults	10.60	15.01
			Carcinus maenas	1.18	1.48
			Small annelids	76.44	133.76
			Total	111.65	192.20
Avocet	0.71	0.09	Hediste diversicolor	23.46	41.06
Recurvirostra avosetta			Nephtys hombergii	4.96	7.29
			Small Annelids	76.44	133.76
			Small Crustacea and Other	0.42	0.79
			Total	105.25	182.90
Dunlin	0.6	0.05	Hydrobia ulvae	5.29	7.14
Calidris alpina			Hediste diversicolor	23.46	41.06
			Nephtys hombergii	4.96	7.29
			Small annelids	76.44	133.76
			Gammarus sp	Included below	
			Crangon crangon	0.05	0.10
			Small Crustacea and Other	0.42	0.79
			Insects	0	0
			Total	110.60	190.14
Redshank	3.9	0.33	Corophium volutator	0.00	0.00
Tringa totanus			Carcinus maenas	1.18	1.48
			Crangon crangon	0.06	0.10
			Hydrobia ulvae	5.29	7.14
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	23.46	41.06
			Nephtys hombergii	4.95	7.29
			Small annelids	76.44	133.76
			Total	111.37	190.83
Black-tailed Godwit	8.8	1.10	Large Polychaetes	29.85	44.10
Limosa limosa islandica			Bivalve molluscs	140.67	211.02
			Crustacea	2.10	3.93
			Total	172.71	259.11
Curlew	7.5	2.53	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	1.54	1.93
			Hediste diversicolor	23.46	41.09
			Scrobicularia plana	0.00	0.00
			Cerastoderma adults	10.60	15.01
			Macoma balthica	0.00	0.00
			Carcinus maenas	1.18	1.48
			Total	36.78	60.37
			Other sources of invertebrate energy		
			Nereis virens	0.00	0.00
			other Crustacea only	0.29	0.54
			Abra alba	5.85	11.70
			Littorina spp	0.00	0.00
Total Energy Requirement		16.04	Total Available	266.85	401.58

Energy requirements and availability table for sector NC3W

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no. birds per month	Overwinter energy requirement kJ x 10^8	Preferred Prey Species	Available biomass (wet weight in kg x 10^3)	Energy (incl. productivity) available over winter in kJ x 10^8
Shelduck	75.9	24.501	Hydrobia ulvae	7.60	10.27
Tadorna tadorna			Small annelids	76.47	133.61
			Total	84.07	143.88
Oystercatcher	22.8	5.82	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	24.11	30.17
			Cerastoderma edule	27.85	41.78
			Scrobicularia/Mya	0.00	0
			Hediste diversicolor	0.00	0.00
			Total	51.96	71.95
Grey Plover	0.1	0.02	Hediste diversicolor	0.00	0.00
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	27.85	41.78
			Carcinus maenas	4.94	6.17
			Small annelids	76.47	133.61
			Total	109.26	181.56
Avocet	3	0.90	Hediste diversicolor	0.00	0.00
Recurvirostra avosetta			Nephtys hombergii	0.00	0.00
			Small Annelids	76.47	133.61
			Small Crustacea and Other	13.17	24.03
			Total	89.63	157.64
Dunlin	38.5	1.70	Hydrobia ulvae	7.60	10.27
Calidris alpina			Hediste diversicolor	0.00	0.00
			Nephtys hombergii	0.00	0.00
			Small annelids	76.47	133.61
			Gammarus sp	included below	
			Crangon crangon	0.00	0
			Small Crustacea and Other	13.17	24.03
			Insects	0	0
			Total	97.24	167.91
Redshank	247.1	22.80	Corophium volutator	0.00	0.00
Tringa totanus			Carcinus maenas	4.94	6.17
			Crangon crangon	0.00	0
			Hydrobia ulvae	7.60	10.27
			Scrobicularia plana	0.00	0
			Macoma balthica	0.00	0.00
			Hediste diversicolor	0.00	0.00
			Nephtys hombergii	0.00	0.00
			Small annelids	76.47	133.61
			Total	89.01	150.05
Black-tailed Godwit	76.6	12.48	Large Polychaetes	0.00	0.00
Limosa limosa islandica			Bivalve molluscs	52.73	79.40
			Crustacea	20.11	37.11
			Total	72.84	116.51
Curlew	50.4	17.85	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	0.00	0.00
			Scrobicularia plana	0.00	0
			Cerastoderma edule	27.85	41.78
			Macoma balthica	0.00	0.00
			Carcinus maenas	4.94	6.17
			Total	32.79	47.95
			Other sources of invertebrate energy		
			Nereis virens	0.00	0.00
			other Crustacea only	8.05	15.09
			Abra tenuis	0.74	1.48
			Littorina spp	4.34	5.68
Total Energy Requirement		84.91	Total Available	159.74	286.05

Energy requirements and availability table for sector NC3E

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no. birds per month	Over-winter energy requirement kJ x 10^6	Preferred Prey Species	Biomass over winter in kJ x 10^6	Energy (inc. productivity) available over winter in kJ x 10^6
Shelduck	53.9	22.28	Hydrobia ulvae	2.76	3.73
Tadorna tadorna			Small annelids	84.70	148.23
			Total	87.46	151.96
Oystercatcher	53.8	13.53	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.09	0.11
			Tapes philippinarum	22.97	26.71
			Cerastoderma edule	105.70	130.06
			Scrobicularia/Mya	48.32	60.40
			Hediste diversicolor	0.65	1.06
			Total	178.33	250.83
Grey Plover	0.0	3.30	Hediste diversicolor	0.95	1.56
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.09	0.11
			Cerastoderma edule	106.70	180.05
			Carcinus maenas	1.78	2.20
			Small annelids	84.73	148.23
			Total	194.21	312.26
Avocet	0	0.00	Hediste diversicolor	0.95	1.56
Recurvirostra avosetta			Nephtys hombergi	7.49	11.25
			Small Annelids	84.73	148.23
			Small Crustacea and Other	1.13	2.13
			Total	94.28	163.66
Dunlin	178.4	7.60	Hydrobia ulvae	2.76	3.73
Calidris alpina			Hediste diversicolor	0.95	1.56
			Nephtys hombergi	7.49	11.25
			Small annelids	84.73	148.23
			Gammarus sp.	included below	
			Corophium sp.	1.00	0
			Small Crustacea and Other	1.13	2.15
			Insects	0	0
			Total	97.06	166.79
Redshank	184.1	15.45	Corophium volutator	0.00	0.00
Tringa totanus			Carcinus maenas	1.78	2.20
			Crangon crangon	0.00	0
			Hydrobia ulvae	2.76	3.73
			Macoma balthica	0.09	0.11
			Scrobicularia plana	48.32	60.40
			Hediste diversicolor	1.25	1.56
			Nephtys hombergi	7.49	11.05
			Small annelids	84.73	148.23
			Total	146.07	227.35
Black-tailed Godwit	89.4	34.81	Large Polychaetes	318.83	467.33
Limosa limosa islandica			Bivalve molluscs	181.08	271.62
			Crustacea	3.55	6.67
			Total	501.47	745.61
Curlew	71.4	24.07	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0
			Hediste diversicolor	0.95	1.68
			Scrobicularia plana	48.32	50.40
			Cerastoderma edule	105.70	180.05
			Macoma balthica	0.09	0.11
			Carcinus maenas	1.78	2.20
			Total	157.82	224.42
			Other sources of invertebrate energy		
			Nereis virens	305.59	431.75
			Large Crustacea spp.	0.00	0.00
			Abra tenuis	3.00	6.00
			Littorina spp.	0.00	0.00
Total Energy Requirement		**95.44**	**Total Available**	**688.37**	**956.01**

Energy requirements and availability table for sector NE3

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no. birds per month	Over-winter energy requirement kJ x 10[illegible]	Preferred Prey Species	Available Biomass over winter in kJ x 10[illegible]	Energy (incl. productivity) available over winter in kJ x 10[illegible]
Shelduck *Tadorna tadorna*	5.3	1.638	Hydrobia ulvae	0.31	0.42
			Small annelids	173.52	303.66
			Total	173.84	304.08
Oystercatcher *Haematopus ostralegus*	85.3	21.47	Mytilus edulis	0	0
			Macoma balthica	0.10	0.12
			Tapes philippinarum	53.32	104.16
			Cerastoderma edule	60.48	90.72
			Scrobicularia plana	34.61	118.26
			Hediste diversicolor	63.24	110.67
			Total	341.74	423.92
Grey Plover *Pluvialis squatarola*	5.3	0.04	Hediste diversicolor	63.24	110.67
			Lanice conchilega	0	0
			Macoma balthica	0.10	0.12
			Cerastoderma edule	60.48	90.72
			Carcinus maenas	2.34	2.92
			Small annelids	173.52	303.66
			Total	299.68	508.09
Avocet *Recurvirostra avosetta*	[illegible]	0.00	Hediste diversicolor	63.24	110.67
			Nephtys hombergi	22.45	33.12
			Small Annelids	173.52	303.66
			Small Crustacea and Other	2.54	4.76
			Total	261.76	452.21
Dunlin *Calidris alpina*	79.7	3.52	Hydrobia ulvae	0.31	0.42
			Hediste diversicolor	63.24	110.67
			Nephtys hombergi	22.45	33.12
			Small annelids	173.52	303.66
			Corophium sp.	included below	
			Crangon crangon	0.30	0
			Small Crustacea and Other	2.54	4.76
			Insecta	0	0
			Total	262.07	452.64
Redshank *Tringa totanus*	17.3	1.90	Corophium volutator	0.00	0.00
			Carcinus maenas	2.34	2.92
			Crangon crangon	0.30	0
			Hydrobia ulvae	0.31	0.42
			Macoma balthica	0.10	0.12
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	63.24	110.67
			Nephtys hombergi	22.45	33.12
			Small annelids	173.52	303.63
			Total	261.97	450.92
Bar-tailed Godwit *Limosa lapponica*	0.3	0.04	Large Polychaetes	222.34	327.90
			Bivalve molluscs	238.60	357.70
			Crustacea	5.75	10.76
			Total	466.60	696.50
Curlew *Numenius arquata*	[illegible]	2.34	Lanice conchilega	0	0
			Arenicola marina	69.36	94.70
			Hediste diversicolor	63.24	110.67
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	60.48	90.72
			Macoma balthica	0.10	0.12
			Carcinus maenas	2.34	2.92
			Total	195.61	299.13
			Other sources of invertebrate energy		
			Nereis virens	67.29	94.21
			Other Crustacea only	0.73	1.30
			Abra tenuis	0.00	0.00
			Littorina spp.	121.87	211.33
Total Energy Requirement		30.94	Total Available	746.23	1181.05

Energy requirements and availability table for sector NE1

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Overwinter energy requirement kJ x 10^5	Preferred Prey Species	Baseline Biomass over winter in kJ x 10^6	Energy (inc. productivity) available over winter in kJ x 10^6
Shelduck	0.5	0.150	Hydrobia ulvae	0.37	0.50
Tadorna tadorna			Small annelids	123.59	218.29
			Total	123.97	218.79
Oystercatcher	49.4	12.28	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	34.08	51.12
			Scrobicularia/Mya	126.14	157.66
			Hediste diversicolor	10.24	17.92
			Total	170.46	226.72
Grey Plover	0.1	0.01	Hediste diversicolor	10.24	17.92
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	34.08	51.12
			Carcinus maenas	0.00	0.00
			Small annelids	123.59	218.29
			Total	167.91	285.33
Avocet	0	0.00	Hediste diversicolor	10.24	17.92
Recurvirostra avosetta			Nephtys hombergii	25.94	44.16
			Small Annelids	123.59	218.29
			Small Crustacea and Other	4.00	7.50
			Total	163.77	286.87
Dunlin	17.8	4.32	Hydrobia ulvae	0.37	0.50
Calidris alpina			Hediste diversicolor	10.24	17.92
			Nephtys hombergii	25.94	44.16
			Small annelids	123.59	218.29
			Gammarus sp	Included below	
			Crangon crangon	0.00	0
			Small Crustacea and Other	4.00	7.50
			Insects	0	0
			Total	188.16	285.37
Redshank	5.1	0.43	Corophium volutator	0.00	0.00
Tringa totanus			Carcinus maenas	0.00	0.00
			Crangon crangon	0.00	0
			Hydrobia ulvae	0.37	0.50
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	10.24	17.92
			Nephtys hombergii	25.94	44.16
			Small annelids	123.59	218.29
			Total	164.14	278.87
Black-tailed Godwit	0.2	0.05	Large Polychaetes	193.95	264.60
Limosa limosa islandica			Bivalve molluscs	160.22	240.33
			Crustacea	4.00	7.50
			Total	357.17	512.44
Curlew	8.6	2.91	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	70.63	85.17
			Hediste diversicolor	10.24	17.92
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	34.08	51.12
			Macoma balthica	0.00	0.00
			Carcinus maenas	0.00	0.00
			Total	114.95	157.21
			Other sources of invertebrate energy		
			Nereis virens	68.25	115.13
			other Crustacea only	1.33	2.31
			Abra tenuis	0.00	0.00
			Littorina spp	0.00	0.00
Total Energy Requirement		20.20	Total Available	481.14	658.47

Energy requirements and availability table for sector SE1

Bird data is based on a [illegible] year mean 1991 - 1996

Bird Species	Mean no birds per month	Over-winter energy requirement kJ x 10^9	Preferred Prey Species	Standing Biomass over winter in kJ x 10^9	Energy (incl. productivity) available over winter in kJ x 10^9
Shelduck	5.1	1.749	Hydrobia ulvae	0.67	0.91
Tadorna tadorna			Small annelids	96.79	169.37
			Total	97.46	170.28
Oystercatcher	19.8	4.50	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	35.20	52.81
			Scrobicularia plana	82.55	103.31
			Hediste diversicolor	0.67	1.52
			Total	118.42	157.64
Grey Plover	1.7	0.20	Hediste diversicolor	0.67	1.52
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	35.20	52.81
			Carcinus maenas	0.00	0.00
			Small annelids	96.79	169.37
			Total	132.66	223.70
Avocet	0	0.00	Hediste diversicolor	0.67	1.52
Recurvirostra avosetta			Nephtys hombergii	1.02	1.51
			Small Annelids	96.79	169.37
			Small Crustacea and Other	17.47	32.75
			Total	115.95	205.15
Dunlin	12.3	0.64	Hydrobia ulvae	0.67	0.91
Calidris alpina			Hediste diversicolor	0.67	1.52
			Nephtys hombergii	1.02	1.51
			Small annelids	96.79	169.37
			Gammarus sp.	Included below	
			Crangon crangon	0.00	0
			Small Crustacea and Other	17.47	32.75
			Insects	0	0
			Total	116.62	206.06
Redshank	3.2	0.31	Corophium volutator	0.00	0.00
Tringa totanus			Carcinus maenas	0.00	0.00
			Crangon crangon	0.00	0
			Hydrobia ulvae	0.67	0.91
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	0.67	1.52
			Nephtys hombergii	1.02	1.51
			Small annelids	96.79	169.37
			Total	99.15	173.31
Black-tailed Godwit	1.4	0.23	Large Polychaetes	124.70	223.09
Limosa limosa islandica			Bivalve molluscs	118.50	[illegible]
			Crustacea	17.47	32.75
			Total	260.67	394.67
Curlew	4.7	1.62	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	122.22	152.77
			Hediste diversicolor	0.67	1.52
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	35.20	52.81
			Macoma balthica	0.00	0.00
			Carcinus maenas	0.00	0.00
			Total	158.09	207.10
			Other sources of invertebrate energy		
			Nereis virens	0.59	0.82
			other Crustacea [illegible]	12.03	22.57
			Abra tenuis	0.73	1.47
			Littorina spp	0.00	0.00
Total Energy Requirement		9.43	Total Available	366.33	617.35

Energy requirements and availability table for sector SC1/2

Bird data is based on a 8 year mean 1991 - 1998

Bird Species	Mean no birds per month	Overwinter energy requirement in kJ x 10^6	Preferred Prey Species	Baseline Biomass overwinter in kJ x 10^6	Energy (inc. productivity) available over winter in kJ x 10^6
Shelduck	120.0	44,085	Hydrobia ulvae	8.56	14.58
Tadorna tadorna			Small annelids	45.94	80.39
			Total	54.50	[illegible]
Oystercatcher	78.8	10.66	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	5.29	4.?1
			Cerastoderma edule	18.34	27.52
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	3.56	6.28
			Total	27.18	40.33
Grey Plover	11.5	1.55	Hediste diversicolor	3.59	6.28
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	18.34	27.52
			Carcinus maenas	0.38	0.46
			Small annelids	45.94	80.39
			Total	68.25	114.66
Avocet	0.163	0.02	Hediste diversicolor	3.60	6.28
Recurvirostra avosetta			Nephtys hombergii	13.95	20.58
			Small Annelids	45.94	80.36
			Small Crustacea and Other	2.29	4.29
			Total	65.78	111.54
Dunlin	45.2	2.13	Hydrobia ulvae	8.56	11.60
Calidris alpina			Hediste diversicolor	3.59	6.26
			Nephtys hombergii	13.66	20.58
			Small annelids	45.94	80.39
			Gammarus sp	included below	
			Crangon crangon	0.01	0.024
			Small Crustacea and Other	2.29	4.29
			Insects	0	0
			Total	74.34	123.12
Redshank	81.4	3.78	Corophium volutator	0.09	0.26
Tringa totanus			Carcinus maenas	0.38	0.46
			Crangon crangon	0.01	0.024
			Hydrobia ulvae	8.56	11.50
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	3.59	6.26
			Nephtys hombergii	13.85	20.58
			Small annelids	45.94	80.39
			Total	72.52	119.06
Black-tailed Godwit	78.6	12.78	Large Polychaetes	53.43	78.57
Limosa limosa islandica			Bivalve molluscs	26.85	43.27
			Crustacea	2.52	5.30
			Total	83.17	124.37
Curlew	39.2	33.10	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	8.28	10.35
			Hediste diversicolor	3.59	6.28
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	18.34	27.52
			Macoma balthica	0.00	0.00
			Carcinus maenas	0.38	0.46
			Total	30.49	44.6?
			Other sources of invertebrate energy		
			Nereis virens	27.60	38.65
			other Crustacea only	0.00	0.00
			Fly larvae	3.28	6.56
			Littorina spp.	0.26	0.52
Total Energy Requirement		88.5?	Total Available	137.7?	213.72

Energy requirements and availability table for sector SC3/6

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Overwinter energy requirement kJ x 10⁸	Preferred Prey Species	Ash free dry weight (AFDW) biomass over winter in kJ x 10⁸	Energy (incl. productivity) available over winter in kJ x 10⁸
Shelduck *Tadorna tadorna*	90.8	31.20	Hydrobia ulvae	1.58	2.13
			Small annelids	176.86	309.51
			Total	178.44	311.64
Oystercatcher *Haematopus ostralegus*	97.5	24.20	Mytilus edulis	0	0
			Macoma balthica	0.14	0.17
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	20.59	39.55
			Scrobicularia plana	134.50	165.20
			Hediste diversicolor	7.55	13.20
			Total	161.31	209.24
Grey Plover *Pluvialis squatarola*	9.6	1.06	Hediste diversicolor	7.55	13.20
			Lanice conchilega	0	0
			Macoma balthica	0.14	0.17
			Cerastoderma edule	29.59	39.58
			Carcinus maenas	3.37	4.22
			Small annelids	176.86	309.51
			Total	214.51	365.78
Avocet *Recurvirostra avosetta*	3.4	0.44	Hediste diversicolor	7.55	13.20
			Nephtys hombergii	0.00	0.00
			Small Annelids	176.86	309.51
			Small Crustacea and Other	21.75	40.78
			Total	206.16	363.49
Dunlin *Calidris alpina*	656.2	2.31	Hydrobia ulvae	1.58	2.13
			Hediste diversicolor	7.55	13.20
			Nephtys hombergii	0.00	0.00
			Small annelids	176.86	309.51
			Corophium sp.	included below	
			Crangon crangon	0.15	0.29
			Small Crustacea and Other	21.75	40.78
			Insects	0	0
			Total	207.88	365.92
Redshank *Tringa totanus*	57.2	6.39	Corophium volutator	0.00	0.00
			Carcinus maenas	3.37	4.22
			Crangon crangon	0.15	0.29
			Hydrobia ulvae	1.58	2.13
			Macoma balthica	0.14	0.17
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	7.55	13.20
			Nephtys hombergii	0.00	0.00
			Small annelids	176.86	309.51
			Total	189.65	329.63
Black-tailed Godwit *Limosa limosa islandica*	77.8	12.82	Large Polychaetes	151.59	146.85
			Bivalve molluscs	108.09	252.64
			Crustacea	20.54	43.75
			Total	297.22	463.24
Curlew *Numenius arquata*	73.7	24.85	Lanice conchilega	0	0
			Arenicola marina	0.00	0.00
			Hediste diversicolor	7.55	13.20
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	26.59	39.58
			Macoma balthica	0.14	0.17
			Carcinus maenas	3.37	4.22
			Total	37.65	57.49
			Other sources of invertebrate energy		
			Nereis virens	94.05	131.67
			other Crustacea only	18.59	35.74
			Abra tenuis	7.91	15.01
			Littorina spp.	0.00	0.00
Total Energy Requirement		102.74	Total Available	474.40	735.87

Energy requirements and availability table for sector SC4

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Over-winter energy requirement (kJ x 10⁸)	Preferred Prey Species	Biomass Biomass over-winter in kJ x 10⁸	Energy (incl. productivity) available over-winter in kJ x 10⁸
Shelduck *Tadorna tadorna*	142.2	46.965	Hydrobia ulvae	9.58	12.94
			Small annelids	234.65	410.65
			Total	244.24	423.59
Oystercatcher *Haematopus ostralegus*	78.2	19.46	Mytilus edulis	0	0
			Macoma balthica	0.16	0.19
			Tapes philippinarum	41.02	51.27
			Cerastoderma edule	42.75	64.13
			Scrobicularia plana	27.52	34.40
			Hediste diversicolor	0.00	0.00
			Total	111.45	149.90
Grey Plover *Pluvialis squatarola*	27.2	3.21	Hediste diversicolor	0.00	0.00
			Lanice conchilega	0	0
			Macoma balthica	0.16	0.19
			Cerastoderma edule	42.75	64.13
			Carcinus maenas	5.35	6.68
			Small annelids	234.65	410.65
			Total	282.91	481.65
Avocet *Recurvirostra avosetta*	11.5	1.43	Hediste diversicolor	0.00	0.00
			Nephtys hombergi	2.60	3.83
			Small Annelids	234.65	410.65
			Small Crustacea and Other	13.04	24.46
			Total	250.30	438.94
Dunlin *Calidris alpina*	187.1	7.39	Hydrobia ulvae	9.58	12.94
			Hediste diversicolor	0.00	0.00
			Nephtys hombergi	2.60	3.83
			Small annelids	234.65	410.65
			Gammarus sp	included below	
			Crangon crangon	0.03	0.054440132
			Small Crustacea and Other	13.04	24.46
			insects	0	0
			Total	259.91	451.93
Redshank *Tringa totanus*	20.9	2.81	Corophium volutator	0.00	0.00
			Carcinus maenas	5.35	6.68
			Crangon crangon	0.03	0.054440132
			Hydrobia ulvae	9.58	12.94
			Macoma balthica	0.16	0.19
			Scrobicularia plana	27.52	34.40
			Hediste diversicolor	0.00	0.00
			Nephtys hombergi	2.60	3.83
			Small annelids	234.65	410.65
			Total	279.89	468.75
Black-tailed Godwit *Limosa limosa islandica*	37.3	6.06	Large Polychaetes	34.07	38.15
			Bivalve molluscs	120.45	180.66
			Crustacea	20.42	36.20
			Total	178.94	276.12
Curlew *Numenius arquata*	100.6	33.92	Lanice conchilega	0	0
			Arenicola marina	0.00	0.00
			Hediste diversicolor	0.00	0.00
			Scrobicularia plana	27.52	34.40
			Cerastoderma edule	42.75	64.13
			Macoma balthica	0.16	0.19
			Carcinus maenas	5.35	5.68
			Total	75.78	104.41
			Other sources of invertebrate energy		
			Nereis virens	35.47	40.88
			Other Crustacea prey	0.16	0.34
			Abra tenuis	0.00	14.00
			Littorina spp	2.74	5.48
Total Energy Requirement		123.29	Total Available	423.91	631.75

Energy requirements and availability table for sector SC5

Bird data is based on a 5 year mean 1991 - 1995

Bird Species	Mean no birds (00 hundreds)	Overwinter energy requirement kJ x 10^6	Preferred Prey Species	Baseline Biomass overwinter in kJ x 10^6	Energy (no predation) available overwinter in kJ x 10^6
Shelduck	110.6	38.103	Hydrobia ulvae	1.87	2.52
Tadorna tadorna			Small annelids	66.70	116.73
			Total	68.57	119.25
Oystercatcher	47.3	11.73	Mytilus edulis	0	0
Haematopus ostralegus			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	5.23	7.84
			Scrobicularia plana	96.01	124.51
			Hediste diversicolor	4.28	7.50
			Total	139.12	139.84
Grey Plover	5.0	9.68	Hediste diversicolor	4.28	7.50
Pluvialis squatarola			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	5.23	7.84
			Carcinus maenas	2.20	2.76
			Small annelids	66.70	116.73
			Total	78.41	134.81
Avocet	66.3	7.24	Hediste diversicolor	4.28	7.50
Recurvirostra avosetta			Nephtys hombergii	0.00	0.00
			Small Annelids	66.70	116.73
			Small Crustacea and Other	23.46	44.02
			Total	94.44	160.24
Dunlin	104.6	4.63	Hydrobia ulvae	1.87	2.52
Calidris alpina			Hediste diversicolor	4.28	7.50
			Nephtys hombergii	0.00	0.00
			Small annelids	66.70	116.73
			Corophium sp	Included below	
			Crangon crangon	0.02	0.046
			Small Crustacea and Other	23.46	44.02
			Insects	0	0
			Total	96.36	170.81
Redshank	20.1	2.46	Corophium volutator	21.24	32.41
Tringa totanus			Carcinus maenas	2.20	2.76
			Crangon crangon	0.02	0.043254943
			Hydrobia ulvae	1.87	2.52
			Macoma balthica	0.00	0.00
			Scrobicularia plana	96.01	124.51
			Hediste diversicolor	4.28	7.50
			Nephtys hombergii	0.00	0.00
			Small annelids	66.70	116.73
			Total	195.93	312.46
Black-tailed Godwit	26.2	4.25	Large Polychaetes	18.64	25.55
Limosa limosa islandica			Bivalve molluscs	109.45	163.72
			Crustacea	25.53	49.74
			Total	150.26	249.04
Curlew	96.3	22.52	Lanice conchilega	0	0
Numenius arquata			Arenicola marina	0.00	0.00
			Hediste diversicolor	4.28	7.50
			Scrobicularia plana	97.01	124.51
			Cerastoderma edule	5.23	7.84
			Macoma balthica	0.00	0.00
			Carcinus maenas	2.20	2.76
			Total	111.32	142.60
			Other Sources of invertebrate energy		
			Nereis spp.	15.30	21.42
			other Crustacea only	0.64	1.20
			Abra tenuis	4.51	6.63
			Littorina spp	0.00	0.00
Total Energy Requirement		101.63	Total Available	225.09	335.85

Energy requirements and availability table for sector SC7/8

Bird data is based on a 5 year mean 1991 - 1996

Bird Species	Mean no birds per month	Over-winter energy requirement in kJ x 106	Preferred Prey Species	Based on biomass over-winter in kJ x 106	Energy (inc. productivity) available over winter in kJ x 106
Shelduck *Tadorna tadorna*	82.2	28.329	Hydrobia ulvae	3.32	4.49
			Small annelids	53.27	93.22
			Total	56.59	97.71
Oystercatcher *Haematopus ostralegus*	28.6	7.17	Mytilus edulis	0	0
			Macoma balthica	0.00	0.00
			Tapes philippinarum	0.00	0.00
			Cerastoderma edule	0.81	1.21
			Scrobicularia/Mya	0.00	0.00
			Hediste diversicolor	33.15	58.01
			Total	33.96	59.22
Grey Plover *Pluvialis squatarola*	8.8	0.75	Hediste diversicolor	33.15	58.01
			Lanice conchilega	0	0
			Macoma balthica	0.00	0.00
			Cerastoderma edule	0.81	1.21
			Carcinus maenas	0.00	0.00
			Small annelids	53.27	93.22
			Total	87.22	152.44
Avocet *Recurvirostra avosetta*	11.2523	1.43	Hediste diversicolor	33.15	58.01
			Nephtys hombergi	0.00	0.00
			Small Annelids	53.27	93.22
			Small Crustacea and Other	20.01	37.51
			Total	106.43	188.75
Dunlin *Calidris alpina*	314.1	6.08	Hydrobia ulvae	3.32	4.49
			Hediste diversicolor	33.15	58.01
			Nephtys hombergii	0.00	0.00
			Small annelids	53.27	93.22
			Gammarus sp.	included in above	
			Crangon crangon	0.00	0.000
			Small Crustacea and Other	20.01	37.51
			Insects	0	0
			Total	109.75	193.23
Redshank *Tringa totanus*	30.9	3.91	Corophium volutator	17.11	47.05
			Carcinus maenas	0.00	0.00
			Crangon crangon	0.00	0
			Hydrobia ulvae	3.32	4.49
			Macoma balthica	0.00	0.00
			Scrobicularia plana	0.00	0.00
			Hediste diversicolor	33.15	58.01
			Nephtys hombergii	0.00	0.00
			Small annelids	53.27	93.22
			Total	106.85	202.77
Black-tailed Godwit *Limosa limosa islandica*	20.1	4.84	Large Polychaetes	233.97	345.15
			Bivalve molluscs	0.81	1.21
			Crustacea	20.01	37.51
			Total	254.79	383.83
Curlew *Numenius arquata*	60.5	19.29	Lanice conchilega	0	0
			Arenicola marina	0.00	0.00
			Hediste diversicolor	33.15	58.01
			Scrobicularia plana	0.00	0.00
			Cerastoderma edule	0.81	1.21
			Macoma balthica	0.00	0.00
			Carcinus maenas	0.00	0.00
			Total	33.95	59.22
			Other sources of invertebrate energy		
			Nereis virens	200.02	261.15
			other Crustacea only	0.02	1.17
			Abra tenuis	0.00	0.00
			Littorina spp	0.00	0.00
Total Energy Requirement		89.46	Total Available	311.34	475.59