IMPACT OF CLIMATE CHANGE ON THE WADDEN SEA ECOSYSTEM

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The Wadden Sea ecosystem is a shallow tidal sea of about 8000 km2 along the coast of The Netherlands, Germany and Denmark. It is a wetland of international importance because of its function as breeding grounds for marine fishes, as a protected area for two species of seals and its wealth of benthic animals that attracts hundreds of thousands of migratory birds.
It is a dynamic system with daily tide movements between the Wadden Islands and the mainland that results in an equilibrium of erosion and deposition of fine and coarser sand. This equilibrium is one of the most important driving forces for the processes that shape the coastal zones of the islands and the continent and the dry falling of tidal flats.

Climatic change is supposed to have two main effects: rising of the average temperature and rising of the sea level. The effects on the Wadden Sea system are direct and indirect and, moreover, have a mutual influence. Research is directed towards measurements, experiments and modelling of the main processes that result from temperature rise and sea level rise (Fig. 1).

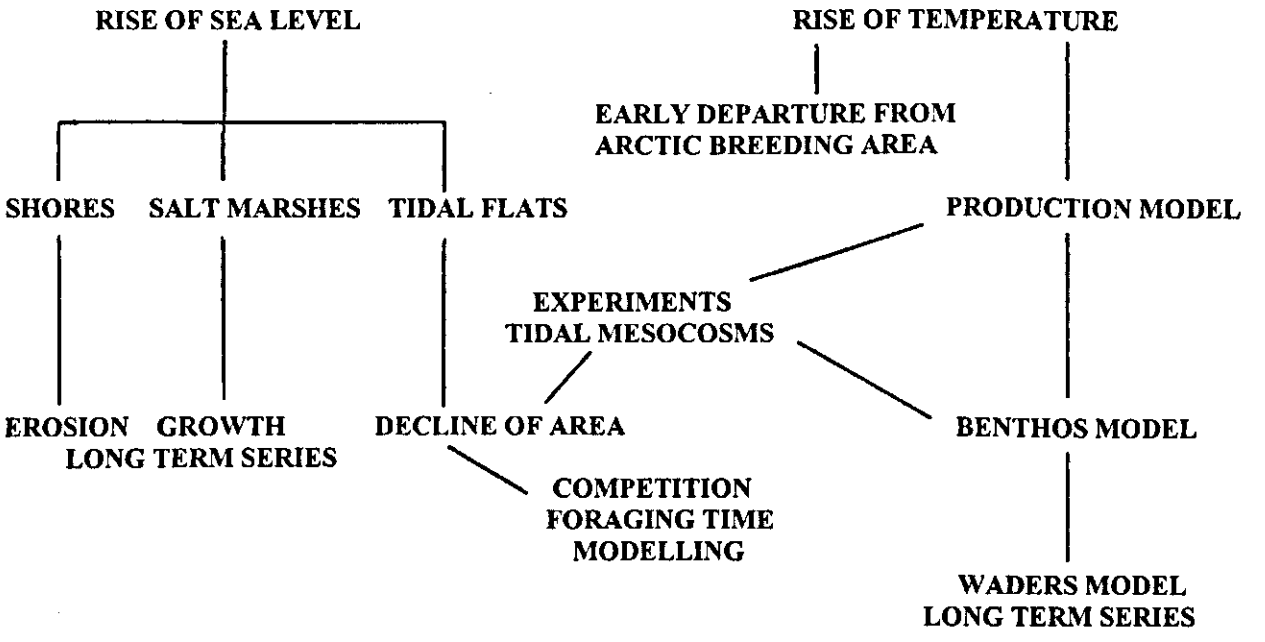

Fig. 1. Climatic change: Relationships and research

Sea level rise may cause a further erosion of shores of the Wadden islands and the mainland. It largely influences the possibilities for growth or erosion of the salt marshes as will be shown later. The tidal flats could fall dry during shorter periods, if the sand suppletion is not sufficient to level up with the sea rise. This influences the production of benthos and consequently the food supply for birds. Competition between benthos eating birds that find fewer preys and have less time to forage results in starvation of young and inexperienced animals, which has dramatic effects on population structure.
The effects of sea level rise are enhanced by the current extraction of natural gas, causing local subsidence of the sea bottom with expected values of 25 cm over the next 20 years (Oost & Dijkema, 1993).

Temperature rise may influence the departure time of migratory birds from the arctic region. They could find a different situation as compared to present in relation to the benthic standing stock and a possible decline in tidal flat area. The primary production of the Wadden Sea shall be influenced, which in its turn affects the secondary producers such as filter feeding molluscs. These are the main food for resident waders and migratory birds.

Mesocosm experiments are directed to measuring the effects of shorter periods of falling dry of tidal flats on selected benthic organisms. In a second series of experiments, sediment temperatures are heightened by 4 oC. Results are used for a large ecosystemmodel of the Wadden Sea in which the results of the other parts of research are also put together as modules that interlink the main processes of the functioning of the ecosystem.

The experiments with temperature rise revealed a lower biomass growth in the high temperature mesocosms for *Cerastoderma edule* and for *Macoma baltica* (Fig. 5) as compared to normal temperatures.

Fig. 5. Ash-free dry weight/individual of *Macoma* baltica in the mesocosms. Bald line is high temperature.

The results of the different subprojects are used as input for the ecosystem model of the Wadden Sea (EcoWasp).This model is explained in the poster of Brinkman et al., reproduced in this volume.

References

Ens, B.J. & A.G. Brinkman, 1998. Predicting the effect of sea level rise or soil subsidence on waders feeding on intertidal mud flats using habitat correlations. Proc. Wader Study Group Conference in Hungary 16-19.10.98.

Neuhaus, R., K.S. Dijkema & H.-D. Reinke, 1998. Die Gefährdung der Flora und Fauna an Küsten durch Meeresspiegelanstieg. P. 313-317 in: Lozán, J.L., H. Grassl & P. Hupfer (Herausgeber) Warnsignal Klima: wissenschaftliche Fakten.

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Salt marshes have a varied flora and fauna that is bound to saltwater. The total area of salt marshes in Europe is threatened by human activities such as embanking and city-building. In The Netherlands, the embanking has taken place since the Middle Ages and this process has only been stopped since 1980. The salt marsh area is considered as an important nature reserve and studies are undertaken to create a natural as possible salt marsh structure. The growth of salt marshes is dependant on suppletion of sand and silt The average high water level is of crucial importance for the processes that create or destroy salt marshes.. Sea level rise, together with sea bottom subsidence, forms the main threat for the marshes. The aggravated erosion due to higher wave energy at deeper flooding leads to the formation of cliffs. These cliffs separate the salt marshes from the other parts of the tidal flats, and limit expansion by encroachment followed by enhanced sedimentation.
A sea level rise of 3-6 mm/yr can be compensated by accretion of the marshes. The vegetated marshes are capable to keep three times more sand than the bare ones (Fig. 2). The two upper graphs in Fig. 2 represent vegetated marshes, the two middle ones marshes with pioneer vegetation and the lower ones are without vegetation.

Fig. 2. Exposed mainland saltmarsh (Lauwerpolder). The height in mm is related to average high water level (from Neuhaus et al., 1998)

Modelling is a powerful instrument to relate bird densities to availability of food in different scenarios. Ens and Brinkman (1998) have estimated the magnitude of the impact of reduction of exposure time of flats on birds. They therefore correlated bird densities at low water with simple habitat variables, such as emersion time of the flats and sediment composition. For each species, the feeding density is plotted as a function of median grain size and emersion time and a bell-shaped curve is fitted to these data. For 12 species, a model could be constructed that was then validated with the high water counts, i.e. the total number of birds for each species in the entire Dutch Wadden Sea is predicted by multiplying the surface of each habitat with the density predicted for that habitat. Next, the predicted values are compared with the number of birds counted during high tide on the roosts. Eight out of the 12 species could be used for scenario calculations cause the predictions were relatively close to the observations. Firstly, it is investigated how relative sea level rise affects the surface of the habitats. Secondly, with use of the model, it is calculated how many birds the area can support.
Fig. 3 shows the expected decrease in numbers per species in the case of progressive sea level rise under the assumption that sand supply is not sufficient to keep up with the loss of area.

Fig. 3. Decrease in numbers of waders with initial exception of the greenshank.

The experiments with low tide (long period of dryfall) and high tide (long period of immersion) resulted in a low total biomass in the low tide mesocosms and a more than twice as high total biomass in the high tide mesocosms (Fig. 4).

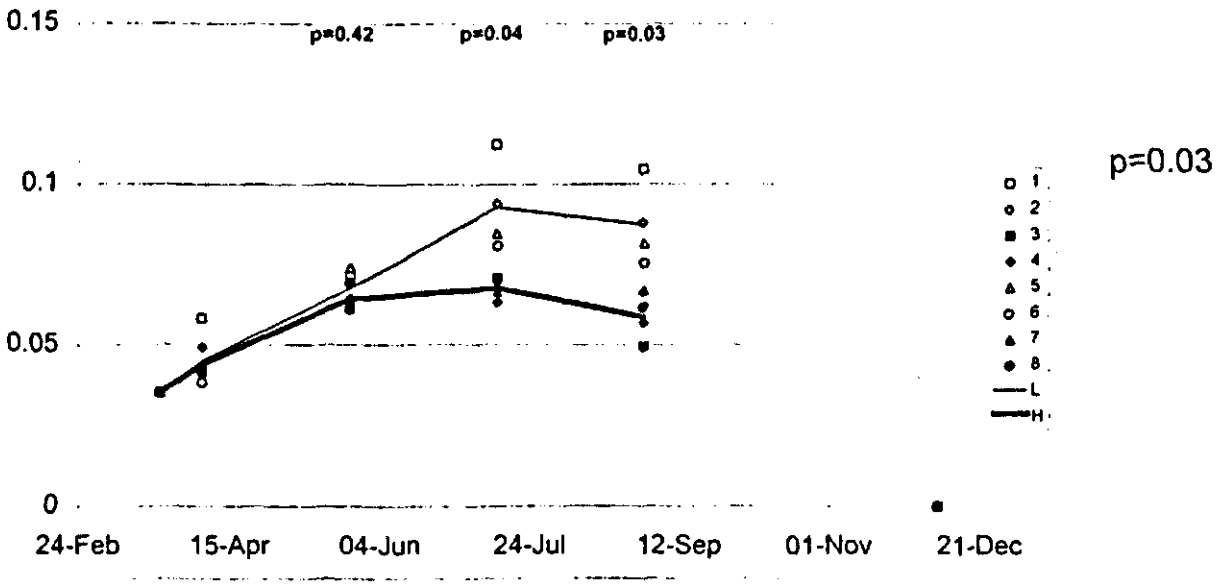
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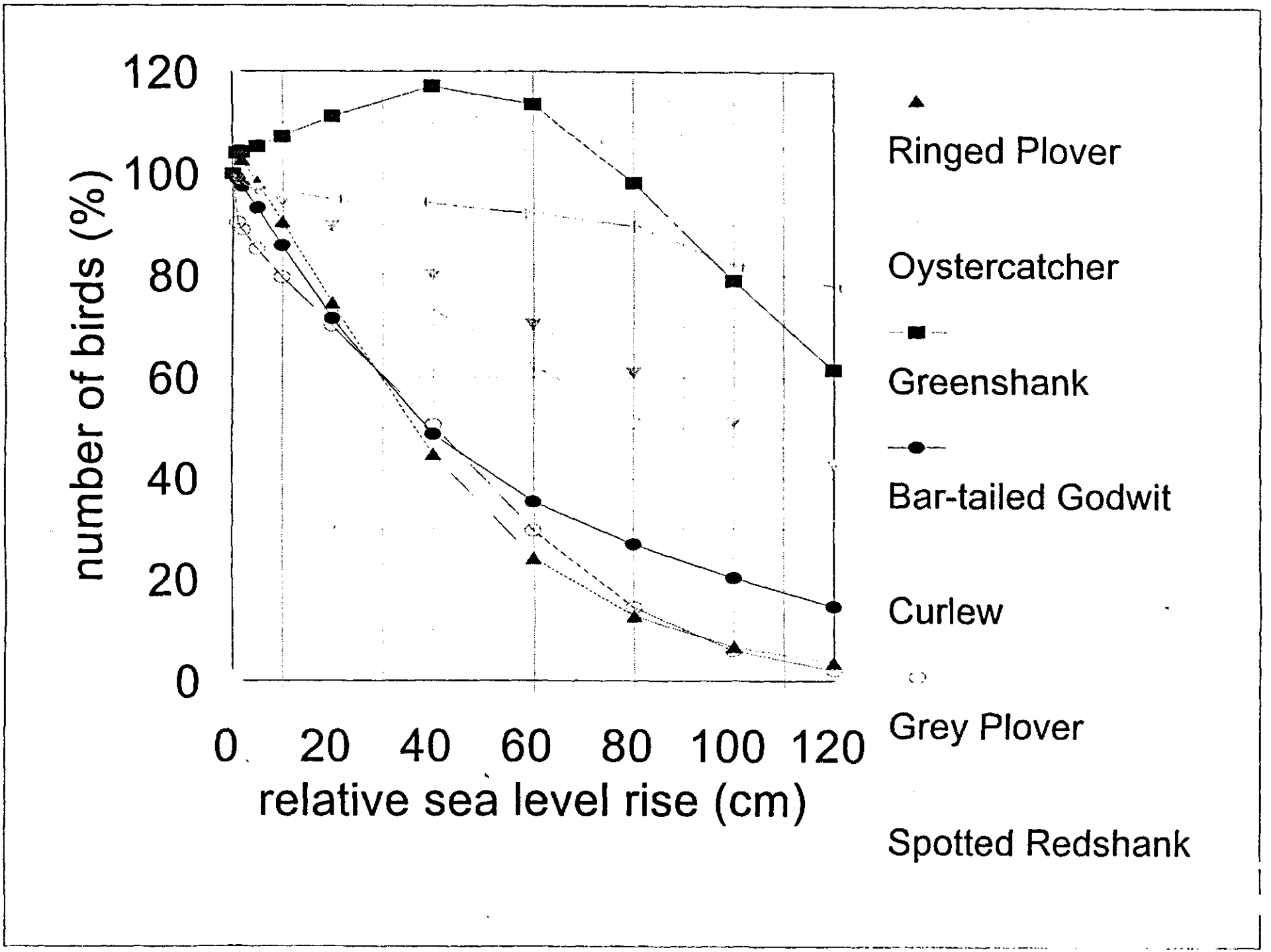
Fig. 5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80
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number of birds (%)
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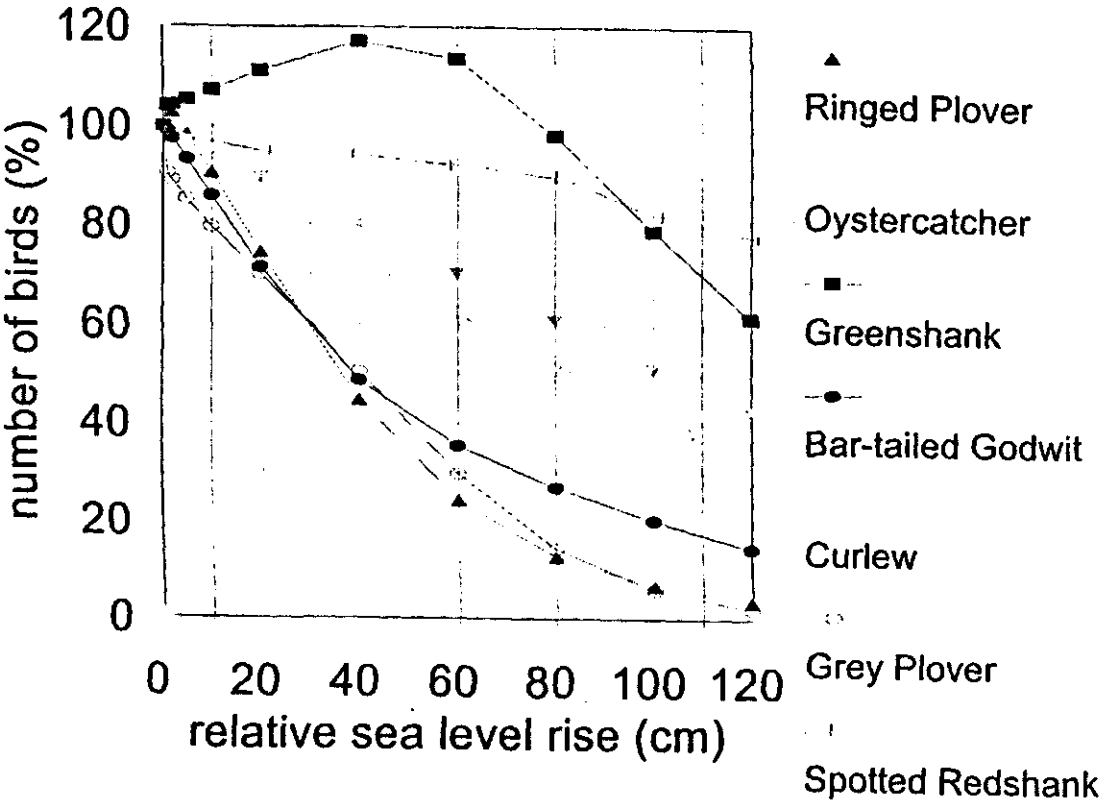
relative sea level rise (cm)
Ringed Plover
Oystercatcher
Greenshank
Bar-tailed Godwit
Curlew
Grey Plover
Spotted Redshank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number of birds (%)
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Ringed Plover
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Curlew
Grey Plover
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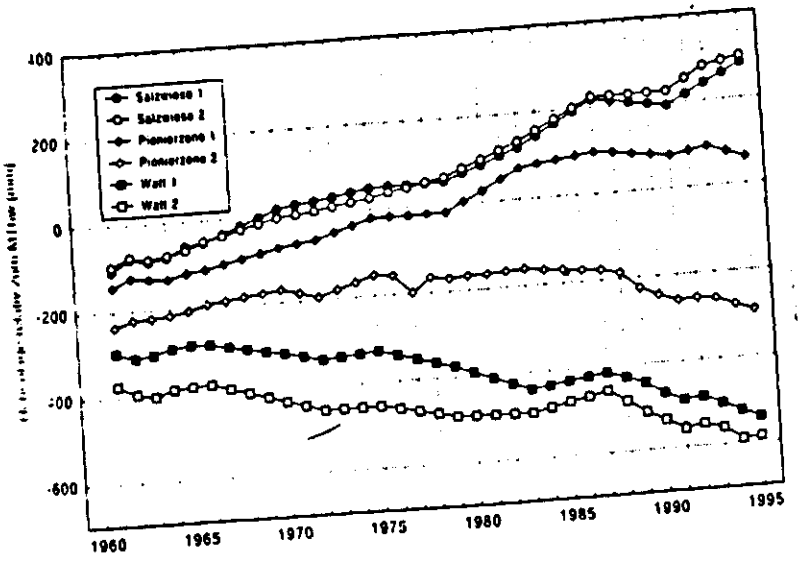

Fig. 2

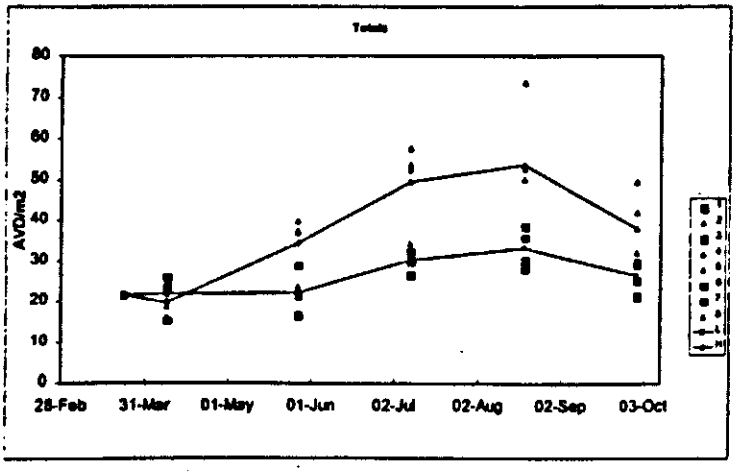

Figure 4 Total biomass of benthic animals