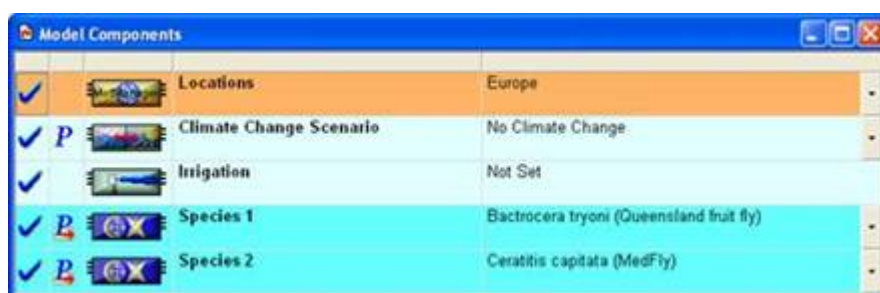# CLIMEX Model

The CLIMEX model describes the response of a species or other taxonomic unit to climate. It operates in two modes: **Compare Locations** and **Compare Years**. In the former, the response of a species to the long-term average climates of different

locations is compared, while in the latter the response to climates in different years at the same place is compared. This means that there are two different types of meteorological data involved in CLIMEX. Section 3 of the user manual provides a thorough conceptual treatment of the CLIMEX model and should be read before using CLIMEX.

Compare Locations

The Compare Locations function enables the user to predict the potential geographical distribution of a species or a pair of species in relation to climate only, based on its climatic preferences. This function uses a meteorological database consisting of monthly long-term average climatic variables for any number of locations. A set of parameters describes the species' response to the average climate of any given location, with the implicit assumptions that (i) the species is able to survive the annual variation in climate that is associated with that location, and (ii) that the annual variation at all locations is equal (to comply with the statistical requirement that comparison of means assumes equal variances). This latter assumption is not true and needs to be considered when comparing results from regions with different annual variation such as occurs when comparing areas with continental climates, like the southern USA or southern China, with other areas that do not experience occasional very extreme seasons, like much of Africa for example. Currently, there is no global database available to allow CLIMEX to take account of the differences in variation between regions.

The model parameters are divided into three groups: one group defines seasonal population growth, one defines stresses that limit the geographical distribution, and the third describes constraints that may exclude species from some areas. An iterative process of comparing the known and predicted distributions for the same region is used to derive values for the parameters. Once the parameter values have been defined, they can be used to predict the potential distribution of the species in other independent locations.

The Compare Locations function is primarily used for describing the potential distribution of a species as determined by climate. Being able to describe and map the potential distribution of species enables policy makers at both national and international levels to make rational decisions about managing pests or distributing natural enemies. For example, if the Compare Locations function indicates that areas are climatically unsuitable for a potential biocontrol agent, there is little point in introducing such a species. From a pest risk analysis perspective, a Compare Locations run may indicate that an area is highly suitable for an exotic pest species and so could cause costly losses of production or damage to the natural environment.

Once the species' parameters have been defined adequately, the Compare Locations function also enables the user to examine the relative seasonal potential for growth of the species in any given location. Having a relative measure of the species' likely performance in a given location has implications for the local management of pest species.

Since defining a species' parameter file involves estimating the stresses that limit its distribution, the Compare Locations function contributes towards understanding the biology of a species for which the user may have little biological information. The process of fitting the parameter values may help a user to identify areas where further research on some aspect of the biology (eg cold tolerance, or adaptations to heat stress) might prove useful.

The Compare Locations function is also useful in selecting field sites for a research project. Ecological research often demands that field sites represent the range of conditions experienced by the species, from marginal to optimal. A Compare Locations run will help an ecologist readily identify the most representative field sites. Furthermore, it is usually the marginal sites that are the most interesting to the researcher. This function of CLIMEX enables the identification of sites that are marginal for different reasons (eg because they are too hot, to dry, to cold, or too wet), and thus helps the researcher to select sites that will yield interesting results.

By running CLIMEX with average data from different years, some indication of the relative changes in the geographical range can be obtained. However, note that averaging smoothes data and so such results cannot be compared directly with those from simulations using long-term average data.

Compare Years

The Compare Years application uses a database consisting of consecutive years of monthly data from the same location, rather than long-term average data from many different places as in the Compare Locations function. Compare Years lets the user examine the effect of climatic variation on the potential population growth and survival of a species over consecutive years. The user can enter weekly or monthly climatic data for any number of years and CLIMEX will display the species' response for each year.

Another use for the Compare Years facility is to compare the times in different years when the climate of representative locations on a migration path become suitable for the establishment of migrant insects. This enables the user to differentiate between climate and arrival times as factors that limit the appearance of migrants in different years.

It is important to note that daily data averaged over weeks or even months will still have greater variability than the long-term average data with which the original parameter values were (usually) estimated by inference from the geographical distribution.

In order to minimise the incompatibility between the different data sets it is desirable first to average daily data to monthly and allow CLIMEX to interpolate it back to weekly averages. Secondly, it is inevitable that even monthly data for a particular year will generate more extreme values than occur in long-term average data, so the results from Compare Years and Compare Locations should not be compared. The values of each index in the Compare Years output can be compared with each other as they are relative measures of growth or stress. Often, stress values at locations within the normal species' distribution will exceed 100 for short periods or years but this should not be interpreted as precluding the existence of the species. The value of 100 is estimated from smoothed, long-term average meteorological data and long-term average geographical distributions and so represents an average value.