The general aim of this project has been to develop a theoretical framework to underpin the discipline of ecological restoration, by simulating model communities under differing restoration scenarios and comparing the restored communities in terms of structure (e.g. community composition) and function (e.g. stability). The project compared the model predictions to real communities data from degraded and restored communities and test the model's predictions using a manipulative field experiment. More specifically, this project addressed three main questions:

(1) To investigate the likelihood that certain ecological properties can be restored in degraded communities, i.e. communities that have experienced destruction of their habitats.
(2) To study how much habitat is needed to be restored to restore some minimum level of stability
(3) To make predictions about what kind of communities are easier to restore or restore more rapidly, providing information about which 'routes' or sequences of species addition are more efficient to restore communities in terms of resilience and stability

SIMULATION MODELS

The project has been carried out according to the work plan. After an initial period of literature review, the cellular automata models have been developed for communities of different trophic levels under no perturbation. These communities are characterised by using a wide set of variables describing their diversity, food web structure and stability. General patterns of these simulated communities were similar to those observed in nature in terms of rank-abundance distributions and degree distributions (the distribution of the number of links per species). Further, the statistical properties of these networks fell within the realistic values reported in real food web communities. All together, these results provide evidence that the simulation models describe multitrophic communities realistically.

The second step in the simulation process involved the implementation of the algorithms defining habitat loss and restoration. The programmed algorithm works as follows. After a period of transient dynamics the simulated multitrophic communities were described in terms of diversity, food web structure and stability. Given the spatial nature of the models, habitat (space) was destroyed in 10% steps and we left communities to stabilise to this new scenario. Once stabilized, the amount of habitat previously destroyed was restored, and communities were left to evolve until they reached a dynamic stable state. We measured diversity, food web properties and stability both for communities under destruction and restoration.

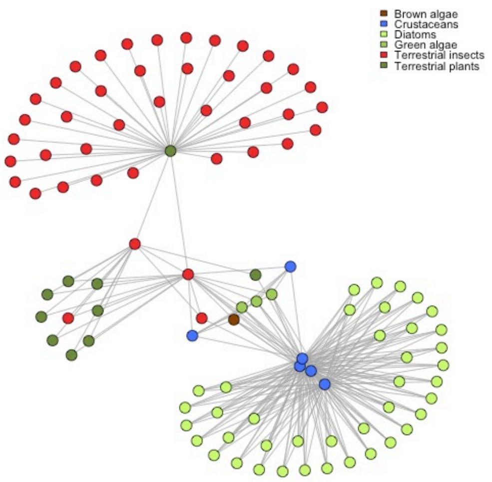
RESULTS FROM SIMULATION MODELS
(1) It is possible to restore ecological properties in degraded communities. However, recovery rates strongly depend on the magnitude of destruction, i.e. the recovery dynamics of the communities inhabiting more impacted habitats take longer to stabilize (they are less resilient). Whereas communities that recover after low levels of habitat destruction are similar to the original ones, restoration in more impacted habitats is more likely to lead to alternative states, i.e. restored communities with different food web properties.

(2 & 3) The proportion of mutualistic (e.g. seed dispersal, plant-pollinator) versus antagonistic (e.g. predator-prey, host-parasitoid) interactions in the global community plays an important role in the restoration of the simulated communities. We found that increasing the proportion of mutualistic vs. antagonistic interactions at the base of the food web affects different aspects of ecological stability in different directions, although never negatively (Lurgi et al. *In review*). Although the recovery rates of communities differing in their mutualism degree are similar, the stability (e.g. distribution of interaction) of the final restored communities is higher in more mutualistic communities. As predicted, the mutualism degree is important in the restoration of natural communities because of its impacts on

community stability, and it could be used in active restoration plans by designing to some extent the sequence of species arrival.

EXPERIMENTAL FIELD WORK

Given the challenges in locating safe, close, and easily accessible field sites, the original fieldwork design has been adapted to include four different locations along the Bristol channel. This new design includes control and experimental islands within every field site, so that replication is done both within and among sites, which allows controlling for spatial effects in the observed diversity patterns. Biological communities from 115 salt marsh islands distributed in four archipelagos have been sampled during the two field seasons (summers 2013 and 2014). These communities comprise different types of interaction and a combination of marine and terrestrial species, including terrestrial plants, marine macrophytes, diatoms, crustaceans, molluscs, spiders and insects, the latter including pollinators, decomposers and a predator. Interactions between species were determined by a mixture of direct, gut content analysis, stable isotope analysis (carried out at Rothamstead Research at North Wyke), literature searches and discussion with experts. We constructed a food web for each island (the regional food web comprising 102 species is represented in the figure).



All island salt marsh communities were sampled during the summer 2013 before the experimental manipulations. This produced an unprecedented dataset consisting of 115 'networks of networks' (Pocock et al. 2012). Once the appropriate permissions were granted (Marine Management Organisation, Natural England, Crown State, etc), destruction experiments were run in September 2013 after the initial sampling and before the end of the field season. Two treatments were considered: 50% destruction, and total destruction. Control and treated islands were sampled after the experiment to look at the effects of habitat destruction. In summer 2014 treated and control islands were sampled again to examine the restoration effects and evaluate the recovery of these salt marsh communities.

The second field season ended in late September 2014. We have been assembling the data collected in the field (e.g. insect pinning, specimen identification, etc) to construct post-destruction/restored food webs. Preliminary results support theoretical findings from the simulation models. Specifically, the communities inhabiting the islands that experienced total destruction are taking longer to restore, which supports the theoretical finding that recovery rates strongly depend on the magnitude of destruction. We expect that a throughout analysis of the 2014 dataset will fully or mostly support our theoretical predictions. We are also aware that 1-year is not enough time for restoration and that recovery dynamics may take much longer to stabilize. However, this is the first replicated study on the restoration of complex food webs, and we expect the information from this research will be useful to inform the practice of restoration of natural communities, especially those combining different types of species interactions.