The present thesis consists of a summary report, four research articles, one technical report and one manuscript. The subject of the thesis is individual-based stochastic models. The summary report is composed of three parts and a brief history of some basic models in population biology. This history is included in order to provide a reader that has no previous exposure to models in population biology with a sufficient background to understand some of the biological models that are mentioned in the thesis. The first part of the rest of the summary is a description of the dramatic changes in the degree of aggregation of sprat or herring in the Baltic during the day, with special focus on the dispersion of the fish from schools at dusk. The next part is a brief introduction to Markovian arrival processes, a type of stochastic processes with potential applications as sub-models in population dynamical models. The last part introduces Markov additive processes as a means of simplifying some individual-based models. In the first part I present the background to article A and some extra material that were not included in the final article. The basic observation is that fish in schools migrate up toward the surface and disperse at dusk and aggregate in schools close to the bottom at dawn. This creates a periodically varying prey field to cod. Apart from humans, cod is the main predator of herring and sprat in the Baltic. In order to evaluate the consequences to cod of this variability it was necessary to describe this prey field. It was shown that the schools follow lines of constant light intensity and that they disperse below a critical light threshold. We propose that the dispersion is due to a random walk when light levels become sub-critical and provide time-scales for the dispersion of this type for different school geometries (random or on a regular square grid)—the time-scales are of the same order as those observed on the echosounder. The second part is an introduction to Markovian arrival processes (MAPs), this is the background needed to understand papers C, B, E, and F, given some previous exposure to Markov chains in continuous time (see e.g. Grimmett and Stirzaker, 2001)). Markovian arrival processes are very general point processes that are relatively easy to analyse. They have, so far, been largely unknown to the ecological modelling community. The article C deals with a functional response in a heterogeneous environment. The functional response is a model of the mean ingestion rate of prey per predator as a function of prey and possibly predator density that appears in most models for populations. A previously proposed model for prey encounter in heterogeneous environments is reanalyzed, it is a stochastic process that easily can be implemented as a MAP. In article C we show that transferring a standard functional response to a heterogeneous environment does not preserve the functional form, contrary to previous assertions. In this simple case we provide a time-scale for when the heterogeneous environment can be assumed to be well-mixed, or close to a Poisson process, for the predator. It is also shown that in some cases the variability may be more important than the mean, thus the mean rate does not necessarily provide sufficient information for the population dynamics. Article B provides the mathematical apparatus for evaluating any moment of a MAP, and also the means for evaluating the conditional moments of a transient or terminating MAP. Transient MAPs are suitable as modelling tools when an important property of the system is that it can stop. This is the case for the young of many animals, where most of a large clutch die rather quickly, and yet it is the survivors that are interesting. The conditional moments can for instance be constructed such that one can evaluate the mean or the variance of the ingestion rate given that the animal did not die. Several different methods are used to obtain the formulas, which is an interesting aspect since some of these methods may be more suitable in situations where it is problematic to proceed using the standard formalism. I provide material on how to model periodic MAPs in paper E. These are, or could be, important since most animals live in a periodic environment and a periodic system generally have dynamics that are different from the corresponding system with mean rates. The technical report F concerns how to model Markovian stomachs. Both aspects can be used in more advanced functional or numerical responses. The third part concerns a larger class of Markov processes, to which the above mentioned MAPs belong. These are the Markov additive processes, which are bivariate Markov processes (Xt, Nt) where the transition probabilities depend on the Xt process only. The Xt process is marginally a Markov process, and the Nt process is a process with conditionally independent increments given the state of the Xt process. This class is rich enough to provide substantial realism into individual-based models yet it is so simple that it is not a great extra burden to solve the partial differential equations (PDEs) that arise for the evaluation of the moments. They are particularly useful in oceanographic contexts since here the apparatus for solving the PDEs is usually present due to the need of solving fluid flow equations. The greatest benefit of the method is due to that it circumvents the need for statistical evaluation of the individual-based models. In all three parts further work has been proposed.

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