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COMPUTER SIMULATION OF GLASSEEL IMMIGRATION THROUGH THE SLUICES OF DEN OEVER

by

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Computer simulation of glasseel immigration through the sluices of Den Oever.

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Abstract

Based on rather straightforward assumptions (peak arrival time, constant probability of successful immigration or normally distributed pass through delays), the density of immigrating glasseels (*Anguilla anguilla*) just in front of sluices are simulated, and parameter estimates tuned to 50 years of data. Contrary to former believes, it is shown that peak arrival times seem to occur early in the evening, and peak pass through late at night. Decisive experiments are suggested.

Resumé

Avec des suppositions simples (le temps des arrivée culminant, probabilité de immmigration réussie constante, ou des retards distribué normal) le densité des civelles (*Anguilla anguilla*) immigrantes en eau douce devant les écluses sont simulé, et les parametres ajusté à 50 ans des données de Den Oever. Contrastant avec des convictions précédents, le temps de arrivée culminant semble d'être du soir et pas de la nuit, et le temps de immigration bien avant dans le grand matin. Des experiences cruciales sont proposé.

Introduction

The reproduction of the European eel is still unknown (Boëtius and Harding, 1985). Thus, the exact identity of the stock is difficult to delimit. Whatever the true identity, it seems beyond doubt, that the whole of western Europe shares at least part of the spawning stock. Thus, the decline in recruitment in recent years in many European countries (Moriarty, 1987) is a common concern, and monitoring the recruitment of common interest.

In a recent review of glasseel monitoring in Europe (Moriarty, et al., 1987) it is shown, that most recruitment surveys are of a rather crude nature: only total catches per night, or even per year are monitored, sometimes even corrupted by varying (commercial) sampling effort. Only one data series gives finer detail: in Den Oever (Netherlands), every two hour during nights in spring, glasseels in front of the sluices discharging water from the IJsselmeer are sampled with a dipnet. Additionally, Den Oever is the only series which did show an earlier decline in recruitment -in the early fifties- since other series do not extend backwards far enough. Thus, the correct interpretation of the Den Oever time series is of utmost importance.

On the other side, monitoring of glasseel immigration throughout Europe takes place in estuaries and river mouths, except for the Den Oever site , where samples are taken in front of sluices, which separate sea from fresh water. The comparison of the data collected at this site with the rest of Europe, might be corrupted by the steep transition from sea to fresh water. In Den Oever, the standing density of glasseels in front of the sluices is sampled; this density has been taken to be an index of the flow of glasseels through the sluices (Deelder, 1958). However, if glasseels delay their migration just in front of the sluices (in order to adapt to the changing abiotic environment, or because of the low chance of successful passage through the sluices), the relationship between standing density and flow through might depend on variable abiotic factors like water temperature and salinity of both water masses.

In an earlier, descriptive analysis (Dekker, 1986) 50 years of data of the Den Oever series were analysed, and correlations with abiotic factors detected. However, although the dependence of the standing density on the migration speed was acknowledged, no historical data were at hand to make any actual estimate. In order to prepare for future experiments, the present study simulated the assumed effect of physiological or abiotic constraints on migration speed on the recording of glasseel densities.

Simulation models

In the current study, the dynamics of the glasseel migration at the sampling location in front of the sluices in the course of an average night was simulated. This location was thought to be bounded by an imaginary border between the estuary and the vicinity of the sluices at the sea side, and the sluices themselves at the fresh water side. For three different assumptions about the actual delay mechanism each, only one simulation was set up, i.e. no distinction was made between early and late spring, small and big water discharges, or steep and mild transitions of abiotic factors, etc.

The models were build upon the following assumptions:

1) **Time interval.** Simulations were made using discrete time intervals. These intervals were taken to be either 0.5, 1 or 2 hours. Within one interval, it is assumed that nothing happens.

2) **Average arrival time** of glasseels from the estuary. It was assumed that all glasseels aim at some optimum arrival time, but that a great number of random factors do actually divert them from this unknown optimum. Thus, the arrival time will be normally distributed around the optimum, with an unknown spread, characterized by the two parameters *mean_arrival_time* and *spread_in_arrival_time* (mean and standard deviation).

3) **Actual number of arriving glasseels** from the estuary. In the preceding section, the average numbers arriving from the estuary were specified. The actual number arriving per time interval was taken to be a random sample from a Poisson-distribution having the average specified in the preceding section as its expectation. This Poisson-distribution corresponds to the log-transform of the historical data used in Dekker, 1986. Tuning of the models and generating the output was done on the mean of 10-1000 Monte Carlo runs. The number of Monte Carlo runs was taken as the minimum having no significantly differing results from much bigger numbers.

4) **Migration delay** just in front of the sluices. It is assumed that the actual migration delays in the vicinity of the sluices. This delay might be determined by factors controlled by the glasseel itself (e.g. physiological adaptation to changing abiotic factors) or might be caused by unfavorable external factors (e.g. high water velocities in the sluices making the swimming effort little successful). Thus, two alternative modules were developed:

4I) **Internal factors** control the delay. In this situation, the moment the migration continues will depend on the arrival time of the glasseel, and thus each group of glasseels with the same arrival time was simulated separately. The adaptation was assumed to start slowly, to peak around some average, and to finish again slowly, quantified in a Verhulst-function with parameters *mean_adaptation_duration* and *adaptation_spread* (mean and interval to adapt the second or third quartile).

4E) **External factors** control the delay. In this situation, all available glasseels get the same chance of success. It was assumed that each glasseel should acquire a minimum number of successes, to pass the sluices. This minimum was arbitrarily chosen to be 1, 3 or 10, generating three different versions of this model. This number is referred to as *number_of_bottle_necks*. The chance per glasseel of successful passage of a single bottle neck was named *passage_chance*.

In cases with *number_of_bottle_necks*> 1, it was arbitrarily decided to force glasseels to wait til the end of a successful interval, before the next bottle neck could be tried. This assumption corresponds to the notion of a very fatiguing bottle neck passage, but with the longest time intervals it might force a somewhat irrealistic delay.

The different model options will be coded as 4I (internal) and 4E1, 4E3 and 4E10 (external, # bottle necks) in the following.

Results

The model building blocks described in the previous paragraph were written out in a Pascal program, and run on a micro-VAX-2 under VMS-4.3. Unknown parameters were fitted to match the results of the historical data analysis (Dekker, 1986, hour-effect) as closely as possible, using a discrete Newton-Raphson algorithm. Results are presented as estimated parameter values, and as predicted quantities of glasseels expressed as fractions of the total immigration per night. Estimated variances and covariances are derived from finite difference quotient approximations.

Table 1 presents the parameter estimates for most of the model options. Since some of the options did not influence the outcomes significantly, not all results are presented in full detail. The choice of the time interval turned out to be rather irrelevant; thus, a 1 hour interval was used throughout. Likewise, the number of Monte Carlo runs had no effect down to as few as 10 runs in some cases. Again, a uniform size of 50 was preferred.

Figures 1 through 4 present the simulated data more comprehensively. Figure 1 shows that, under the assumption of an internal delay mechanism, the observations are best simulated when arrival peaks early in the evening, has nearly stopped around midnight, while the pass through really starts around midnight, and peaks in the late night. Using the external control assumption (fig 2-4) produces almost the same picture, if the *number_of_bottle_necks* = 3. With a greater *number_of_bottle_necks*, arrival moves towards the afternoon, while a smaller number shifts the arrival to the mid-evening. Accordingly, many bottle_necks retards the pass through to late night.

Discussion

In the current study, the hypothesized immigration delay of glasseels in front of the sluices at Den Oever was simulated. First we consider the simulation model adequacy, then the relevance to glasseel studies.

The simulation models used were purposely constructed from as simple assumptions as possible. However, almost no information on actual quantities and relationships is available. Thus, the present assumptions should be considered as first guesses.

Firstly, the model assumptions have been selected to be simple, but realistic. In retrospect, we have some doubts whether analytical derivations of deterministic models instead of Monte Carlo simulations would not have derived the same results much more cheaply. But this would not have affected the outcomes seriously.

The normally distributed arrival times seem reasonable in having a peak in the evening, coming to zero before and afterwards. However, it is rather dubious whether this function should have been chosen symmetrically, i.e. the incline before the peak taking exactly the same time as the decline afterwards. In fact, using model option 4E10, estimates indicate that arrival peaks around 15.00 in the afternoon. This result undoubtedly is an artefact caused by the historical sampling scheme: since afternoon samples never catch any glasseels, no samples have historically been taken at this hour; thus, there was no penalty on assuming non-zero catches in the afternoon. Obviously, a rapid incline in the early evening, and a gradual slowing down of the arrival would have been more probable.

The keystone of the simulations was the delay mechanism. Since this simulation study precedes field experiments, absolutely no information was available on relevant characteristics of the delay mechanism. Thus, two classes of delay mechanisms (internally and externally controlled) were tried. For externally controlled delays, with several bottle_necks, it was decided on almost no grounds to consider the passage of only one bottle_neck per time interval. This assumption forced long delays in cases with many bottle_necks, thereby converging the internally and externally control mechanisms. Probably, externally controlled pass through without forced delays would have covered the scope of possible models better.

At the bottom line, we note that studying several model options and wide ranges of parameter values resulted in 4 figures, which essentially indicate the same outcome: glasseel arrival probably does not peak around midnight, but early in the evening, and pass through late in the night.

Finally, turning towards the interpretation of glasseel statistics, it is noted that simulation studies can not reveal the actual truth; merely, they can show alternative interpretations do explain observations equally well. The Den Oever time series covers more than half a century, with numerous publications based on it. The classical interpretation of the daily catch curve is, that glasseels concentrate their migration on fresh water discharging sluices (Deelder, 1952, p 204), peak their passage around midnight (Deelder, 1952, p 197), and hide in or near the bottom as soon as they have entered the fresh water system (v. Heusden, 1943).

This paper claims that exactly the same observations can be interpreted more simply, by assuming migration delays just in front of the sluices. If glasseels concentrate at any sluice expelling inland water (salt or fresh), principally arriving early in the evening, but delaying their pass through just in front of the sluices (resulting in increased densities of up to tenfold the initial density) till the late night, after which they continue their migration (i.e. no increased density at the fresh water side of the sluices), all observations have been covered equally well. However, the consequence of this alternative interpretation is, that - since delay intervals may vary in length - monitoring the standing densities in front of the sluices can not adequately reflect the actual migration intensity.

Obviously, actual field experiments are required. Monitoring glasseels in front of fresh water discharges which can not be passed by glasseels (e.g. water overflow systems) - either by catch per unit effort techniques or by dilution of marked population essays - might give some clue to the actual arrival time, and thus indirectly of the actual delay of glasseels during the night.

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Table 1.

Estimated parameter values for all simulated models.

model option	4I	4E1	4E3	4E10
mean_arrival_time	18.21 ± 0.02	20.42 ± 0.01	19.37 ± 0.01	15.07 ± 0.02
spread_in_arrival_time	3.16 ± 0.02	3.55 ± 0.02	4.19 ± 0.02	5.06 ± 0.02
mean_adaptation_duration	7.16 ± 0.14			
adaptation_spread	2.42 ± 0.27			
numer_of_bottle_necks		1	3	10
passage_chance		0.23 ± 0.0	0.37 ± 0.0	0.58 ± 0.0

Figure 1

Simulated results on arrival frequency, standing density and pass through using model option 4I, i.e. internal control.

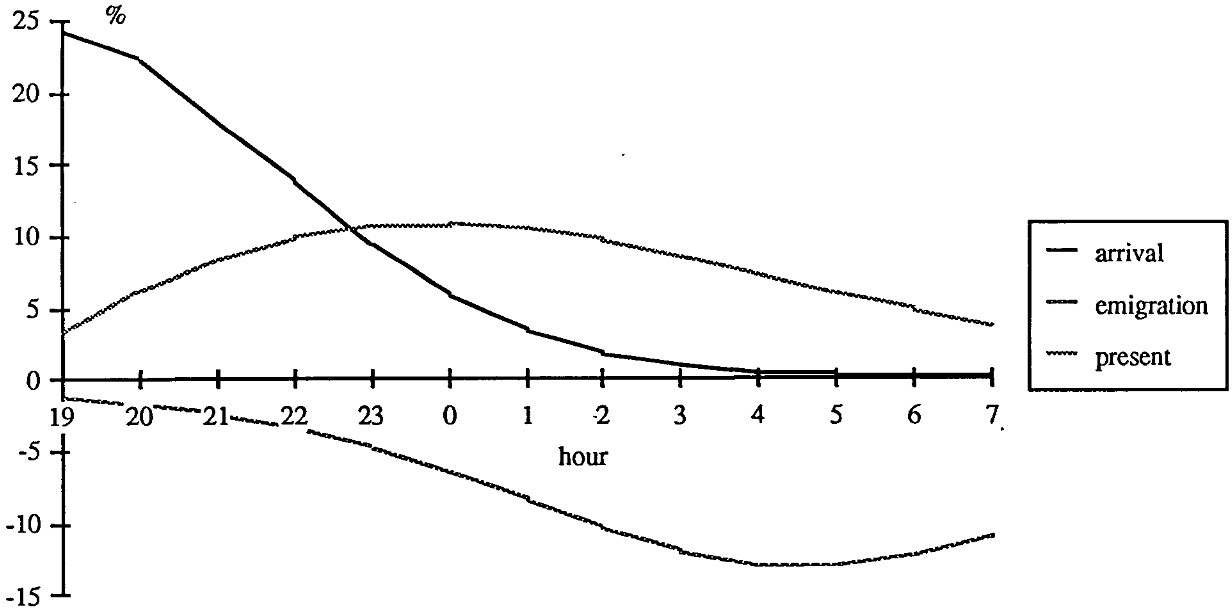

Figure 2

Simulated results on arrival frequency, standing density and pass through using model option 4E1, i.e. external control, with only one bottle neck to be passed.

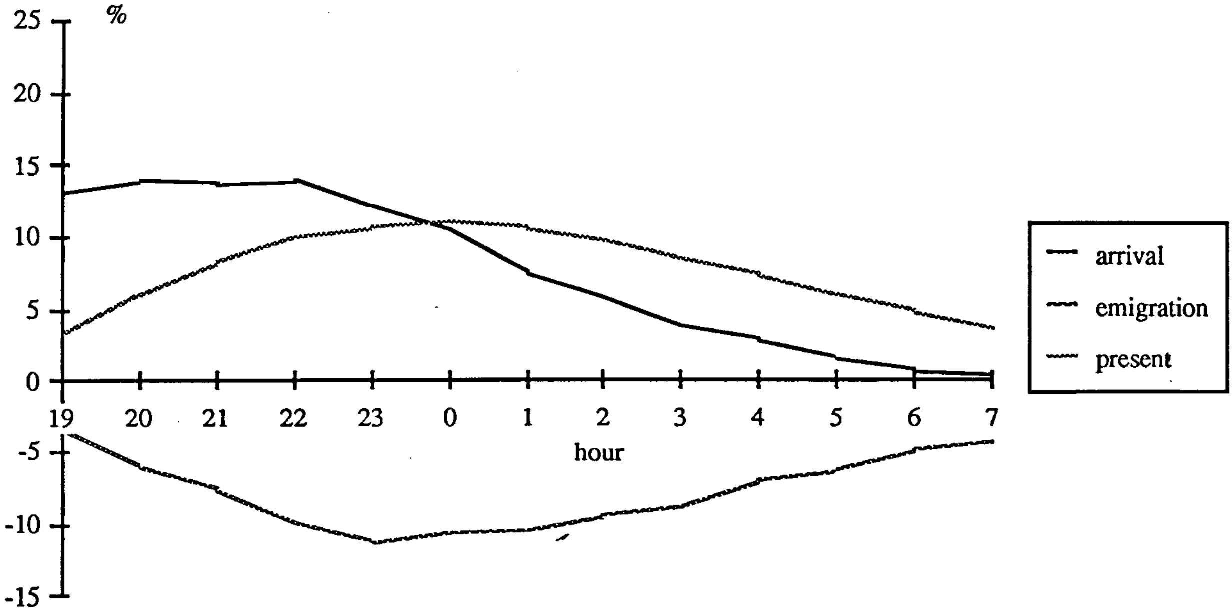

Figure 3

Simulated results on arrival frequency, standing density and pass through using model option 4E3, i.e. external control, with three bottle necks to be passed.

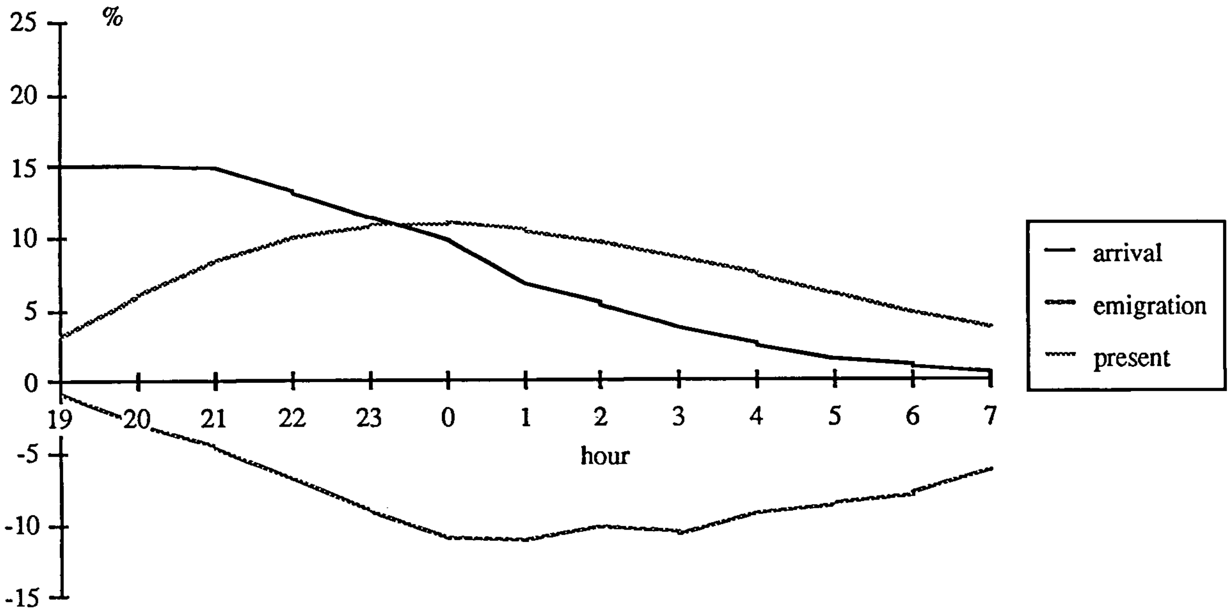

Figure 4

Simulated results on arrival frequency, standing density and pass through using model option 4E10, i.e. external control, with ten bottle necks to be passed.