A109

EFFECTS OF PCBs, PCDDs AND PCDFs ON REPRODUCTIVE SUCCESS AND MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL PARAMETERS IN CHICKS OF THE COMMON TERN (*Sterna hirundo*)

PART 1: FIELD STUDY

A joint research performed in 1991/92

G. Rossaert[1], S. Dirksen[2], T.J. Boudewijn[2], P.M. Meire[3], T. Ysebaert[1], E.H.G. Evers[4], P.L. Meininger[5]

1 Universiteit Gent, Laboratorium voor Oecologie der Dieren, Zoögeografie en Natuurbehoud, K.L. Ledeganckstraat 35, 9000 Gent, Belgium.
2 Bureau Waardenburg bv, P.O. Box 365, 4100 AJ Culemborg, The Netherlands
3 Institute for Nature Conservation, Kiewitdreef 3, 3500 Hasselt, Belgium
4 Rijkswaterstaat, Tidal Waters Division, P.O.Box 20907, 2500 EX Den Haag, The Netherlands
5 Rijkswaterstaat, Tidal Waters Division, P.O.Box 8039, 4330 AK Middelburg, The Netherlands

January 1993

Universiteit Gent report RUG-WWE nr. 35

Bureau Waardenburg report nr. 92.35

Institute for Nature Conservation report nr. 93.06

CONTENTS

SUMMARY

In 1991, an integrated ecotoxicological project on possible effects of PCBs, PCDDs and PCDFs on common terns (*Sterna hirundo*) in Dutch and Belgian coastal and intertidal wetlands was carried out. In this project ecological field studies on food, feeding and breeding biology were carried out alongside chemical and toxicological laboratory studies. The latter will be presented elsewhere (Murk et al. 1993), while the ecological studies are presented in this report.

Colonies were selected using several criteria: the polluted estuaries of Rhine / Meuse and Scheldt should both be included, the colonies should cover a range of pollution levels, feeding grounds should be rather homogeneous, etc. The eight colonies selected were: Saeftinge, Terneuzen and Zeebrugge as a gradient along the Scheldt towards the North Sea; the Prinsesseplaat representing the Oosterschelde; Slijkplaat and Westplaat as a two-step gradient of Rhine and Meuse towards the North Sea; Griend representing the Wadden Sea and Zeewolde as a relatively clean freshwater location.

Food and feeding areas of all colonies were qualitatively assessed in the period of egg-laying and in the young-rearing period. Especially clupeids (herring and sprot) were important food species in the colonies along salt water, while in fresh water not only fish but also emerging Chironomids were taken.

In all colonies as many clutches as possible were checked once every two or three days. Eggs and young were marked and measured, and the fate of eggs and young was established as precisely as possible. In all colonies 15 second eggs from 3-clutches were collected for further incubation and analysis in the laboratory.

The terns breeding results in all colonies were negatively affected by the extremely unfavourable weather conditions in spring 1991. In two colonies flooding caused an almost complete failure, while a third one was affected by Oystercatcher predation.

The breeding biology data were analysed for differences between colonies, and the possible explanations for differences evaluated. Although contaminants as a cause for differences got special attention, other factors were taken into account as well.

Clutch size was in the species' usual range in all colonies except the Westplaat, where the mean clutch size was relatively low. Egg volume differed betwen colonies, the Westplaat again showing the lowest mean. Most colonies showed a decrease of egg volume in later clutches. The common terns on the Westplaat that did produce a 3-clutch, took a relatively long time to produce the third egg as compared to other colonies. The mean incubation period in the colonies ranged from 21 to 23.5 days. Terns in Terneuzen had the longest incubation period, probably because of the frequent disturbances on the sluices.

Hatching success differed largely between colonies. However, the factors responsible for the major losses in some of the colonies were not related to contaminants: flooding, other direct and indirect effects of bad weather and predation took quite some eggs in some of the colonies. In colonies where these 'catastrophic events' did not occur, the hatching rate of eggs varied between 0.58 (Westplaat) and 0.96 (Zeebrugge). However, these differences were probably also mainly caused by effects of predation on a smaller scale and, to a lesser extent, flooding. Analysis of the proportion of eggs that failed to hatch (although completing the whole incubation period) revealed that the absolute numbers were low and the differences between colonies were small (range: 5.3% - Terneuzen to 8.2% - Westplaat). This means that, excluding effects of predation and flooding, over 90% of all eggs would have hatched in all colonies. No chicks with morphological aberrations were found.

Finally, it is concluded that no reduction of breeding success because of organochlorine pollutants could be established, although some features in the breeding biology in a few colonies might indicate that these compounds do have some (relatively small) impact. This should be analysed further in combination with the chemical and toxicological data.

1 INTRODUCTION

During this century large quantities of all sorts of pollutants have been brought into the environment as a consequence of human activities. Especially rivers have become the dirty drains of our society, although of course other routes of distribution are important as well. The Netherlands comprise the deltas of several European rivers: Rhine, Meuse, Scheldt and Eems. All these rivers are bringing large quantities of pollutants to and through the Dutch part of their basin and into estuarine and marine habitats. Therefore, large pollution problems have to be faced, and tackled, in various Dutch wetlands.

At present, in many cases the types and quantities of these pollutants are known, but the effects on species and ecosystems are only partly known and understood. However, while research continues, policy has to be made and action to be taken. In this context an integrated ecotoxicological project has been set up: some relatively new lines of research have been carried out in a rather applied set-up, not only to obtain more insight into the effects of organochlorine pollution on wildlife in estuarine and coastal habitats but also to get a tool which can soon be used for risk-assessment, as well as for monitoring future changes in the presence and in the effects of these pollutants.

One of the methods presently used to assess the ecological development of aquatic systems in the Netherlands is the so-called 'AMOEBE'-approach (Ten Brink & Hosper 1989). The numbers of a species are compared with their numbers in a reference year. On the other hand, the presence of chemicals is monitored in water, sediment and several biota (e.g. shrimps, mussels, fish; ICONA 1992). In order to evaluate the effects of pollutants on the development of numbers of the 'AMOEBE'-species, research aiming at establishing dose-effect-relationships for both ecological and toxicological parameters is essential. Such species can be used for monitoring of both contaminant levels and effects. Indicator-species on an integrated level are still needed, not only in estuarine and coastal habitats (LAC 1990).

Following the needs mentioned above, the general aim of the project was to investigate whether persistent organochlorine pollutants cause negative effects on bird reproductive success in Dutch estuarine and coastal habitats. The project should result in data on these effects in areas of different degrees of contamination, and enable a risk-evaluation of the impact on higher organisms of the various compounds concerned.

Fish-eating birds and raptors are well-known for being vulnerable to contamination of aquatic and terrestric habitats with organochlorine pollutants. Already in the sixties the toxic effects of organochlorine pesticides were established in populations of species of several systematic groups, e.g. cormorants, raptors, ducks, gulls and terns. These pesticides and compounds like PCBs (polychlorinated biphenyls), PCDDs (dioxins)and PCDFs (furans) have had, and in some areas still have, a heavy impact on bird populations, and therefore have been studied extensively. Research on birds from the groups mentioned above has linked (some of) these contaminants with reproductive failure through several mechanisms. Eggshell thinning and subsequent breakage of eggs can be caused by DDE (Ratcliffe 1967, 1970, Anderson et al. 1969, Anderson & Hickey 1972, Koeman et al. 1972, Cooke 1979, Pearce et al. 1979, Moriarty et al. 1986, Lundholm 1987). Mainly PCBs and related compounds are held responsible for mortality of embryos and little chicks (Fox 1976, Morris et al. 1976, Vermeer & Peakall 1977, Gilbertson 1983, Kubiak et al. 1989) and morphological aberrations in chicks (Hays & Risebrough 1972, Gochfeld 1975, Gilbertson et al. 1976, 1989, in press).

In the 1960s the negative effects of pesticides on e.g. terns and eider duck (*Somateria mollissima*) populations along the Dutch coast were clearly established (Koeman et al. 1972). It took quite some time after that before the effects of PCBs and related compounds on birds along rivers, in estuaries and along the coast were investigated. Laboratory experiments with tufted ducks (*Aythya fuligula*) feeding on zebra mussels (*Dreissena polymorpha*) from two different areas clearly indicated that such effects were likely to occur (Scholten et al. 1989). An integrated ecotoxicological project on cormorants (*Phalacrocorax carbo*) breeding along the Rhine and in the sedimentation area of the rivers Rhine and Meuse recently established dose-effect relationships on an individual clutch level between levels of PCBs and both ecological parameters measured in the field (e.g. hatching success) and biochemical parameters (Dirksen et al. 1991, in prep., Craane et al. 1990, Van der Gaag et al. 1991, in prep, Van den Berg et al. in prep.). Breeding success of cormorants breeding in the most polluted area was reduced to about one third of the breeding success in relatively unpolluted areas.

It was not possible to use cormorants for research on the effects of pollutants on bird reproduction in Dutch estuarine and coastal habitats: there are only two colonies of the species along the Dutch coast (Zijlstra & Van Eerden 1991) and the birds of at least one of these colonies uses freshwater habitats for feeding as well (Lok & Bakker 1988, Dirksen et al. 1989). Therefore, another species had to be selected.

The common tern (*Sterna hirundo*) was chosen. The following criteria have been used:

* the majority of common terns are breeding and foraging in estuarine and coastal habitats;
* foraging takes place in the vicinity of the colony;
* fish is the (main) prey;
* common terns, and close relatives, are sensitive to PCBs, PCDDs and PCDFs; effects of these pollutants have been established before (Morris et al. 1976, Hoffmann et al. 1987, Kubiak et al. 1989);
* the species is well-spread over suitable habitats in The Netherlands (Teixeira 1979, Stienen & Brenninkmeijer 1992), enabling research in areas with a differing degree of contamination;
* the common tern is not listed as an endangered species in The Netherlands (Osieck 1986);
* enough colonies are available where access could be obtained to do research.

In two areas preliminary research was carried out in earlier years: Westerschelde and Haringvliet. In the Westerschelde the data obtained indicated that levels of PCBs in eggs were close to effect levels (Stronkhorst et al. in prep). On the Slijkplaat (Haringvliet) one young was found with hip displasia (Dirksen & Boudewijn 1990), a developmental aberration which can be caused by high levels of PCBs. No PCB levels in eggs were measured there.

This project aimed at assessing whether in the present situation effects of PCBs, PCDDs and PCDFs on the reproductive success of common terns could be established. Acute lethal effects on adults were not to be expected but dead birds found in unexpectedly high numbers would of course be taken for analysis as well. Eight colonies, spread over the country and in areas differing in degree of contamination were selected. This enabled a comparison of colonies in a range from 'relatively clean' to 'heavily contaminated'. In these colonies two groups of possible effects were considered: ecological and toxicological. The toxicological parameters were measured in 1-day old young from eggs that were taken from the colonies and artificially hatched in an incubator in the laboratory. The remaining eggs and other clutches were monitored individually, enabling an optimal integration between results of ecological and toxicological research. The latter will be dealt with elsewhere (Part 2: Murk et al. 1993). In this report the ecological studies will be presented.

The ecological studies included all parameters of breeding biology potentially affected by contaminants. These are: laying date, clutch size, egg volume, laying interval, incubation time, hatching success, growth of young, developmental abnormalities in young, fledging success. Together with factors like food availability, weather, predation etc. these parameters determine the final breeding success. Breeding success in the colonies has to be compared with data from other colonies, especially with those from (relatively) unpolluted areas. A detailed analysis of breeding biology data is required in order to assess the factors causing differences between colonies. Of course other factors than pollutants have to be taken into account at this point as well. Especially the phase in which losses occur and the cause of these losses provide important information on which factors mainly determine breeding success.

2 PROJECT PARTICIPANTS AND ACKNOWLEDGEMENTS

The research reported here is part of an integrated field and laboratory ecotoxicological project. The project was financed by the Ministry of Transport and Public Works, Rijkswaterstaat, Tidal Waters Division. Additional funding was provided by Rijkswaterstaat, Institute for Inland Water Management and Waste Water Treatment (RIZA); Rijkswaterstaat, Directorate Zuid-Holland; and the Belgian Institute for Nature Management. The toxicological laboratory research was carried out by the Research Institute for Toxicology (RITOX), University of Utrecht (A.T.C. Bosveld, J. Gradener, M. van den Berg), and the Department of Toxicology, Agricultural University Wageningen (A.J. Murk, A. Spenkelink, A. Brouwer), and will be reported separately as Part 2: laboratory study (Murk et al. 1993).

The three institutes and their researchers responsible for the research presented here are:
Bureau Waardenburg, Culemborg: T.J. Boudewijn, S. Dirksen;
Institute for Nature Management, Hasselt / Universiteit Gent, Laboratorium voor Oecologie der Dieren, Zoögeografie en Natuurbehoud (B): P. Meire, G. Rossaert, T. Ysebaert;
Rijkswaterstaat, Tidal Waters Division, Den Haag / Middelburg: E.H.G. Evers, P.L. Meininger.

A substantial contribution to the project was provided by:
Delta Institute for Hydrobiological Research (through the biological monitoring programme of Rijkswaterstaat): C.M. Berrevoets, R.C.W. Strucker, P. Wolf;
Rijkswaterstaat, Tidal Waters Division, Middelburg: H. Schekkerman, J. Stronkhorst;
Rijkswaterstaat, Directorate Zuid-Holland, Dordrecht: N. Antens, A.J.A. Schipperen, J. Tempelaars, M. van Wouwe;
Rijkswaterstaat, Institute for Inland Water Management and Waste Water Treatment, Lelystad: E.C.L. Marteijn, R. Noordhuis;
DLO Institute for Forestry and Nature Research: A. Brenninkmeijer, M. Klaassen;
H. Lichtenbeld, Utrecht.

The following institutions gave permission to carry out research in their area(s):
Saeftinge: Stichting het Zeeuwse Landschap: J. Neve;
Terneuzen: Rijkswaterstaat, Directorate Zeeland: W.M. Vinke;
Zeebrugge: Maatschappij van de Brugse Zeevaartinrichtingen n.v.: L. Maertens, J. Kimpe;
Prinsesseplaat: Rijkswaterstaat, Directorate Flevoland, section Delta: D. Fluijt, J. Visser;
Slijkplaat: State Forestry Service: A. Wesdorp;
Westplaat: Stichting het Zuidhollands Landschap: J. van der Berg, M. Hoekstein, J. Timmerman, and Rijkswaterstaat, Directorate Zuid-Holland: S. Bonte, A. Jans;
Zeewolde: Rijkswaterstaat, Directorate Flevoland;
Griend: Vereniging tot Behoud van Natuurmonumenten in Nederland.

The Dutch Ministry of Agriculture, Nature Management and Fisheries (A. Binsbergen), and the Belgian Ministry for Agriculture and Fisheries gave permission to collect eggs for the laboratory breeding experiment.

The following persons assisted in the field on one or several occasions:
M. Arends, H. van de Berg, J. van der Berg, B. Bosveld, H. van Buel, N. De Regge, J. Dragt (mv. Tille), A. Erkman, F. van Essen, A.van Gilst, J. Gradener, R. Griffioen, C. van der Guchte, M.Hoekstein, J. Klunder (mv. Tille), C. van der Lijcke, S. Lilipaly, G. Meijer, D. van der Molen, A.J. Murk, J. Oldenburg, F. de Roder, F. Schepers, A. Smaal, A.J.M. Smits, M. van der Spek, N.D. van Swelm, A. bij de Vaate, H.W. Waardenburg, J.A.W. de Wit, A. van Wouwe, J. Zeeuwen.

J. van der Horst (Bureau Waardenburg) prepared several maps.

Table 3.1 Number of colony-visits for food and feeding and for breeding biology.

colony	food & feeding	breeding biology
Zeewolde	10	22
Saeftinge	8	20
Terneuzen	24	56
Zeebrugge	16	28
Kl.P. Plaat	4	11
Gr.P. Plaat	6	20
Westplaat	16	23
Slijkplaat	13	19

3 MATERIALS AND METHODS

3.1 Eggs and breeding: field procedures and visits

Observations of the colonies started late April-early May 1991 during the pair-formation phase (see Nisbet 1977) and continued through chick fledging (second half of July). Nests were marked with a numbered wooden stake placed within 30 - 50 cm of the nest. In most colonies all nests were marked. Only in the colonies of Zeebrugge, Slijkplaat and Griend a selection of the nests was made. In Zeebrugge the colony was crossed during every visit and every clutch found was marked. The last nest was marked on 8 June. Although after that date the Zeebrugge colony continued growing, no additional nests were marked.

The eggs were marked with a number (1,2,3) corresponding to the sequence of laying or with a letter (A,B,C) if the sequence was unknown. Of every newly laid egg the length and the width was measured with a sliding calipers to the nearest 0.1 mm. During colony visits a standard form was used on which for each nest the data of the previous visit were printed. Thus, any changes in nest contents were immediately established. New eggs or young could be marked and measured, disappeared eggs or young were searched for.

During the peak of the first wave of egg-laying the nests were checked nearly daily. Before and after the peak of laying the colonies were checked less frequently. During the period of hatching the colonies of Saeftinge, Terneuzen and Zeebrugge were checked nearly daily. The other colonies every two days. Table 3.1 summarises the number of visits to each colony. In general the colonies were checked before 12.00 or after 15.00 h. In order to reduce disturbance and thermal or cold stress of both the eggs and the chicks, the duration of the visits did not exceed 2 hours and in case of bad weather (rain, high temperatures) the duration was shortened or the visit was cancelled. During each visit the following information was collected: number of eggs, damage and/or mortality of eggs (with the cause if possible), and date of hatching.

Of every colony about 15 eggs were collected and incubated in the laboratory. Only the second egg of 3-clutches of which the exact laying date of every egg was known, were collected. The eggs were collected after at least 7 days of incubation.

At the end of the breeding season the exact position of the nests was recorded with a 'theodolite' in the colonies of Saeftinge, Terneuzen, Westplaat and Zeewolde.

3.2 Eggs and breeding: data treatment

3.2.1 Laying date

To index the laying date of a clutch, the date the first egg appeared was used. When the excact laying date of at least one egg was known, the laying date of the first egg was calculated by means of the mean laying period (see 3.2.4). For clutches that were already complete at the time of finding, the laying date was calculated by subtracting the mean incubation period (see 3.2.5) from the hatching date of the first hatched egg. When no eggs hatched the mean laying date could not be determined and the clutch was not included in the analysis of the laying date.

The date of laying can have an effect on several parameters. To analyse this effect, the laying date was classified into 5-day periods, starting with period 1 (1 - 5 May) up to period 15 (13 - 17 July). To overcome the small number of cases in some periods in a number of colonies, clutch initiation dates were also classified as 'early', 'peak' and 'late'. This was based of the frequency distribution of the number of clutches. Clutches started during the first wave of laying were classified as peak clutches. Clutches started before and after the first wave were classified as early and late clutches respectively.

Although in the colonies of Zeebrugge and Slijkplaat a selection of nests was made, we consider the daily number of nests found in these colonies to be proportional to the daily number of clutches started. For the selection made on Griend this was not possible.

3.2.2 Clutch size

To determine the overall clutch size, all clutches were used. As the nests were marked individually and the contents was recorded over a large number of visits, underestimation of clutch size due to the fact that one-egg or two-egg clutches might not yet have been completed or underestimation due to predation, was minimised in most colonies.

In order to estimate clutch size in relation to the period of laying, in some colonies (Saeftinge, Terneuzen, Zeebrugge) a number of cases were excluded. These included clutches (mostly three-egg clutches) of which the egg-laying dates were not known.

Due to the fact that in the colony of Zeebrugge not all nests were studied, and that the nests were difficult to find, one-egg clutches might have been overlooked. This might result in an overestimation of clutch size.

The colony of the Kleine Prinsesseplaat was subjected to heavy predation resulting in a resetlement of the birds to the colony of the Grote Prinsesseplaat. Because this predation took place in a short time span, and partially during colony visits (see 7.1.4) clutch size was probably underestimated in this specific case.

The data of the colony of Griend were not included in the statistical analysis as the one-egg clutches of this colony were not monitored.

3.2.3 Egg volume

The volume of the eggs was calculated using the formule of Hoyt (1979):
volume (ml) = 0.509 x length (mm) x $(\text{width})^2$ (mm^2)/1000

3.2.4 Laying period

Laying period of the eggs was defined as the time (days) the bird needed to lay the eggs. In case of 2- and 3-clutches the laying period of the second egg, was defined as the laying date of the first egg through the laying date of the second egg. The laying period of the third egg of the 3-clutches was defined as the laying date of the second egg through the laying date of the third egg. The total laying period of the 3-clutches was calculated by adding the laying period of the second and the laying period of the third egg, or if the laying date of the second was not known by subtracting the laying date of the first egg from the laying date of the third egg.

Laying period was only calculated if the excact laying dates of both eggs were known.

3.2.5 Incubation period

Wiggins and Morris (1986) defined the period of effective incubation as the day following clutch completion through the day prior to the hatching of the first chick. This choise was based on the observation that full incubation was disrupted upon the hatching of the first chick. Although during this study no specific observations were done with regard to the incubation, several birds were seen incubating from the first egg on. According to this observation we defined the period of incubation of every egg as the day of laying through the day of hatching.

Incubation period was only calculated if the excact laying and hatching dates were known.

3.2.6 Fate of eggs, hatching success

All possible information concerning the fate of eggs (hatching vs. not hatching, causes of not hatching / disappearing of eggs) was gathered. Damaged eggs were checked for signs of predation and other causes of destruction. Empty eggshells could either be predated or hatched: normally this was easy to establish. When eggs had disappeared the nest and surroundings were searched for eggshells or fragments. By the time young could have disappeared, the surroundings of nests were searched any way for all young possibly present in the colony.

Eggs did not hatch because of the following (categories of) factors:

1. egg with dent
2. cracked, cause unknown
3. cracked by research activities
4. egg destroyed and removed by researchers
5. egg disappeared, cause unknown
6. egg pecked by predator
7. eggs trampled by young
8. egg not hatched (after completing incubation period)
9. egg flooded away

10. egg displaced
11. embryo died while hatching
12. nest abandoned
13. egg sampled for laboratory breeding experiment
14. covered with sand
15. whole nest disappeared

These categories were taken together as follows:

A predation (6)
B damaged, cause unknown (1, 2) or very rare (7, 2 eggs in total)
C disappeared, displaced, cause unknown (5, 10)
D washed away, covered with sand, nest disappeared (9, 14, 15)
E failed to hatch (8, 11, 12)
F sampled or damaged by researchers (3, 4, 13)
G unknown

Hatching success was scored in the following categories:

0. Not hatched. The egg had disappeared or was damaged before incubation could have been completed, or was still in the nest at least several days after it should have hatched.
1. Hatched. Young observed, and/or numbered eggshells clearly indicating hatching, were found.
2. Unknown because egg/young disappeared around the day it should have hatched.
3. Unknown because nest was not observed around the day the egg should have hatched.

Following Nisbet et al. (1990), we did not use the Mayfield method of computing hatching and fledging success. Nisbet et al. argued that this method is 'frequently inappropriate for colonial waterbirds, because chick mortality in these species is irregular or concentrated into the early part of the fledging period'. The same holds for many of the causes of egg mortality in tern colonies (mass predation is often linked to bad weather, flooding).

3.3 Young birds: field procedure and visits

During visits in and after the hatching period the whole colony area was searched for young terns. Young were marked and the following measurements were taken: wing, total-head, weight. All young were checked for any developmental aberrations (feet, eyes, bill, wing). Small young were marked with a little picric acid and put back in their nest. When they were large enough a metal ring was put on. After the peak hatching period (see 3.1) colonies were less regularly visited. The main objective of this study was investigating hatching success, as it was known beforehand that fledging success would be difficult to measure in this precocial species.

3.4 Young birds: data treatment

Because of time-budget problems, the data on young birds will not be presented in this report.

3.5 Foraging behaviour: field procedures and visits

Due to the differing circumstances around the colonies, the quality and the quantity of the data on food and foraging is different for each colony. However, the data enable at least a qualitative description for all colonies.

In the period shortly before egg-laying the surroundings of the colony were checked for terns. Wherever possible, observations on food, prey selection and feeding behaviour were made. These observations started in the second half of April. After the onset of egg-laying, observations were made in the colonies, from a hide or a car. The number of visits during which observations were done with regard to foraging behaviour are presented in table 3.1.

The food choice was mainly studied by observing the prey carried in the bill by adults with binoculars or a telescope. Outside the colony this was done for prey caught at the place of foraging. Within the colony prey were brought for display or to feed the chicks. Species and size of prey, nest-identification, hour and circumstance (prey delivered to adult on nest, during courtship behaviour, for feeding the young,...) were noted. In addition, the colonies were checked for rejected prey items during every visit.
All these species with the exception of the flat-fishes were identified at species level and their length was measured.

3.6 Foraging behaviour: data treatment

The results of the observations of feeding sites were summarised on a map for every colony. Analysis of prey selection was done by comparing prey composition of different periods (period before and period after hatching of the first egg) and by comparing prey composition of the adult with the prey composition of the young.

In several occasions prey captured and/or brought to the colony could not be identified (either the prey weas eaten before it could be identified; the individual with the prey item landed behind vegetation, etc.). As our "speed" of identifying the prey items increased through the breeding period, the proportion of the unidentified prey decreased. As the unidentified prey items were not unknown species, we may assume the class of unidentified prey to have the same proportional composition as the class of identified prey. Consequently no error was made by excluding these observation from the analysis.

3.7 Statistical analysis

Statistical analysis was carried out using SPSS/PC+ 3.1 (Norusis 1986). For the analysis of the distribution of clutch size and food composition the X^2-test was used. Parameters of which the data were normally distributed, were analysed by means of a one, two or three way analysis of variance (Anova) (mean laying date and egg volume). Multiple comparison among category means was done with the Duncan's multiple range test. Some parameters had to be transformed (log10+1 transformation) before using Anova. Data not being normally distributed were analysed using nonparametric tests (Kruskall-Wallis one way Anova or Mann-Whitney U test). The assumption of normality was tested with the Kolmogorov-Smirnov test. A posteriori-tests in case of non-parametric tests were calculated according to Connover (1980).

4 WEATHER CIRCUMSTANCES DURING BREEDING SEASON 1991

4.1 Introduction

Climatic circumstances during the breeding season are generally an important factor determining the breeding success of coastal breeding birds. Not only temperature, wind and precipitation as such, but also the combination of these parameters is important. In this chapter the most relevant weather data from the period 1 May-31 July 1991 have been summarised.

4.2 Methods

Data on daily precipitation have been extracted from monthly reports on precipitation in the Netherlands of the Koninklijk Nederlands Meteorologisch Instituut (KNMI 1991a, 1991b, 1991c). Because of large regional differences, for all seven colonies studied the closest observation station for precipitation was selected (colony name and distance to weather station in parentheses): Harlingen (Griend 13.5 km), Zeewolde (Zeewolde 2 km; normal precipitation per 10-day periods are from Harderwijk), Oostvoorne (Westplaat 4.5 km, Slijkplaat 12.5 km), Tholen (Prinsesseplaat 3 km), Rilland (Saeftinge 8 km), Terneuzen (Terneuzen 0 km); Cadzand (Zeebrugge 12 km).

Data on temperature and wind speed have been extracted from monthly reports on the weather in the Netherlands of the Koninklijk Nederlands Meteorologisch Instituut (KNMI 1991d, 1991e, 1991f). Although there are some regional differences, presentation of data on temperature and wind has been limited to only two sites: De Kooi (Northern Netherlands) and Vlissingen (Southwest Netherlands).

4.3 Results

4.3.1 Temperature and wind

Figure 4.1 shows the mean daily temperature in May-July 1991, figure 4.2 the mean wind speed, and figure 4.3 the combination of these two: "the wind chill factor" (based on human skin).

With a mean temperature of 10 °C, May 1991 was one of the coldest May months of this century. Night frost occurred on a large scale during several days until late in the month. There were 153 hours of sunshine, compared to a mean of 205 hours.

June 1991 was extremely wet, very cool and exceptionally cloudy. Due to this combination of precipitation, temperature and sunshine, it is considered the "worst" June of this century. It was one of the coldest June months of the century, with extremely little sun (119 hours compared to 207 hours normally. July 1991 was warm, sunny and generally dry.

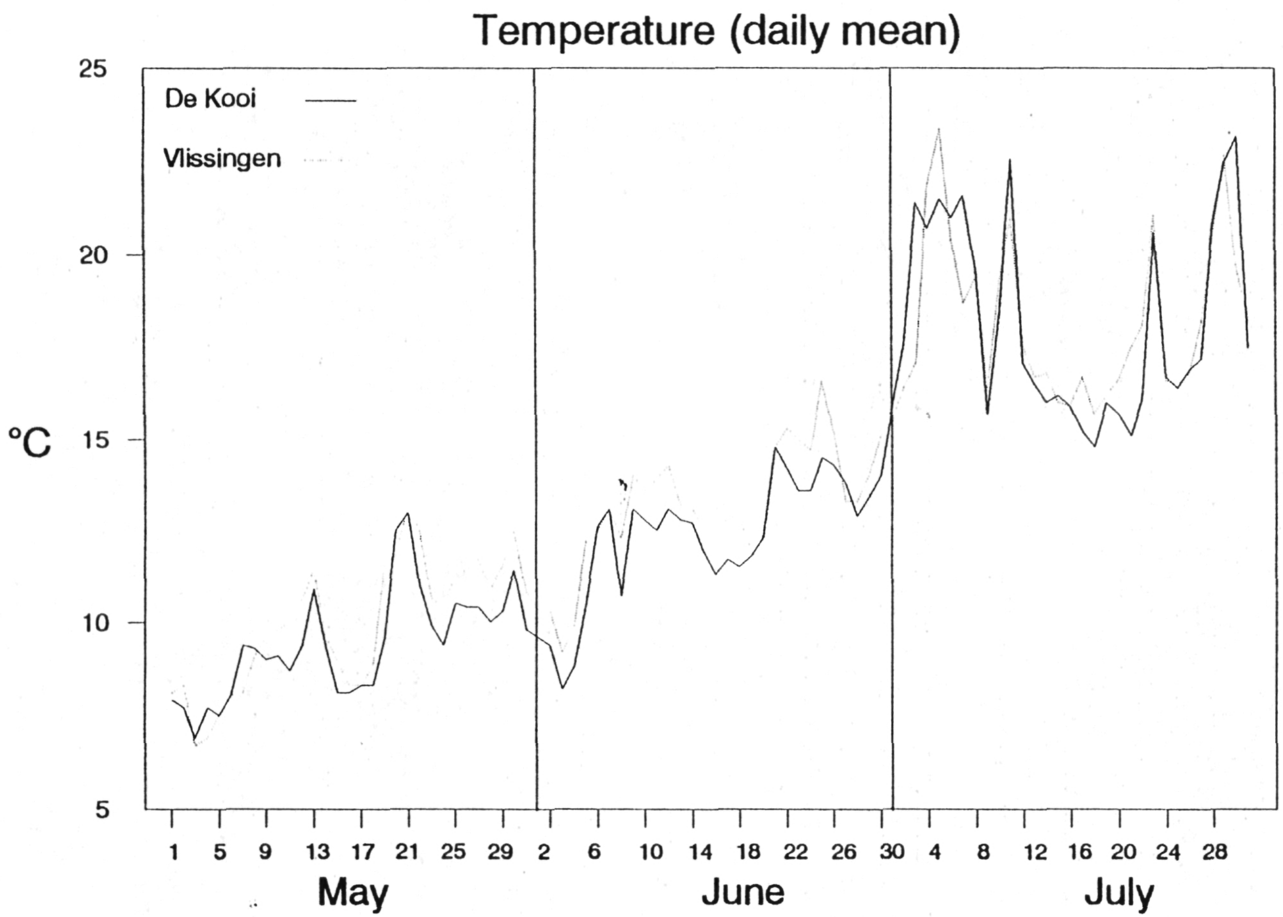


Figure 4.1 Mean daily temperature (°C) in May - July 1991 at De Kooi and Vlissingen.

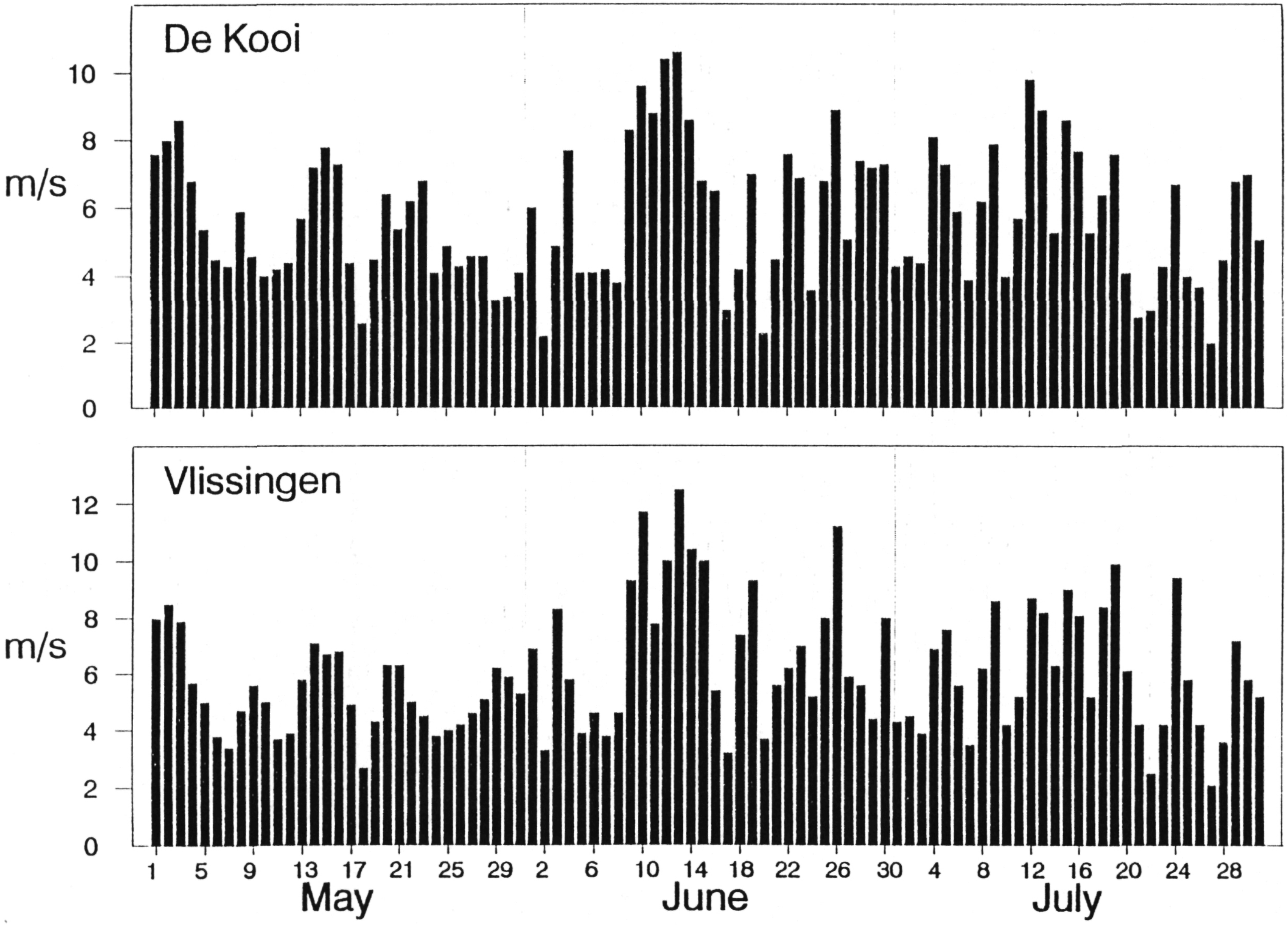


Figure 4.2 Mean daily wind speed (m/s) in May - July 1991 at De Kooi and Vlissingen.

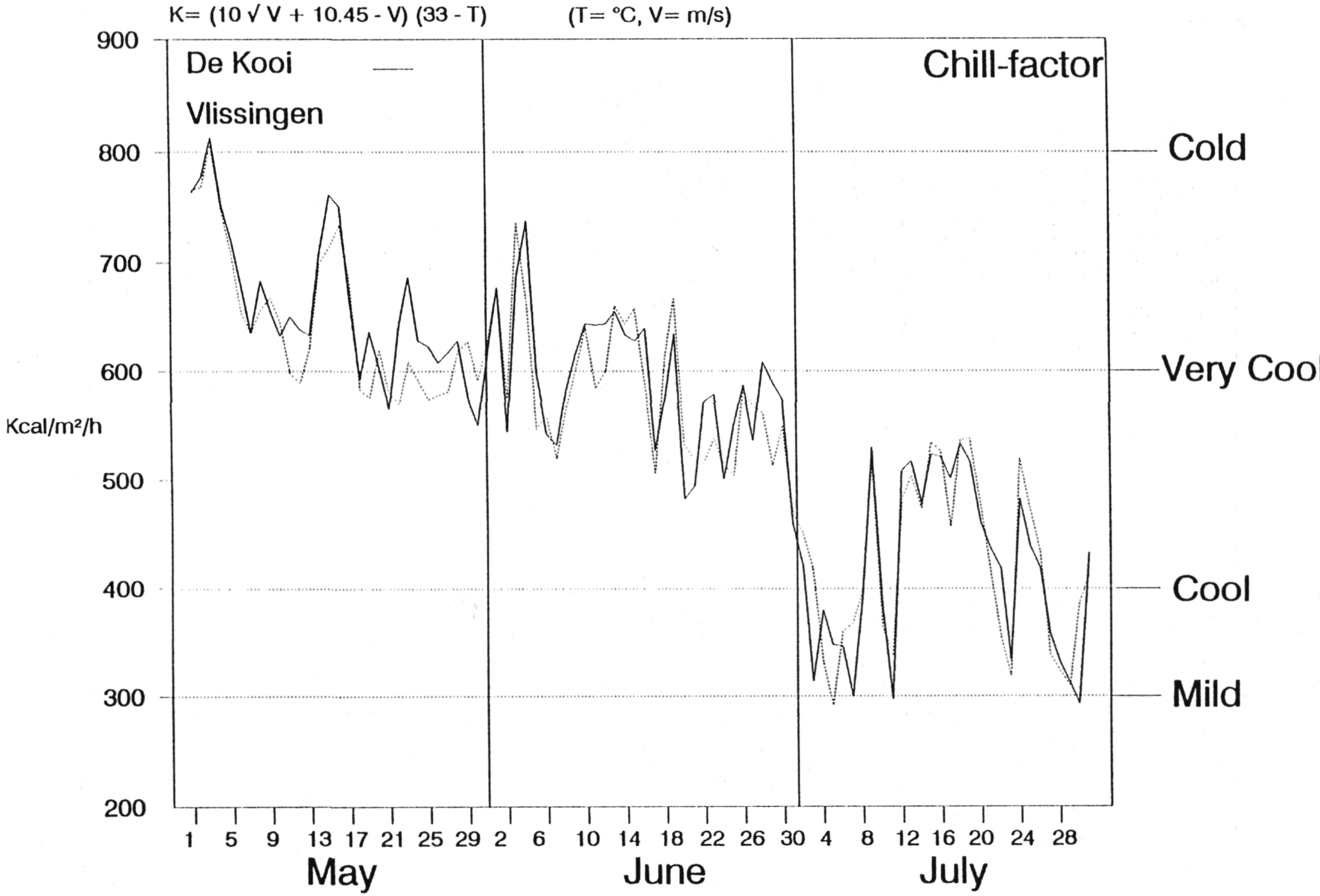


Figure 4.3 Mean daily wind chill factor (Kcal/m^2/h) in May - July 1991 at De Kooi and Vlissingen.

4.3.2 Precipitation

Figure 4.4 shows the daily precipitation in May-July 1991 for seven stations. May 1991 was relatively dry: total precipitation during this month (mean of all registration sites in the Netherlands) was 31 mm, compared to 52 mm normally.

With a mean of 122 mm of precipitation (normal 62 mm), June 1991 was the wettest June of the century. Near most common tern colonies there were several days with more than 10 mm of rain. The combination of heavy rains, often in heavy showers or for long periods and on succeeding days, in combination with low temperatures and strong winds, resulted in most unfavourable hatching circumstances for young birds. In several colonies this resulted in considerable mortality of chicks. In some colonies, situated on little permeable soils (e.g. Prinsesseplaat, Zeewolde), heavy showers resulted in a layer of up to 10 cm of water which sometimes took days to disappear. This resulted in massive losses of eggs and chicks.

Strong winds, in combination with spring tide, caused additional losses of nests in Saeftinge and - to a lesser extent - on the Slijkplaat.

Although July 1991 was generally dry, there were several days with heavy showers, particularly during the first half of the month.

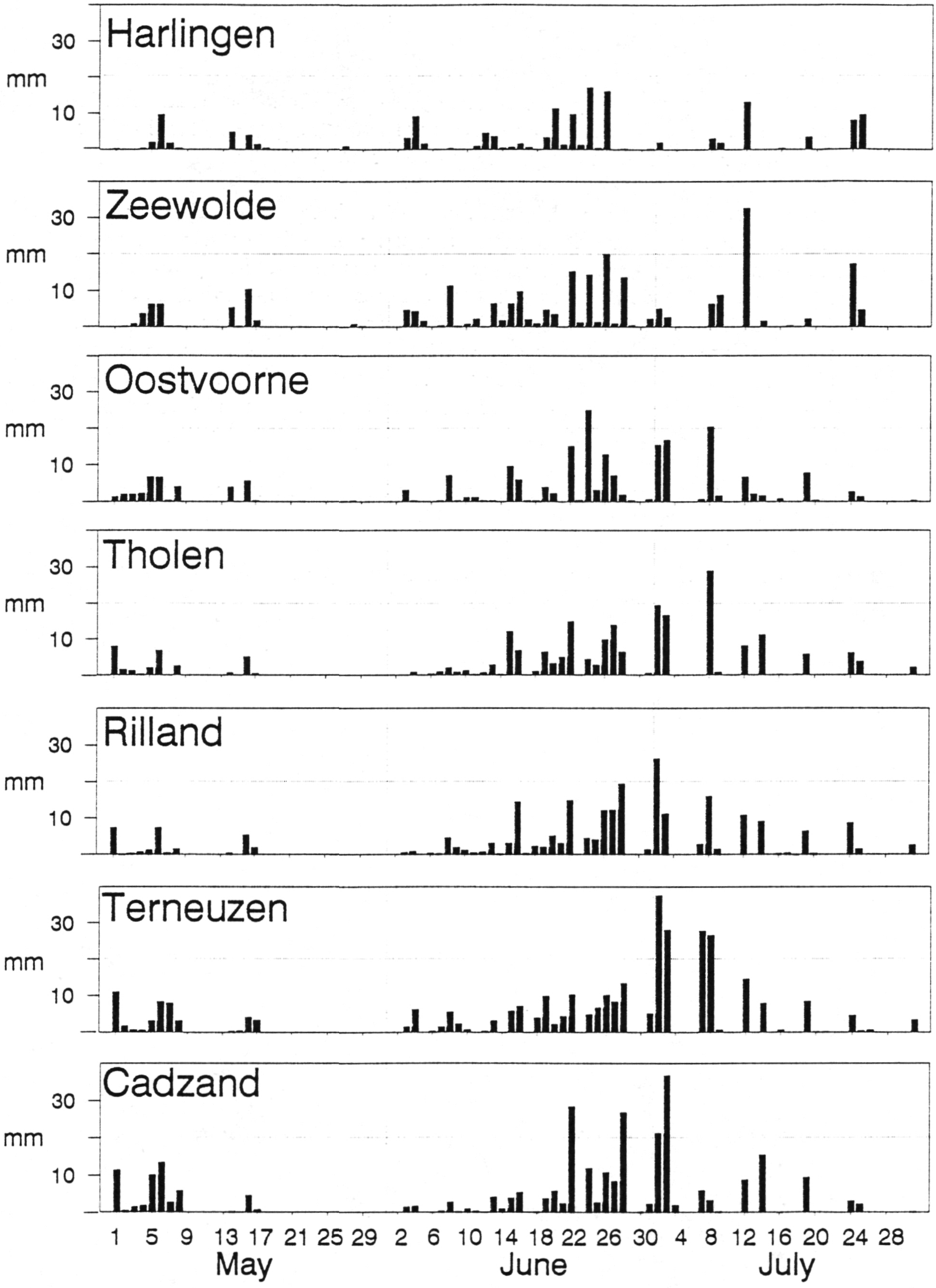


Figure 4.4 Daily precipitation (mm) at seven stations in May - July 1991.

Figure 5.1 Location of the colonies of 1: Zeewolde, 2: Griend, 3: Saeftinge, 4: Terneuzen, 5: Zeebrugge, 6: Grote Prinsesseplaat, 7: Kleine Prinsesseplaat, 8: Westplaat, 9: Slijkplaat.

5 STUDY AREAS

5.1 Selection of colonies

The study area comprised Dutch and Belgian estuarine and coastal waters. Along the coast of both countries, areas with different characteristics regarding ecology, landscape and pollution can be found. Colonies were selected using the following criteria:

1. Rhine / Meuse and Scheldt are the main rivers carrying pollutants towards Dutch and Belgian estuarine and coastal areas. Colonies with feeding areas influenced by water of these rivers should be included.
2. Colonies with a differing level of pollution should be included. For some locations the degree of contamination could be predicted, e.g. the Slijkplaat (Haringvliet, water from Rhine / Meuse) should be relatively polluted, and the Prinsesseplaat (near the Oosterschelde) should be relatively clean. This can also be done by choosing colonies along a gradient (e.g. along the Scheldt towards the sea). Also a colony from a probably relatively unpolluted freshwater area was included.
3. Colonies from the two main Dutch internationally important intertidal wetland areas, the Wadden Sea and the Delta, should be included.
4. The feeding grounds of the colony should be as homogeneous as possible.
5. Practical considerations like the availability of data from recent years, colony size (minimum ca. 100 pairs), travel distances (for observers) between colonies etc.

Finally the following eight colonies were selected (figure 5.1): Saeftinge, Terneuzen and Zeebrugge as a gradient along the Scheldt towards the North Sea; the Prinsesseplaat representing the Oosterschelde; Slijkplaat and Westplaat as a two-step gradient of Rhine and Meuse towards the North Sea; Griend representing the Wadden Sea and Zeewolde as a relatively clean freshwater location.

In the following paragraphs each colony will be described. Aspects covered are: location in relation to potential (tidal and freshwater) feeding areas, vegetation and soil structure, other breeding birds and historical data on numbers of breeding common terns. A general description of the 1991 breeding season, covering topics like predation, colony structure and colony-specific weather influences will be given in 7.1.

5.2 Saeftinge

The " Verdronken Land van Saeftinge" (further called Saeftinge) is a typical brackish-water tidal area in eastern part of the Westerschelde estuary (figure 5.2). Due to sedimentation a vast salt marsh has been formed, intersected by numerous fine branches, creating a fanciful creek system. The tidal amplitude (4,50 m) is the most extreme of the Netherlands causing strong surface relief. The creek depth averages 2.5 m, the average difference in height between natural levees and back swamps is 1.5 m. The levee-back swamp system dominates the geomorphology of the salt marsh. The levees along the creeks reach a height of 0.5-1.5 m above N.A.P. (mean sea level) (Leemans & Verspaandonk 1972).

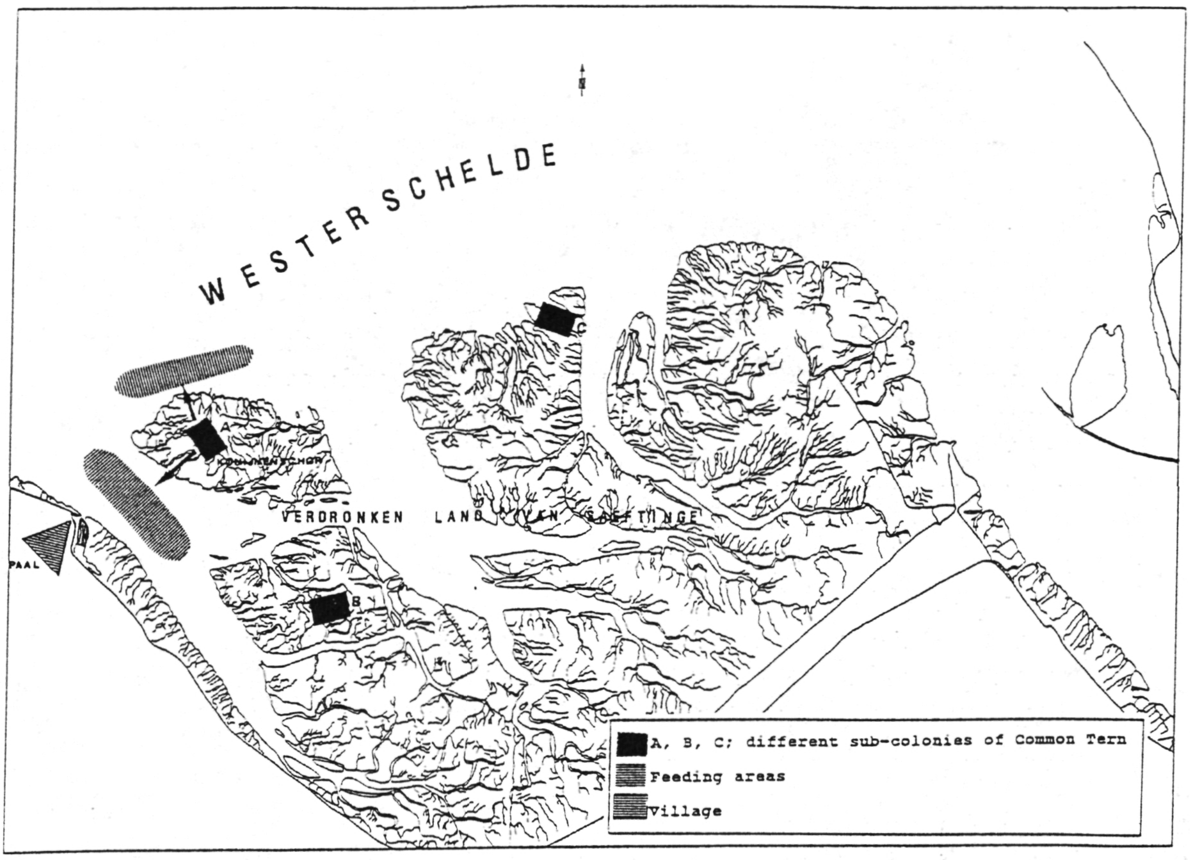


Figure 5.2 The 'Verdronken Land van Saeftinge' with the location of the different sub-populations of common terns in the season 1991 and of the feeding areas.

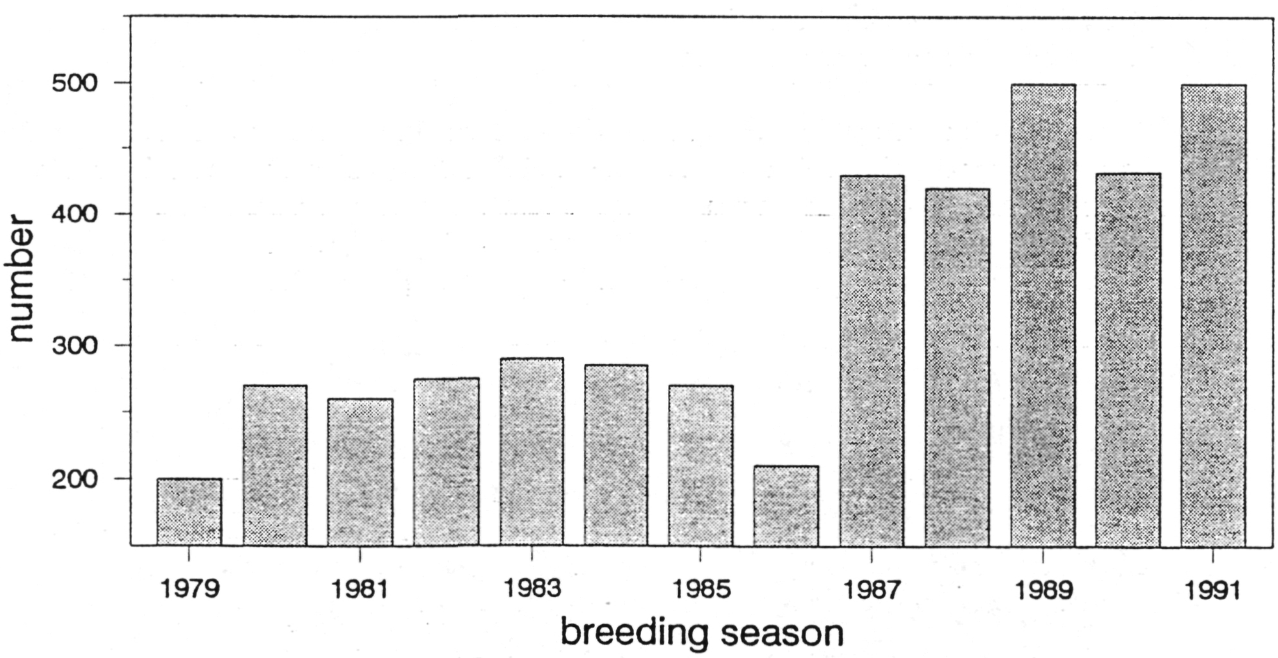


Figure 5.3 Number of breeding pairs on the 'Verdronken Land van Saeftinge' during the breeding seasons of 1979-1991.

Characteristic for the area are soils containing a large mud fraction, large and small-scale gradients, and a low plant diversity. The most important environmental gradient is the transition from mesohalinicum to polyhalinicum, resulting in several vegetation-types (Moerland 1987).

Different factors influenced the composition of the vegetation. Due to the introduction of common cord-grass (*Spartina townsendii*) in the early 1930s, Saeftinge became the largest salt marsh area of the southwest-Netherlands, with about 2242 ha of the area concist of marshes (Ysebaert & Meire 1989). Recently, species like maritime club-rush (*Scirpus maritimus*), sea couch-grass (*Elytrigia pungens*) and hastate orache (*Atriplex hastata*) were able to expand at the expense of e.g. common cord-grass (Van Schaik & De Jong 1988). An other recent important factor is the grazing by sheep, causing a shift in the vegetation.

Saeftinge is an area with a rich avifauna. During the breeding season black-headed gull (*Larus ridibundus*) and herring gull (*L. argentatus*) are present in high numbers: in 1990 a total of 1300 pairs of black-headed gulls and 7000 pairs of herring gulls were counted. Other breeding birds include mallard (*Anas platyrhynchos*, 350 pair), shelduck (*Tadorna tadorna*, 70), shoveler (*Anas clypeata*, 19), coot (*Fulica atra*, 15), oystercatcher (*Haematopus ostralegus*, 390), avocet (*Recurvirostra avosetta*, 21), redshank (*Tringa totanus*, 464) and common tern (432) (Maebe 1991).

Saeftinge is also an important area for migrating and wintering birds. Large numbers of mallard, wigeon (*Anas penelope*), pintail (*A. acuta*), greylag goose (*Anser anser*), white-fronted goose (*A. albifrons*), dunlin (*Calidris alpina*) and lapwing (*Vanellus vanellus*) use the area during winter and migration.

Data on the number of breeding common terns are presented from 1979 onwards (figure 5.3). That year 200 pairs were counted. The numbers increased slightly until 1986. During the breeding season of 1987 the numbers doubled and reached 500 pairs in 1989.

5.3 Terneuzen

The colony of Terneuzen is situated in the middle of the sluice-complex of Terneuzen (figure 5.4) near the centre sluice, on a small plateau of about 2375 m^2 (95x25 m) covered with gravel. Another colony was situated about 3 km to the west of Terneuzen.

The degree of coverage of the vegetation was low. The colony consisted of 145 nests, mostly laid on pebbles. A few nests were situated on biting stonecrop (*Sedum acre*). Other plant species present were goosefoot (*Chenopodium*), smooth sow-distel (*Sonchus oleraceus*), common chickweed (*Stellaria media*) and smaller ragworth (*Senecio minus*).

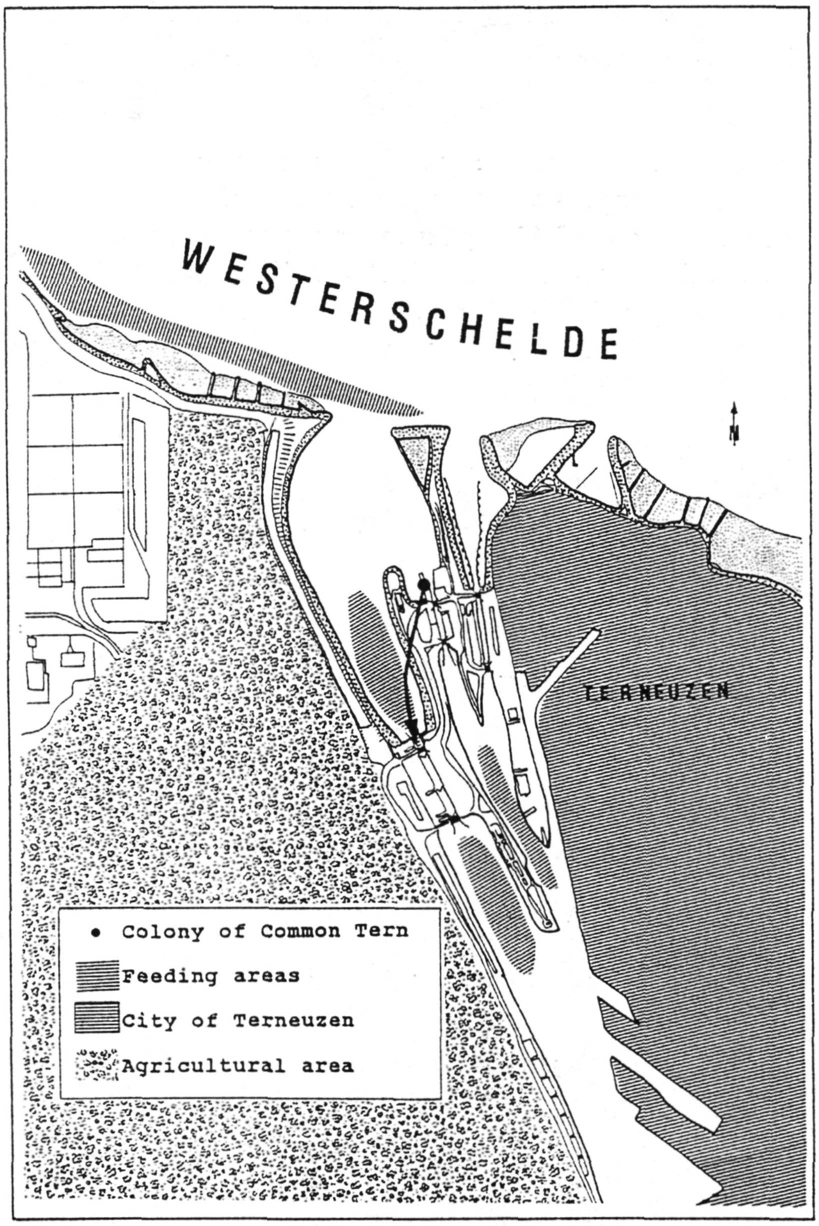


Figure 5.4 Location of the colony of Terneuzen in the sluice complex of Terneuzen and of the feeding areas.

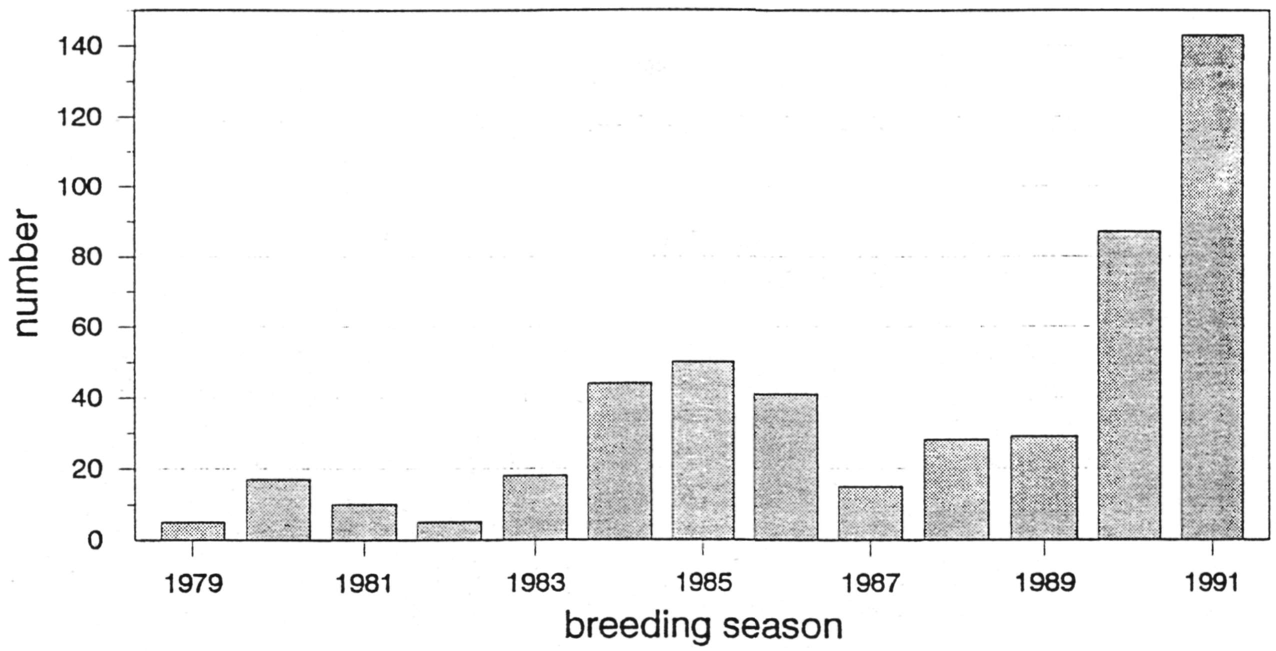


Figure 5.5 Number of breeding pairs in the colony of Terneuzen during the breeding seasons 1979-1991.

Seven concrete tubes of a length of about 1 m were scattered in the colony. During bad weather these tubes were used by some chicks for shelter, the purpose for which these tubes had been placed several years ago.

As the colony was situated several meters above mean high water level there was no danger of flooding. In order to avoid the chicks jumping over the edge, the colony was fenced for this study.

During the breeding season of 1979 the colony was occupied for the first time by five pair. From that year on the numbers increased to 50 pair in 1985. The next year the numbers collapsed to 15. From 1988 the numbers increased again to reach a maximum of 145 in 1991 (figure 5.5).

5.4 Zeebrugge

The colony of Zeebrugge was situated on an area of 150 ha created in the 1980's by raising of the site by fluid sand and silt. It forms part of the harbour of Zeebrugge (figure 5.6). The first raisings evolved to a pioneer stage of primary dunes overgrown with lyme-grass (*Leymus arenarius*), prickly saltwort (*Salsola kali*), sea rocket (*Cakile maritima*). To avoid wind erosion the area was leveled and sawn with a mixture of grass, corn-crops, and medick (*Medicago spec.*) to fixe the sand. The site contains a tidal part and during low tide a large area of tidal flats is exposed.

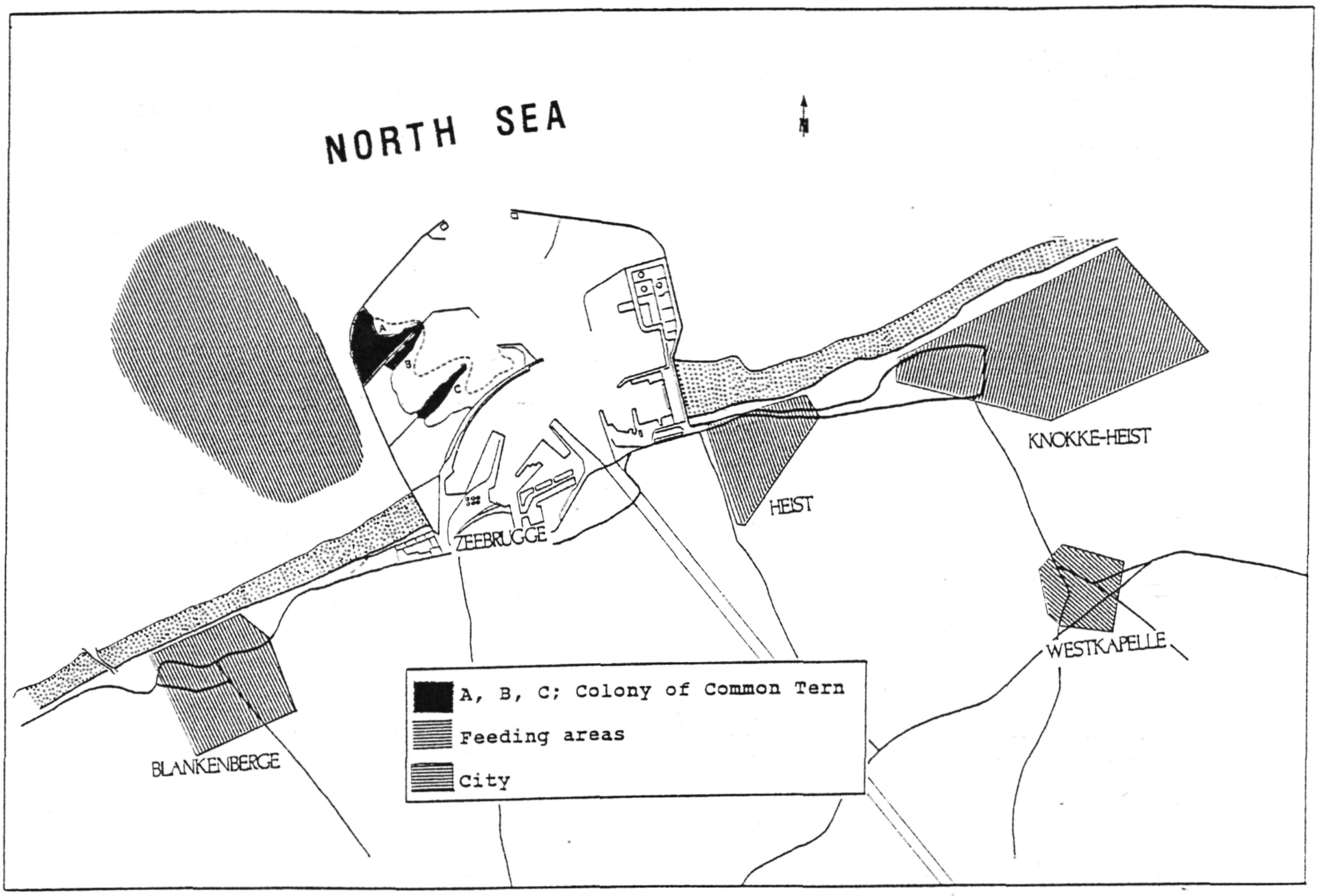


Figure 5.6 The breeding areas of the Common Tern in the 'Voorhaven' of Zeebrugge and the location of the feeding areas.

Due to the advanced position in the sea and the presence of tidal flats, the area is an important resting and feeding site for migrating and wintering birds. Also the inaccessibility for the public contributes to its attractiveness. Large numbers of several species (e.g. oystercatcher, dunlin and curlew, *Numenius arquata*) use the flats to forage during winter. The flats are also used by several species of ducks (shelduck, wigeon, shoveler). Diving ducks and seaducks (scaup, *Aythya marila*, and eider) use the deeper water and occur in considerable numbers in the eastern part of the harbour.

From 1985 on an increasing number of gulls and terns has bred in the area. It holds the only Belgian breeding population of little tern (*Sterna albifrons*) and sandwich tern (*S. sandvicensis*). The colonies of both species constitute about 2 % of the Northwest European population and can be considered of international importance. The area is also of importance for the kentish plover (*Charadrius alexandrinus*) and the common tern, holding over 50 % of the Belgian breeding population of both species (Devos 1991).

The number of common tern breeding pairs was quite constant during the last three years and numbered about 650. For this species, the area is the most important breeding place in Vlaanderen. In the past the nature reserve "het Zwin" at Knokke-Heist contained the largest population but during the last years a considerable decrease was observed: from about 285 pairs in 1986 to 135 pairs in 1991 (Devos 1991).

The common terns bred more dispersed than the other tern species using the area. Most of the common terns bred in the northern part of the area (area A; figure 5.6) on an area of about 80 ha. A smaller part of the population was found in the areas B and C (respectively 10-15 % and 5-10 % of the population).

5.5 Kleine Prinsesseplaat and Grote Prinsesseplaat

The Prinsesseplaat is a former tidal flat, which was a part of the Oosterschelde until April 1987. After the closure of the Oesterdam, it became part of the newly formed freshwater lake 'Zoommeer' (figure 5.7). The Oesterdam was part of the coastal engineering works carried out as part of the storm-surge barrier project in the Oosterschelde. The newly formed lake has a stagnant water level. Apart from feeding in the fresh water directly neighbouring the breeding site, the common terns mainly have intertidal waters available for feeding. In fact, preliminary observations before 1991 indicated that their main feeding grounds were in the Oosterschelde. There are two (sub-)colonies of common terns on different parts of the Prinsesseplaat (Kleine and Grote Prinsesseplaat; figure 5.7).

Since the closure of the Oesterdam the vegetation of the Prinsesseplaat has changed. On both the Grote and the Kleine Prinsesseplaat glasswort (*Salicornia europaea*) covers a large area. Along the shore marsh fleawort (*Senecio congestus*) is very common, while stands of reed (*Phragmites australis*) and bulrushes (*Scirpus sp.*) occur as well.

Other breeding birds in the area include several wader, duck and gull species. In 1991 the most important species were: avocets (161 pairs), black-headed gull (292), herring gull (97). Little tern (26) and arctic tern (*Sterna paradisaea*, 6) were present as well (Van Buel 1991, Meininger et al. 1992).

The first breeding common terns were recorded in 1988, 7 and 5 pairs on the Kleine and Grote Prinsesseplaat respectively. These numbers increased in the years following to a level of approx. 230 pairs on both sites in 1990 and 1991.

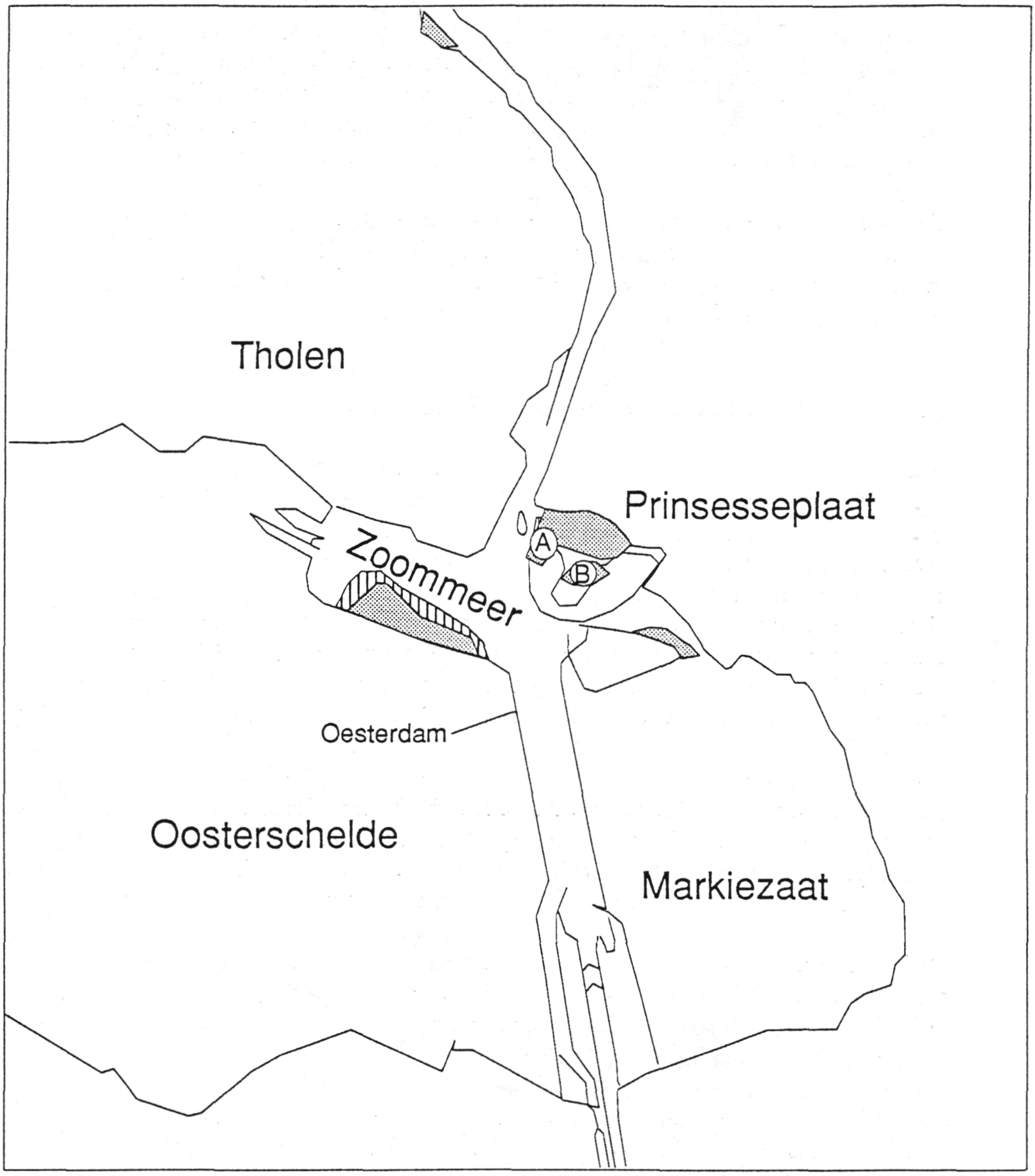


Figure 5.7 The breeding areas of the common tern on the Prinsesseplaat (A: Kleine Prinsesseplaat and B: Grote Prinsesseplaat and the location of the feeding areas (Zoommeer and Oosterschelde).

5.6 Slijkplaat

The Slijkplaat is situated in the western part of the Haringvliet, a freshwater area where waterlevels normally have a tidal difference of 30-40 cm. Due to wind and water levels at sea and the discharge of the rivers, relative and absolute levels can rise significantly. The Slijkplaat is a sandy, shallow flat, in the middle of which two small islands are above mean high water levels (figure 5.8). The west side of the area is protected against erosion by rubble stone dams. On the higher parts of the islands several vegetation types occur. Along the water a sparse vegetation of grasses and herbs can be found. Towards the central areas higher vegetations of creeping thistle (*Cirsium arvense*) en great willowherb (*Epilobium hirsutum*) become dominant. Especially the vegetation structure of the area with the fast-growing thistles change rapidly throughout the breeding season.

The number of breeding pairs on the Slijkplaat has increased rapidly over the last decade (Veerkamp et al. 1988, N.D. van Swelm unpubl., Meininger et al. 1992). Although the number in 1990 was lower, the total number seems to have been stabilized at about 1000 breeding pairs (figure 5.9). This makes the Slijkplaat one of the largest common tern colonies in the Netherlands, and together with the colonies in Europoort (Rotterdam harbour) and Hooge Platen (Westerschelde) it is the largest in the Delta region.

5.7 Westplaat

The Westplaat is a man-made bird island, constructed through the raising of a local shallow with sand. It is located at the coast near Voorne, along the channel Brielsche Gat (figure 5.8). Potential foraging areas for common terns in the immediate surroundings include coastal North Sea, parts of Rotterdam harbour, a stagnant salt water lake (Oostvoornse Meer), the area near the Haringvliet-sluices (where freshwater is let out into the sea during low tide) and some smaller freshwater areas.

The island was constructed in 1987, as a compensating measure for the loss of natural habitat caused by the construction of new parts of Rotterdam harbour. It is a sandy island, of which the higher part ('dune') originally measured approximately 1 ha. In 1991 only 0.22 ha (above normal high water level) was left, as a consequence of erosion during heavy storms. The highest point is ca. 3.75 m above NAP, or 1.70 m above mean high water level. During spring tides the lower parts of the island are flooded. On the higher parts a vegetation mainly consisting of marram grass (*Ammophila arenaria*) is growing, and on the lower parts sea rocket and sea-kale (*Crambe maritima*) as well. The area is a nature reserve, where no visitors are allowed during the breeding season.

Numbers of breeding birds were monitored from the first year onwards (Van Swelm 1990 a, b and c). Common terns first bred on the island in 1988. In 1989 black-headed gull (max. 57 pairs in 1990) and sandwich tern (max. 329 in 1990) settled on the Westplaat. Several wader species breed in small numbers on the island as well, eg. avocet, oystercatcher and kentish plover.

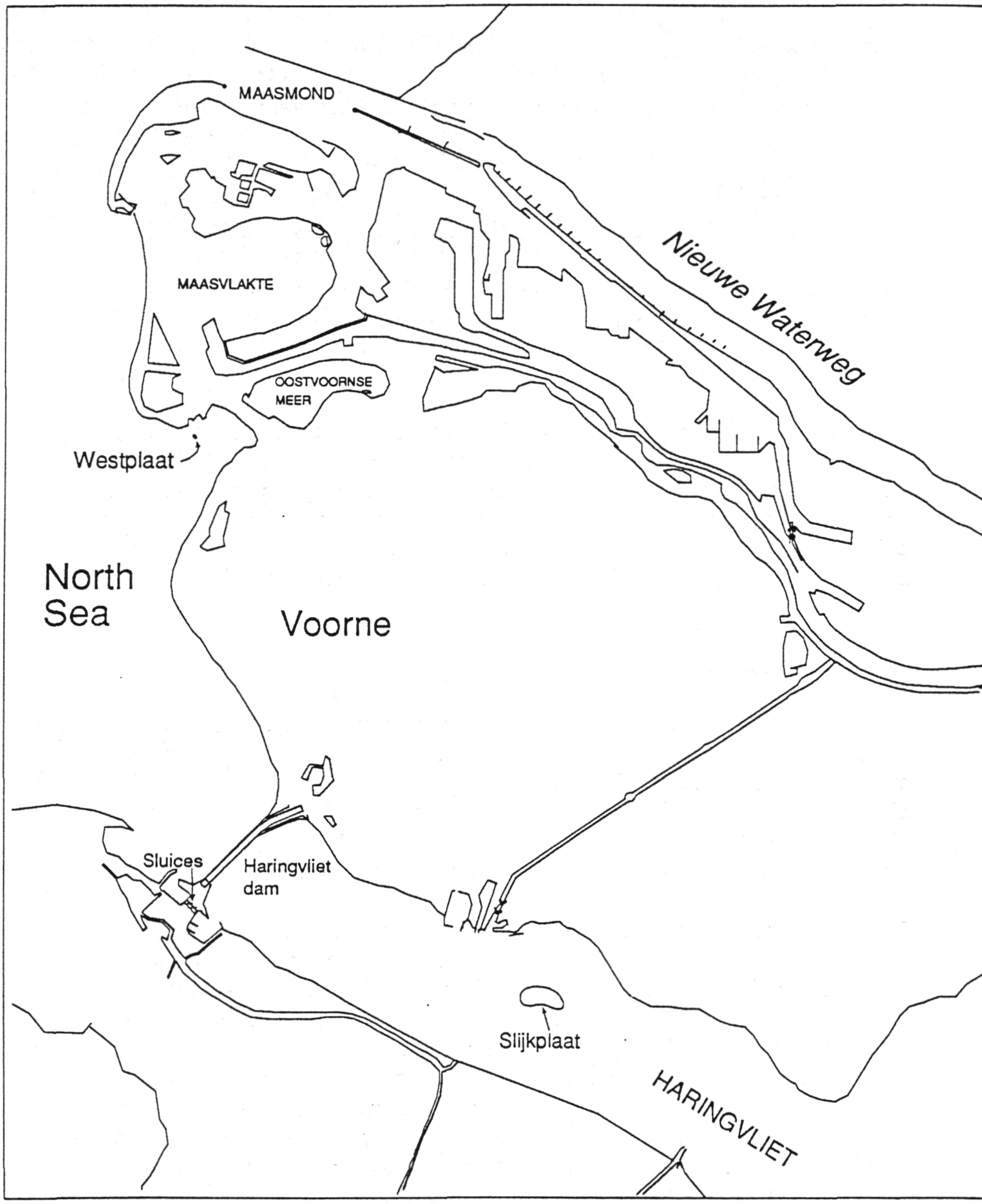


Figure 5.8 The location of Slijkplaat, Westplaat and the feeding areas around these colonies.

In the first year after construction, 1988, 70 pairs of common terns were breeding on the island. This number increased in the next year, but decreased in 1990 (figure 5.10) (Van Swelm 1990a, b, c). In 1991, a total of 160 breeding pairs was estimated.

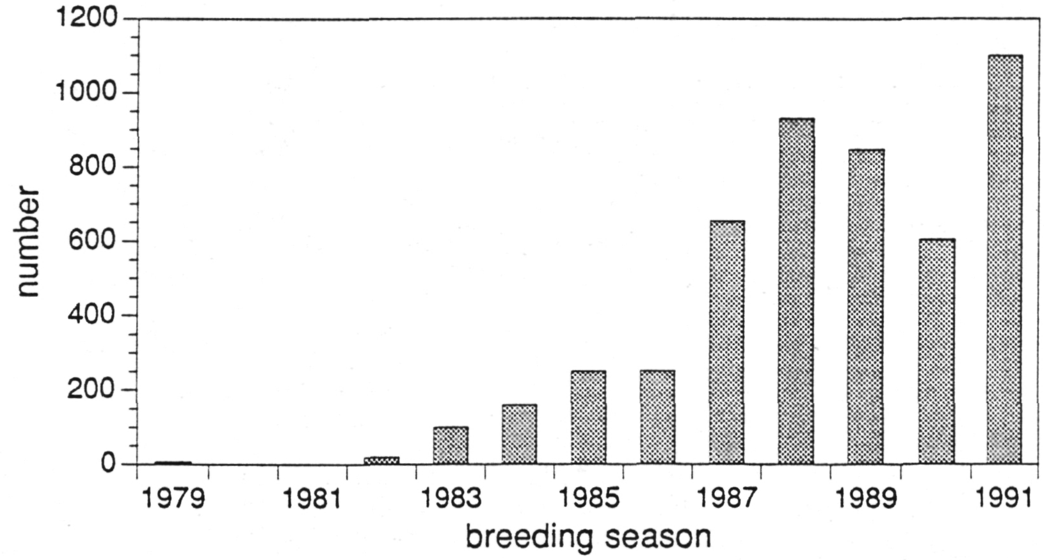


Figure 5.9 Number of breeding pairs on the Slijkplaat during the breeding seasons of 1979-1991.

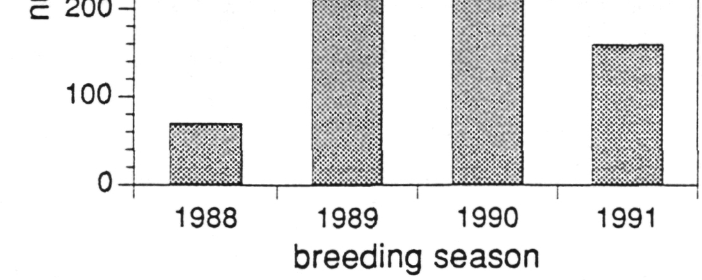


Figure 5.10 Number of breeding pairs on the Westplaat during the breeding seasons of 1979-1991.

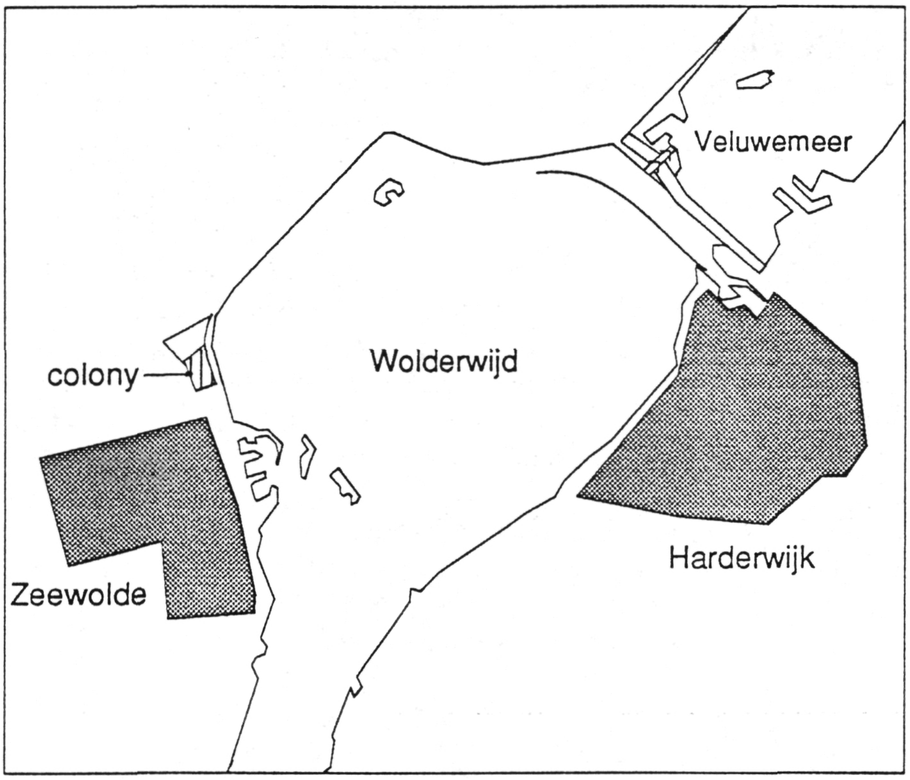


Figure 5.11 The location of the colony near Zeewolde and the feeding areas (Wolderwijd, Veluwemeer) around the colony.

5.8 Zeewolde

The colony is situated on the top of a sand depot along the Wolderwijd dike north of the town Zeewolde (figure 5.11). It is ca. 2.5 m above surfacelevel and in 1991 the depot surface measured ca. 4 ha. Most of the top is bare sand, although some patches with herbs and grasses occur. Other breeding birds include black-headed gulls (100-200), common gull (*Larus canus*, 1), kentish plover (9), ringed plover (*Charadrius hiaticula*, 1), little ringed plover (*C. dubius*, 2) and avocet (2-4).

Although this colony has been present from at least 1989 onwards, no detailed data on numbers of breeding pairs could be obtained.

5.9 Griend

Griend is a small island, situated in the middle of the western part of the Dutch Wadden Sea (figure 5.12). It is protected because of its importance for breeding and resting birds, and closed for the public throughout the year. Although there is a small saltmarsh at the eastern side, the island mainly consists of a sandy beachwall. To prevent it from disappearing, the island has been reinforced several times during the last decades. The main vegetation types in the sandy parts are dominated by sand couch-grass (*Elymus farctus*), lyme-grass with dense inflorescence (*E. pycnanthus*) and lyme-grass (Veen & Van de Kam 1988). Especially the breeding colony of sandwich terns is well-known (7,000 pairs in 1991). Common and arctic terns breed in large numbers as well: in 1991 1,900 and 410 pairs respectively. Other breeding birds are: black-headed gull (22,000 pairs), and several other gull, duck and wader species (Brenninkmeijer & Stienen 1992).

Common terns have already been breeding on Griend for long times. The island has always been one of the most important colonies within the Wadden Sea (Stienen & Brenninkmeijer 1992). Around 1930 ca. 7,000 pairs were breeding on the island. In figure 5.13 the data of 1981-1991 have been plotted (data from Brenninkmeijer & Stienen 1992). In recent years an increase in numbers can be seen, with a total of 1,900 pairs in 1991.

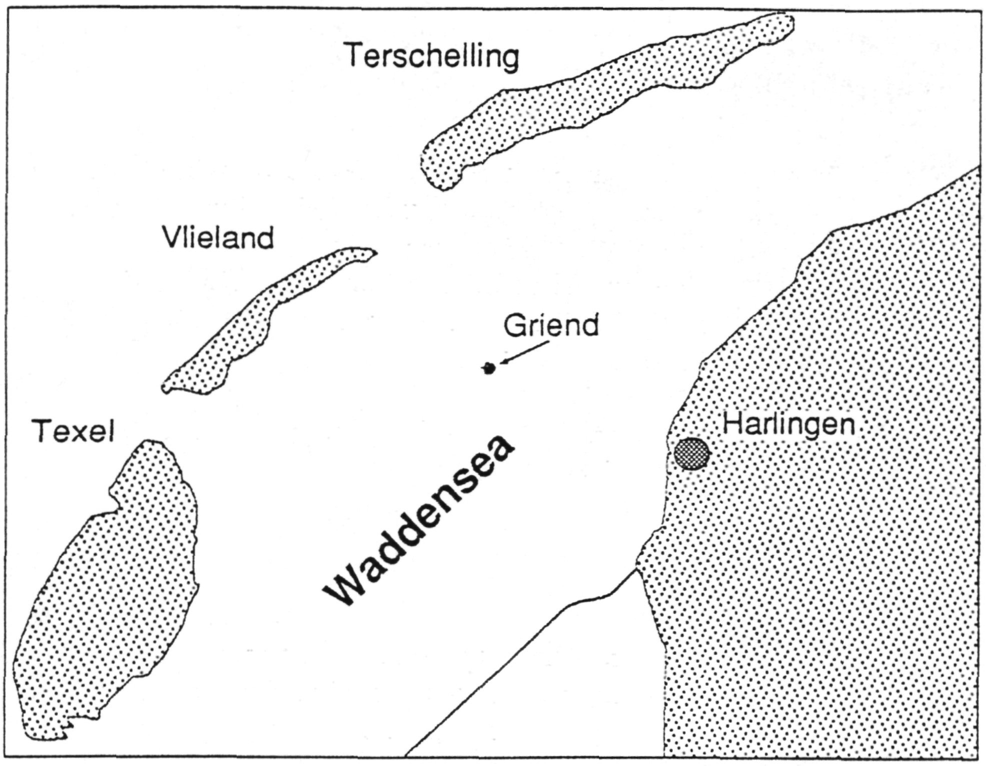


Figure 5.12 The location of the colony on Griend in the Waddensea.

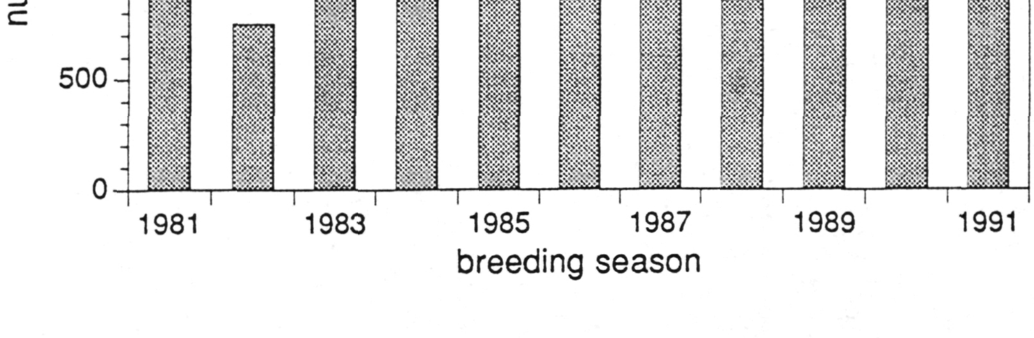


Figure 5.13 Number of breeding pairs on Griend during the breeding seasons of 1981-1991 (data from: Brenninkmeijer & Stienen 1992).

6 FOOD AND FEEDING AREAS

6.1 Introduction

For several reasons it was important to obtain data on the food and feeding areas of the terns in the colonies where this study was carried out. The selection of the colonies was based upon information on feeding areas of different precision, while detailed knowledge on food choice was only available for a few colonies. However, as the contaminants of which the possible effects were to be studied, are ingested with the food, and the levels may vary according to food type and area, at least a qualitative description of the food and its geographical origin should be made for each colony.

Although information on food choice in the pre-breeding period is the most important in relation to the topic of this study, data gathered later in the season will be presented as well.

6.2 Saeftinge

Before the laying period during high tide, only few common terns were seen in the surroundings of Saeftinge. Most of the birds were probably foraging in the Westerschelde (figure 5.2). Several times we saw large numbers of common terns foraging in the wake of passing ships. During receding tide on the other hand, we observed the adult birds several times foraging in large flocks mixed with black-headed gulls in the main gully in front of 'Paal', a small harbour near the study area. The birds were probably attracted by the large numbers of shrimps, mysids and small fish.

During laying period and during the feeding of the young, foraging mainly took place in front of the Konijnenschor in the Westerschelde and in the main gully off Paal.

Of the 619 prey items identified, clupeids (herring, *Clupea harengus* or sprat, *Sprattus sprattus*) and goby (*Gobius spec.*) were the commonest food (figure 6.1a). Other species including flatfish, whiting (*Merlangius merlangus*), sandeel (*Ammodytes spec.*) were seen less frequently. Most food items measured between 1 and 1.5 times the bill-length (figure 6.2). Statistically significant seasonal changes in the composition of the diet occurred during the periods before and after hatching (figure 6.1b): the proportion of clupeids increased, while the proportion of sandeel and goby decreased. A comparable pattern was observed in the diet of the adults before and after hatching of the first egg (figure 6.1c). Comparing the diet of the adults with the diet of the chicks during the period after hatching of the first egg (figure 6.1d), it is clear that flatfish, whiting and goby were selectively fed to the chicks. Due to the small sample size of the diet of the adults in the period after hatching the difference was not significant.

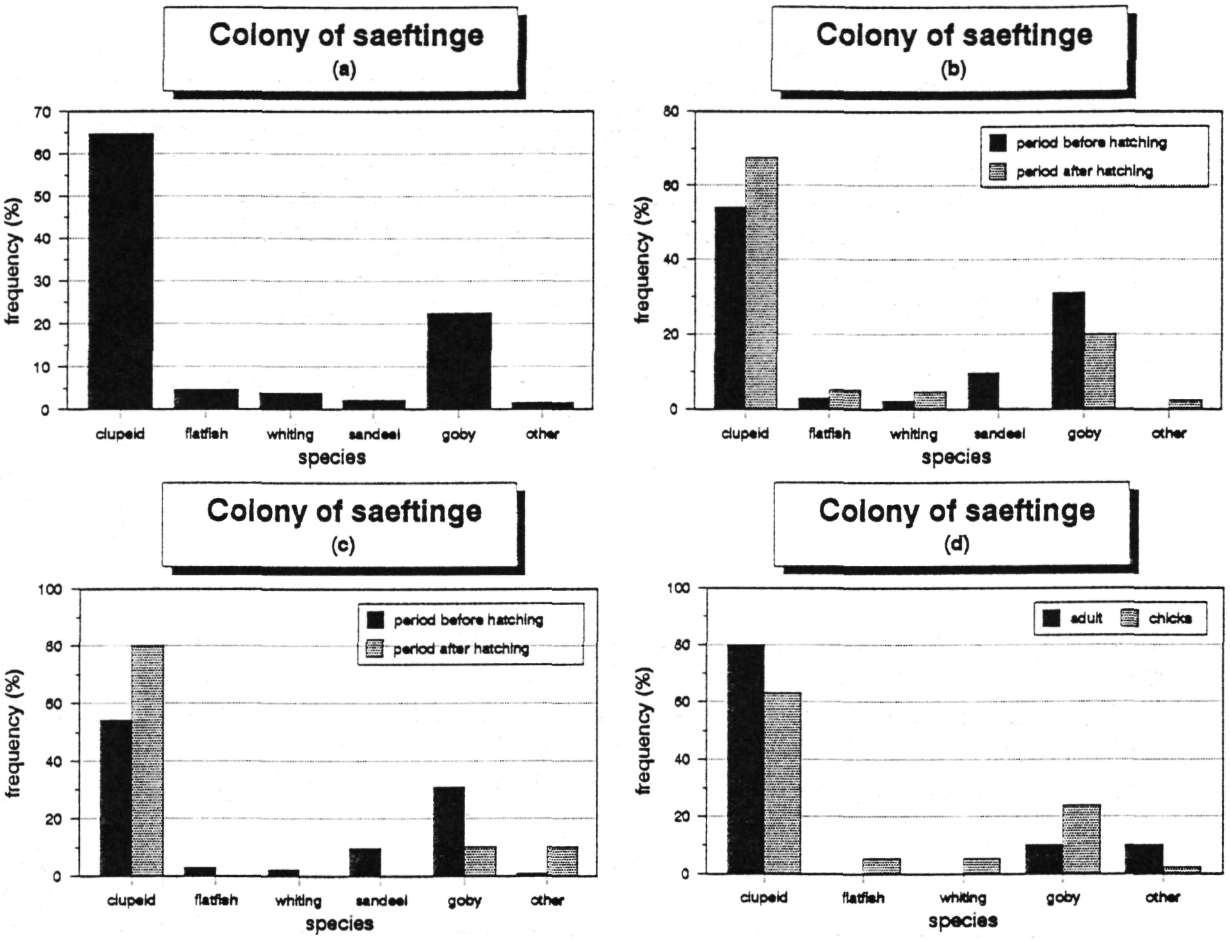


Figure 6.1 (a) Food supply of the colony of Saeftinge. 619 food items were identified concisting mainly of clupeids, flatfishes, whiting or cod (*Gadus morhua*), sandeel and goby spec. The category 'other' includes species only seen a few times like crab (*Carcinus* spec.), shrimp (*Crangon crangon*) and pipefish (Syngnathidae).

(b) Food supply of the colony of Saeftinge before and after hatching of the first egg. The change in the composition of the diet was statistically significant (N=619, X^2=55.8288, D.F.=8, P<0.0001).

(c) Food supply of the adult of the colony of Saeftinge before and after hatching of the first egg. The change in the composition of the diet was statistically significant (N=143, X^2=17.50096, D.F.=5, P<0.001).

(d) Food supply of the adult and the chicks of the colony of Saeftinge in the period after hatching of the first egg. The difference in composition of the diet of the adult and the chicks was not statistically significant (N=241, X^2=9.52141, D.F.=6, P>0.05).

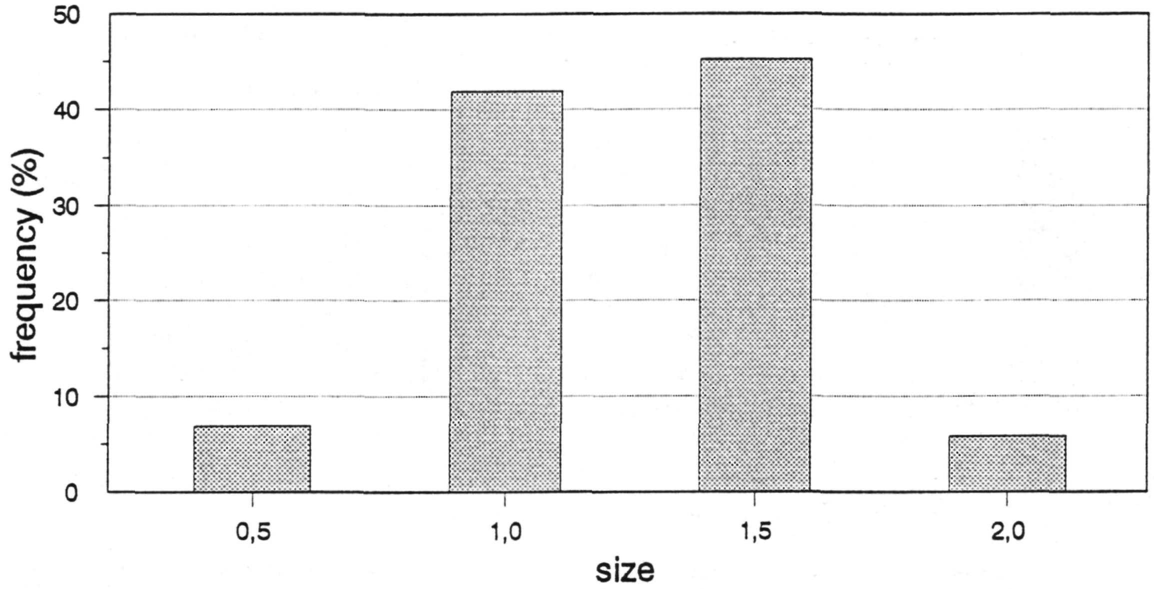


Figure 6.2 Size distribution (relative to bill size) of the food supply of the colony of Saeftinge.

Table 6.1 Not eaten food items collected in the colonies Saeftinge and Terneuzen.

species	Terneuzen number	Terneuzen size (cm)	Saeftinge number	Saeftinge size (cm)
herring	62	6.6	1	6.0
sprat	5	7.4	1	5.0
clupea spec.	21	5.6	1	6.5
whiting	3	7.2	1	10.5
cod	4	8.4	1	8.5
bib	1	8.0		
gadus spec.	3	6.0		
silver bream	11	11.3		
flatfish	22	5.7	16	5.5
eel	1	17.0		
butterfish	2	6.8		
black goby	1	3.5		
shrimp	1	1.0		
stickleback	1	7.0		
pipefish	1	14.0		
crab	3	2.7		

During every visit, the colony was checked for not consumed food items. These items consisted mainly of flatfish. The young chicks often had difficulties with swallowing these species. Other species found included clupeids, cod and whiting (table 6.1).

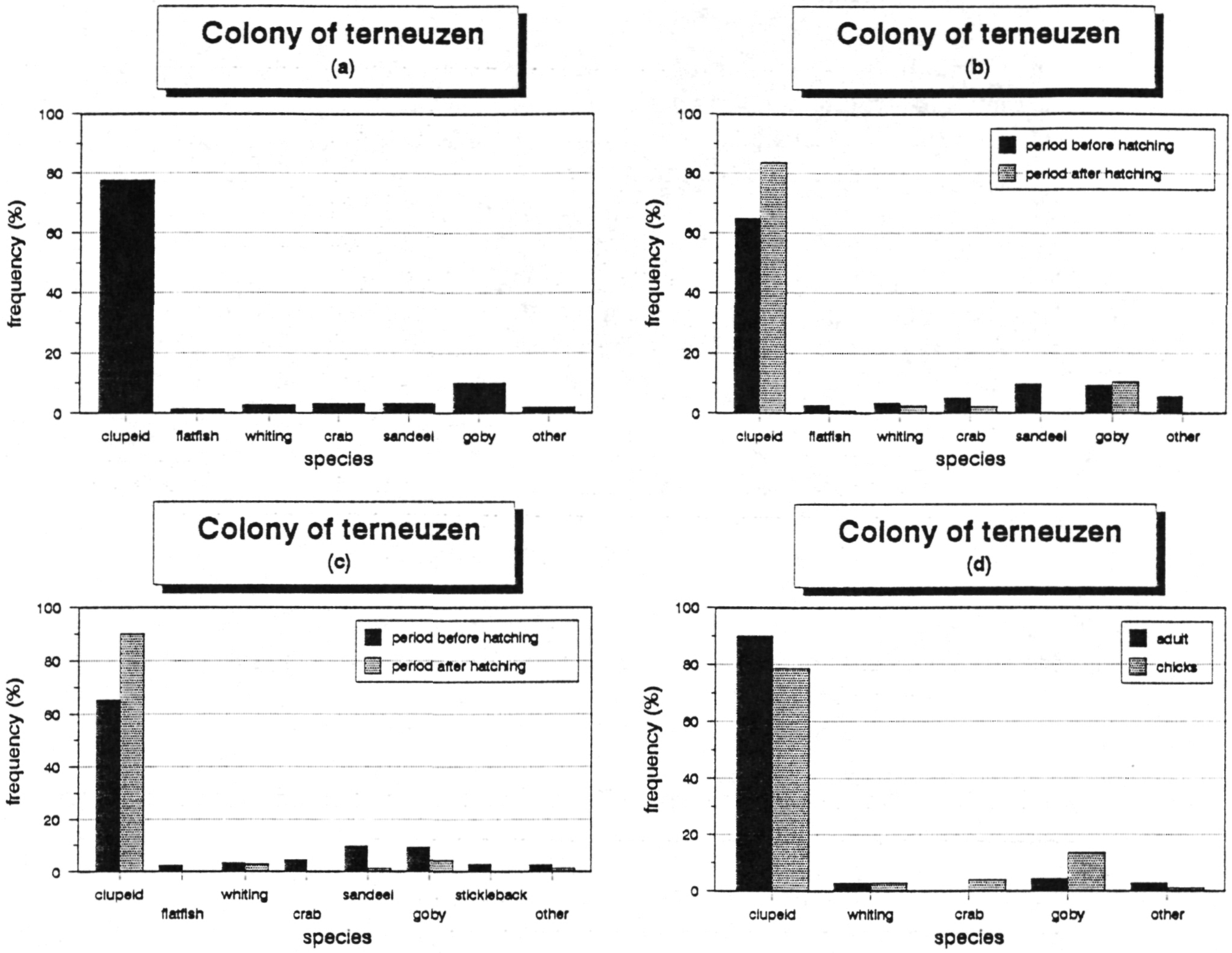


Figure 6.3 (a) Food supply of the colony of Terneuzen. 745 food items were identified concisting mainly of clupeids or sprat, flatfish, whiting or cod, crab, sandeel, goby spec. and stickleback (Gasterosteidae). The category 'other' includes species only seen a few times like shrimp, pipefish and Eel (*Anguilla anguilla*).
(b) Food supply of the colony of Terneuzen before and after hatching of the first egg. The change in the composition of the diet was statistically significant (N=745, X^2=85.87239, D.F.=9, P<0.0001).
(c) Food supply of the adult of the colony of Terneuzen before and after hatching of the first egg. The change in the composition of the diet was statistically significant (N=310, X^2=19.54410, D.F.=9, P<0.05).
(d) Food supply of the adult and the chicks of the colony of Terneuzen in the period after hatching of the first egg. The difference in composition of the diet of the adult and the chicks was not statistical significant (N=356, X^2=16.65857, D.F.=6, P<0.05).

6.3 Terneuzen

Mostly the birds were seen foraging in the sluice complex itself or in the immediate surroundings (figure 5.4). Other foraging areas included the Westerschelde and a drain off of warm water in the Westerschelde near Dow-Chemical. A few times birds were seen foraging in inland creeks and ditches.

Foraging mostly occurred in the western sluice, when there was a high turbulence. When feeding in these conditions a lot of crabs were caught. The common terns also foraged in the wake of ships leaving the sluice. When there was no turbulence in the sluices, foraging took place behind the sluices in the channel of Gent-Terneuzen or more dispersed in the harbour in front of the sluices or east of Terneuzen.

In the beginning of the breeding season dipping ('contact dips', see Nisbet 1983) was the most frequently used feeding technique, especially when feeding in the turbulent water of the sluice. Later on, when the intensity of courtship feeding increased plunging ('partial and full plunge dive', see Nisbet 1983) became more important.

Out of 745 prey items identified during the breeding season, 96.8 % were fish and 3.2 % crustaceans (figure 6.3a). Most food items measured between 1 and 1.5 times the bill-length (figure 6.4). Most common fish caught was herring or sprat. Clupeids were the most common species fed to the females during courtship behaviour. Statistically significant seasonal changes in the composition of the diet occurred during the period before and after hatching of the first egg (figure 6.3b): the proportion of clupeids increased considerably, while the proportion of flatfish, whiting, sandeel, crab and other uncommon species decreased. There was a slight increase of the proportion of gobies as well. The diet of the adults before and after hatching of the first egg was significantly different, due to a strong increase of the proportion of clupeids and a decrease of the proportion of the other species (figure 6.3c). The diet of the adults after hatching of the first egg and the diet of the chicks were significantly different as well (figure 6.3d). The diet of the adults contained a higher proportion of clupeids, while the diet of the chicks contained a higher proportion of whiting, crab and goby: these species probably were selectively fed to the chicks.

The results of the rejected prey found on the colony are presented in table 6.1. Most species found were salt water species. The 11 individuals of silver bream (*Abramis bjoerkna*) support the observation of inland foraging. 44 % of the items found on the colony consisted of clupeids, mainly herring. In a number of cases the chicks were not able to swallow flat-fishes offered: this explains the quite large number of flat-fish found in the colony.

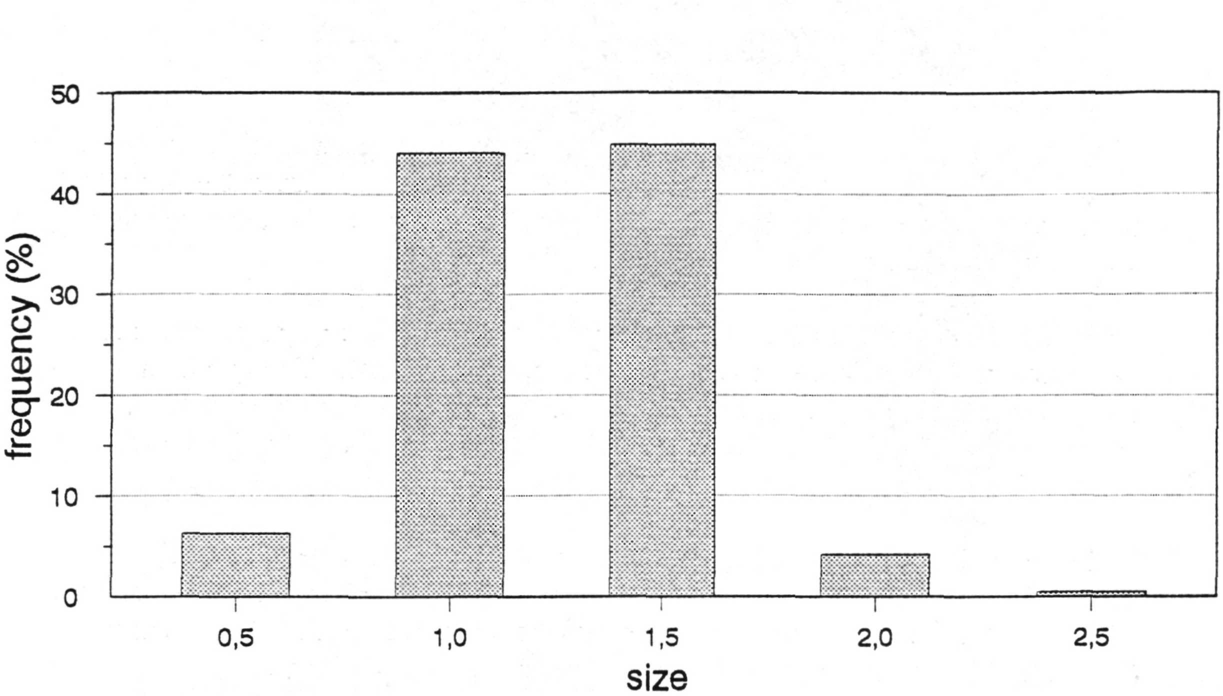


Figure 6.4. Size distribution (relative to bill size) of the food supply of the colony of Terneuzen.

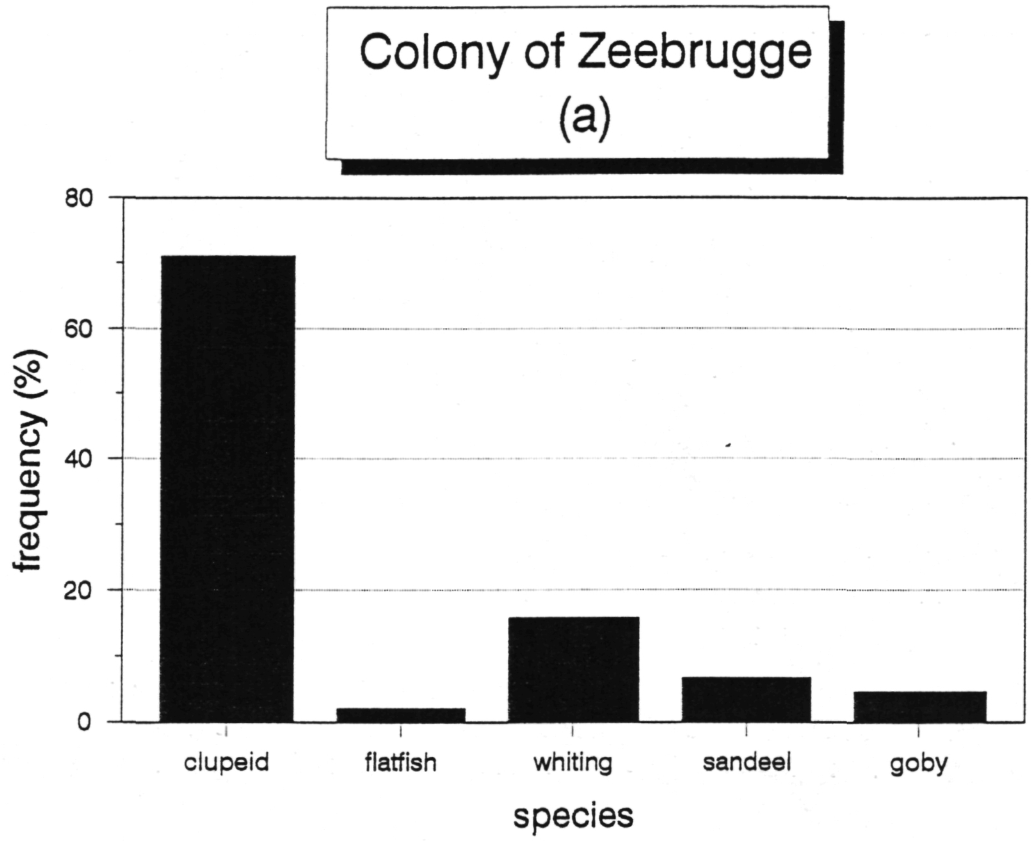
6.4 Zeebrugge

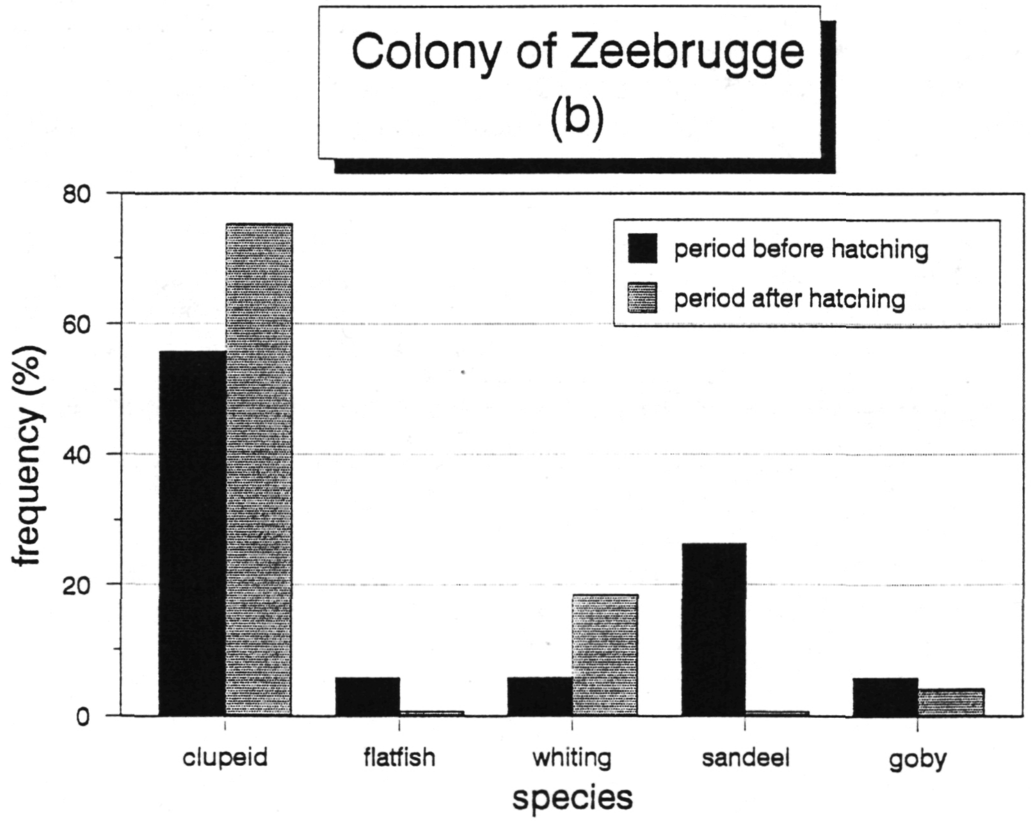
Most of the time the common terns were seen foraging in the North Sea, west of the colony at a distance of about 500-1000 m (figure 5.6). On a few occasions the birds stayed close to the coastline. During early breeding season several common terns were seen foraging more inland in fresh water.

A total of 152 prey items were identified. Of these items clupeids were the most common food brought to the colony (figure 6.5a). Statistically significant seasonal changes in the composition of the diet occurred during the period before and after hatching of the first egg (figure 6.5b): the proportion of clupeids and gadids increased considerably, while there was a strong decrease in the proportion of ammodytids and flatfish, and a small decrease of gobies.

---

next page:
Figure 6.5. (a) Food supply of the colony of Zeebrugge. 152 food items were identified consisting mainly of clupeids, flatfishes, whiting or cod, sandeel, and goby spec.
(b) Food supply of the colony of Zeebrugge before and after hatching of the first egg. The change in the composition of the diet was statistical significant (N=152, X^2=34.0269, D.F.=4, P<0.0001).


Colony of Zeebrugge
(a)
80
60
40
20
0
frequency (%)
clupeid
flatfish
whiting
sandeel
goby
species


Colony of Zeebrugge
(b)
80
60
40
20
0
frequency (%)
period before hatching
period after hatching
clupeid
flatfish
whiting
sandeel
goby
species

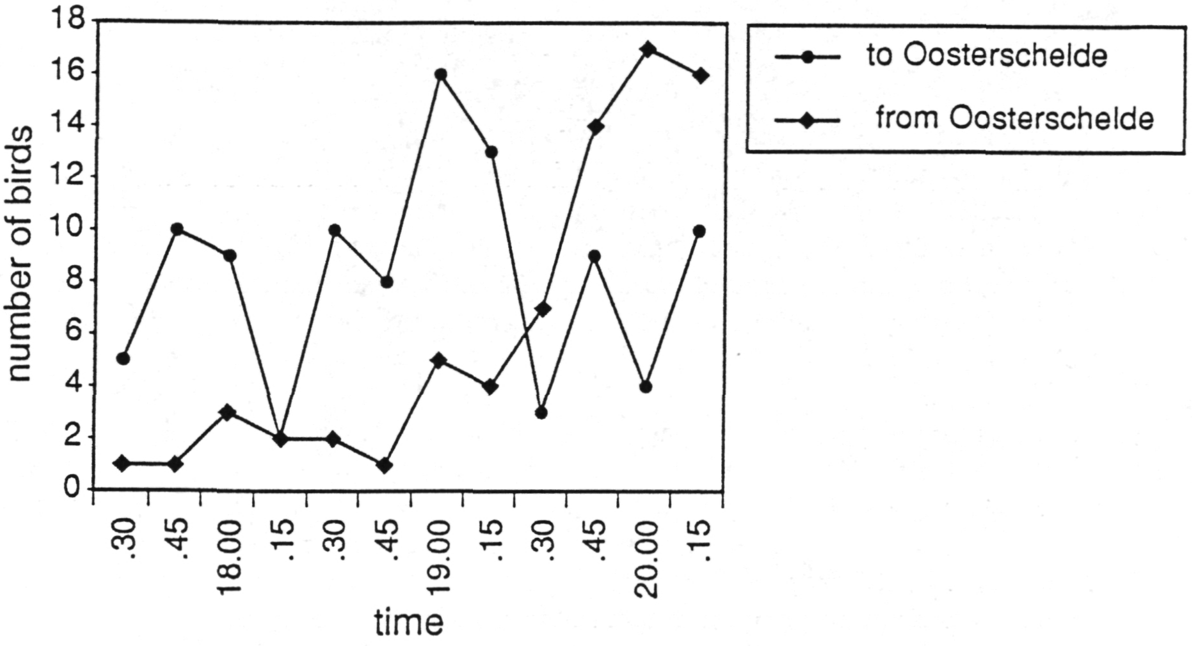


Figure 6.6 Number of common terns flying from the colony on the Prinsesseplaat to the Oosterschelde and birds returning from the Oosterschelde on 13 May 1991. The number of birds is expressed as the total per quarter of an hour.

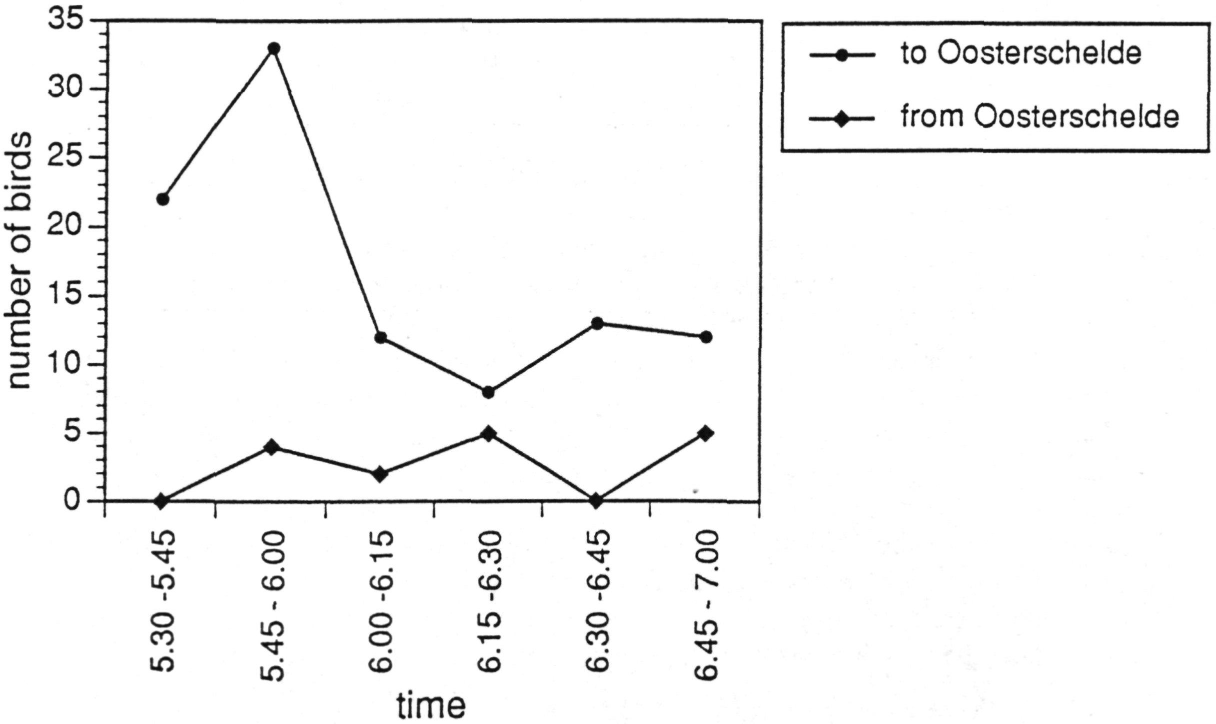


Figure 6.7 Number of common terns flying from the colony on the Prinsesseplaat to the Oosterschelde and birds returning from the Oosterschelde in the morning of 15 May 1991. The number of birds is expressed as the total per quarter of an hour.

6.5 Prinsesseplaat

The area was first visited on 22 April. No terns were observed in the area. During a second visit in the afternoon of 1 May 20-35 terns were foraging in the gully between the two parts of the Prinsesseplaat. There was one observation of a bird offering a small fish to another bird. In the morning of 8 May no common terns were leaving the Prinsesseplaat into the direction of the Oosterschelde. Several small groups of common terns were foraging, probably on emerging Diptera, in the Zoommeer in mixed flocks with black terns (*Chlidonias niger*), little gulls (*Larus minutus*) and black-headed gulls.

In the afternoon of 13 May a maximum of 55 common terns were foraging in the Zoommeer, but there was also a constant stream of birds flying from the colony to and from the Oosterschelde (figure 6.6) with a sharp increase of returning birds from 19.30h onwards. Observations in the early morning of 15 May showed that most birds from the Prinsesseplaat forage in the Oosterschelde (figure 6.7). Only small numbers stay in the Zoommeer. In early May emerging Diptera can probably be an important food-source in the Zoommeer. Later in this month the Oosterschelde becomes the most important foraging area.

No food-observations were made in the colony. During every visit the colony was checked for not-consumed food items. Only two food items were found: a small flatfish and a three-spined stickleback (*Gasterosteus aculeatus*) of 5.5 cm.

6.6 Slijkplaat

In the pre-breeding period the seaside area of the Haringvliet-sluices (figure 5.8) is the most important feeding area of common terns of the Slijkplaat and also of the Westplaat. Up to 1800 birds gather here during periods with low tide when water of the Haringvliet is discharged into the sea. Here the common terns forage together with black-headed gulls and cormorants. In the breeding period the area between the Slijkplaat and the Haringvliet-sluices is also used as a feeding area, when birds are feeding on both fish and emerging Diptera. But the seaside area of the Haringvlietsluices remains an important feeding area.

Most birds leave the area when the discharge of fresh water has stopped. On 2 May there is an outflux of birds into the direction of the Slijkplaat after 14.00h when the discharge has stopped (figure 6.8). At 16.30h 750 of the remaining 1000 terns near the sluices leave the area into the direction of the Slijkplaat.

The common terns were foraging during discharge periods of the Haringvliet-sluices in front of the third sluice and in a discharge stream of a fish-tube at the south side of the sluices. The discharge of the fish tube occurred at the same moment as the discharge of the sluices. In the observation period only the third sluice was used for the discharge of fresh water.

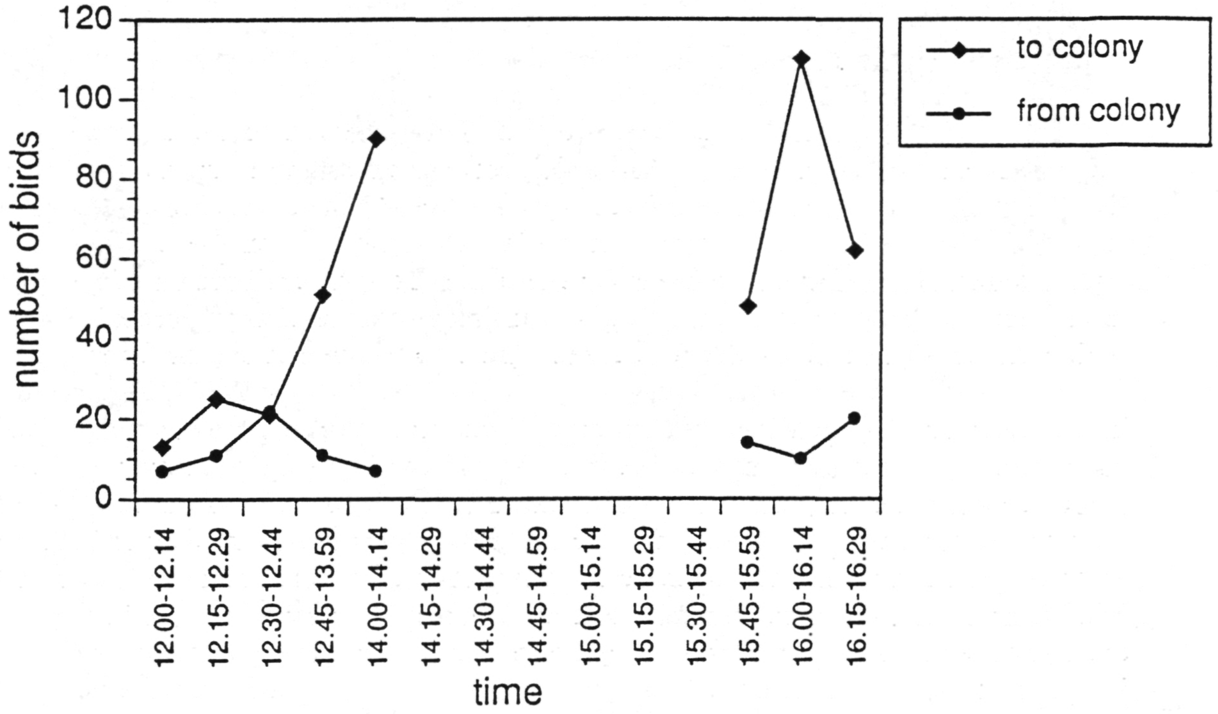


Figure 6.8 Number of common terns flying from the colony on the Slijkplaat to the Haringvliet-sluices and birds returning from the sluices to the colony on 7 May 1991. No observations were made between 14.15 - 15.44h.

On 7 May the number of foraging common terns was counted every hour at the sluices and the food in the water was sampled every hour by casting a fishing net with a surface of about 0.2 m^2 in the discharge stream of the fish-tube and by using a small net with a diameter of 15 cm on the same spot. The small net was held during 1 minute just below the surface. In the period 9.00-12.00h the net was moved actively back and forth in the water and in the period 13.00-16.00h the net was held passively in the waterstream. The throwing net was slowly hauled in after half a minute. Three samples were taken with both nets every hour. All species caught in the small net were counted. With the exception of sea-gooseberry (*Pleurobrachia pileus*), opossum shrimp (*Neomysis integer*) and flatfish, present in all catches, all species caught with the throwing net were also counted. The discharge of freshwater started at 12.04h at the sluice and at 12.26h at the fish-tube, where the sampling station was.

Figure 6.9 presents the results of the bird counts and the sampling. During the day there is a decrease of sea-gooseberry in the catches of the small net. At first the number of opossum shrimp is also decreasing, but after the start of the discharge there is a small increase as by the flatfish. Also new species are appearing in the catches like sandhopper (*Amphipoda*), smelt (*Osmerus eperlanus*) and woodlice (*Idotea spec.*). In all catches of the large net sea-gooseberry, opossum shrimp and flatfish are present. Other species are only present after the start of the discharge of fresh water. The number of common tern feeding near the sluices shows a sharp increase after the start of the discharge. The catches with the nets showed that sea-gooseberry, opossum shrimps and flatfish were available during non-discharge periods even just below the surface, but no terns were foraging in the area. So it assumed that sea-gooseberry, opossum shrimp and small flat-fish (1 cm) are not important prey species.

On 16 May the numbers of common tern near the sluices were counted every hour during the discharge period and the food was sampled with the throwing net every hour during 5 minutes. Three samples were taken. The observation period lasted from 6.30h to 16.30h and the period of discharge of fresh water from 7.45h to 15.45h. Apart from the sampling station and the area in front of the third sluice the birds resting and displaying on the nearby dam were also counted. Again there is a sharp increase in bird numbers after the start of the discharge (figure 6.10). Most birds forage in front of the third sluice, but after 11.30h there is a decrease and the numbers at the sampling station are increasing. During the day about 300 birds are resting and displaying on the dam. At 16.00h there were no common terns left at the sluices. The number of preys caught in the throwing net is also increasing after 8.00h. Especially a large number of smelt is caught. After a few hours there is a sharp decrease in the number of prey, but after 11.00h the numbers are increasing again, but they do not reach the same level as in the morning. The number of smelt is lower in this period. The number of common terns at the sampling station is about 50 during the morning but it is increasing during the after-noon. Many birds switch from the area near the third sluice to the sampling station.

Figure 6.10 suggests that common tern do not prefer smelt, for the number of birds is low at the sampling station during the morning and high in the afternoon when the number and the percentage of smelt is lower. But the potential food near the third sluice is not sampled. It is possible that the offer of smelt on this place is better than at the sampling station and therefore the terns prefer to forage near the third sluice in the morning. Direct observations in the morning showed that common terns caught at least 17 smelt at the sampling station in 5 minutes. Allthough the number of prey is lower in the afternoon at the sampling station than in the morning, the terns shift to the sampling station. Also the black-headed gulls and the cormorants are shifting from the Third sluice to the sampling station in the same period.

The decreasing total number of terns foraging in the area can indicate that the foraging conditions became less favourable during the day or that the birds are satisfied. Unfortunately there are no observations on foraging success during the day.

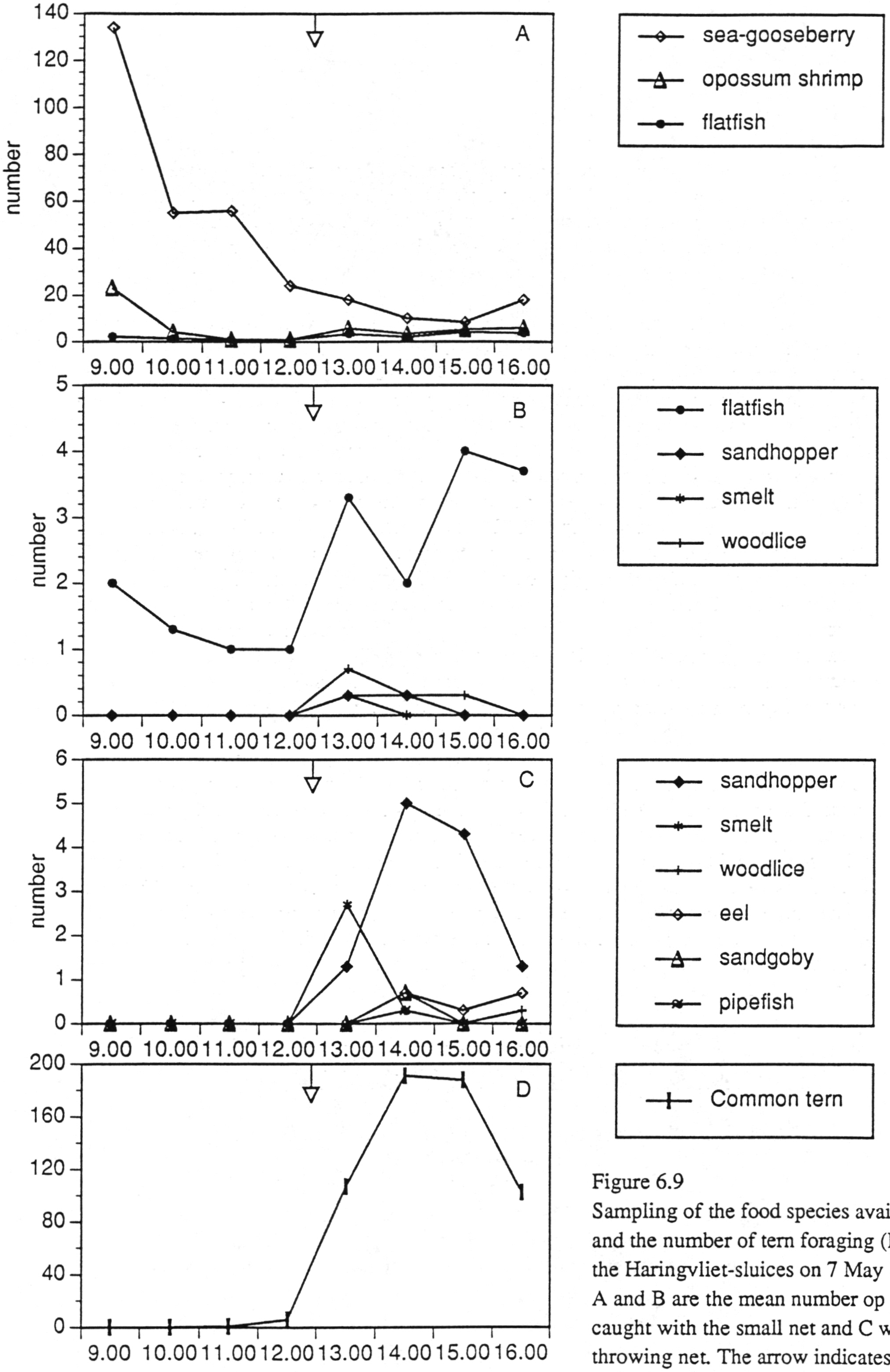


Figure 6.9
Sampling of the food species available and the number of tern foraging (D) at the Haringvliet-sluices on 7 May 1991. A and B are the mean number op prey caught with the small net and C with the throwing net. The arrow indicates the start of the discharge of fresh water.

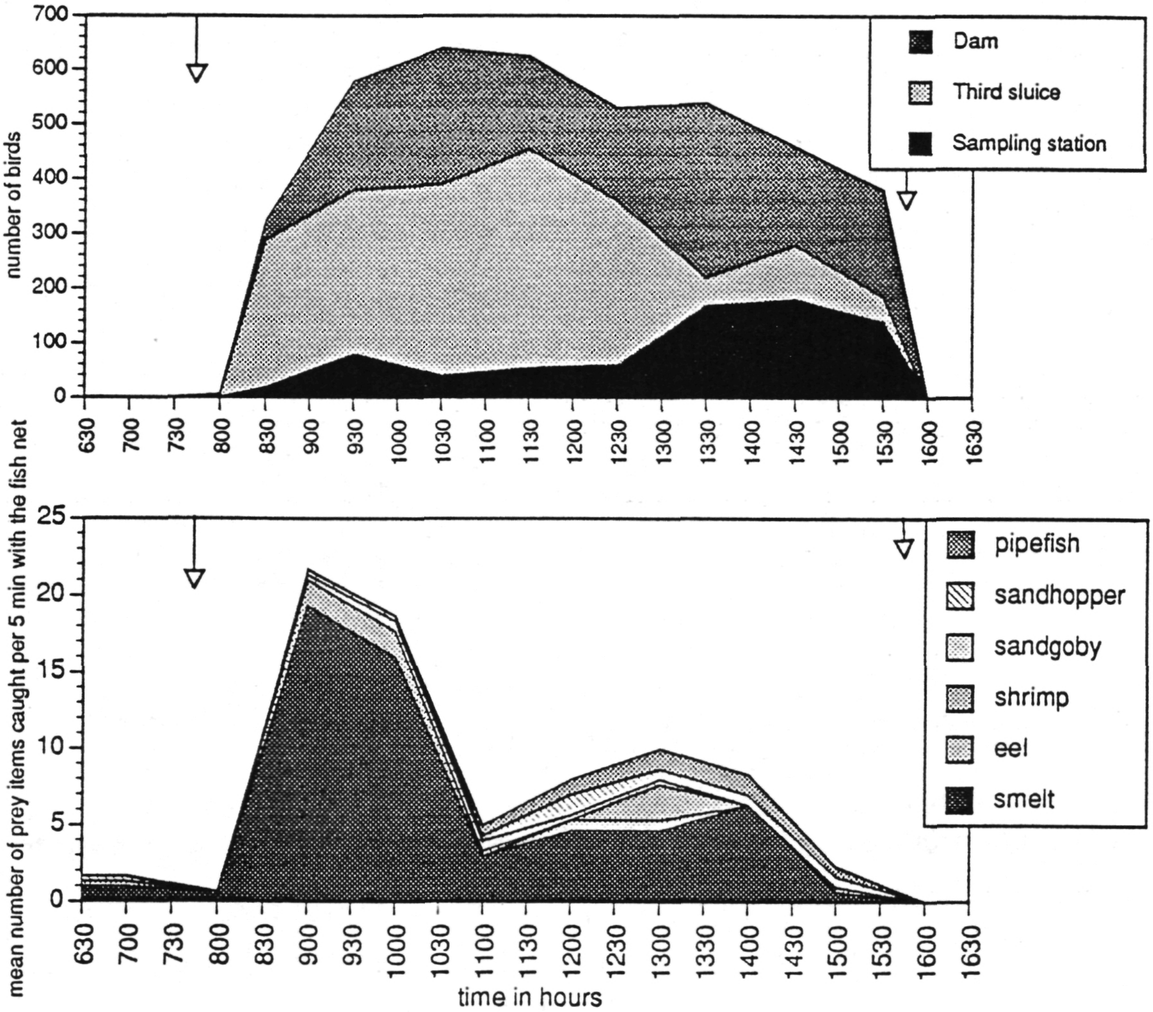


Figure 6.10 Number of common terns at the Haringvliet-sluices and the mean number of prey items per 5 minutes fishing with a throwing net. The large arrow indicates the start of the freshwater discharge, the small arrow indicates the end.

The size of the food items consumed in the beginning of May is presented in table 6.2. Table 6.3 presents the food items determined during the observations near the Haringvlietsluices. Smelt is the most common food species followed by herring. Smelt is probably in this period the most important food item, but it is possible that smaller food items like sandhopper and shrimp are underestimated.

Table 6.2a Outcome of feeding dives (successfull / not successful and prey size) of common terns in front of the Haringvlietsluices on 2 May 1991.

begin of ten minute-period	not successful	swallow	size 0,5 bill	size 1,0 bill	size > bill	total dives
12.00	30	8	9	3		50
12.10	17	9	15	2	1	44
12.30	23	10	7	2		42
12.50	14	10	9	3		36

Table 6.2b Outcome of feeding dives (successfull / not successful and prey size) of common terns in front of the Haringvlietsluices on 3 May 1991.

Observation period (time in s)	not successful	swallow	size 0,5 bill	size 0,75 bill	size 1,0 bill	size 1,5 bill	size 2 bill	unknown	total
11.20 (1277 s)	10 (22 %)	8 (17 %)			9 (20 %)	2 (4 %)		17 (37 %)	46
11.50 (320 s)	1 (7 %)				2 (14 %)	3 (21 %)	1 (7 %)	7 (50 %)	14
12.00 (661 s)	10 (37 %)	1 (4 %)			7 (26 %)			9 (33 %)	27
14.40-15.30 (1800 s)	2 (2 %)	10 (11 %)			3 (3 %)		1 (1 %)	74 (82 %)	90

Table 6.3 Food items consumed by Common terns at the Haringvlietsluices in May.

species	number
herring	4
smelt	29
flatfish	1
common shrimp	»1
pipefish	2

The largest part of the food species observed or found on the Slijkplaat are saltwater species (table 6.4), but also some freshwater species are found like perch (*Perca fluviatilis*) and rudd (*Scardinius erythrophthalmus*). Most common species found during the young-rearing period was the herring. It is unknown if this species is the basic food in this period, but it proves that during this period the area in front of the Haringvlietsluices remains an important feeding area.

Table 6.4 Food items observed or found at the Slijkplaat.

species	egg-laying period (May)	young-rearing period (June)
smelt	2	
goby	1	
three-spined stickleback	1	
perch	1	
fish unknown	1	
eel		1
herring		7
rudd		1

6.7 Westplaat

In April, before the laying period, no common terns were seen on the Westplaat. Also there were no terns foraging in the vicinity. In May during the laying period the birds were partly foraging in front of the Haringvliet-sluices and partly in the surroundings of the Westplaat. There were only birds foraging directly in front of the sluices when the sluices discharge into the sea (see 5.6.4). No observations were made during the incubation period and the period with young, but probably the same feeding areas were used.

During observations on 7 May 22 prey items were identified. Smelt and herring were the most numorous food items with resp. 14 and 5 ex. Other prey species were goby (*Pomatoschistus spec.*) and three-spined stickleback. Most food items measured between 1.5 and 2.5 times the bill length (table 6.5). On 23 May 19 prey items were identified: 5 smelts and 14 herrings.

Table 6.5 Observations of the food choice on the Westplaat during the laying period.

size		Observations on 7 May		
(* bill length)	herring	smelt	goby	stickleback
1			1	
1.25		1	1	
1.5	1	2	1	
1.75		1		
2	1	5		
2.25		2		
2.5	2	2		
?		1		1
size		**Observations on 23 May**		
(* bill length)	**herring**	**smelt**	**goby**	
1.5		2		
?	14	3	1	

During every visit the colony was checked for not consumed food items. Herring was the most abundant food species (table 6.6). Only one flatfish was found. In contrast with the observations in May no smelt was found in the colony in June and July.

Table 6.6 Not eaten food items collected in the colony on the Westplaat in June and July.

length in cm	herring	flatfish
0 -1.0		
1.1 -2.0		
2.1 -3.0	2	
3.1 - 4.0		
4.1 - 5.0	2	1
5.1 - 6.0	2	
6.1 - 7.0	8	
7.1 - 8.0	1	
8.1 - 9.0	4	

6.8 Zeewolde

On 9 and 10 May, which was shortly before the first peak of egg-laying, hundreds of common terns were observed foraging on emerging midges (chironomids). They were accompanied by many black-headed gulls, 150 black terns and 200-300 little gulls. In this period the 'spring-wave' of chironomids emerges in a short time. Later in the season common terns were observed diving for fishes.

During the control visits in the colony a total of 40 pellets could be sampled between 11 and 28 June. In four of these the remains of insects were present. Even in the period in which the pellets were found the proportion of insects in the food may have been higher, as pellets with insects were more difficult to find between the vegetation.

In 39 pellets fish remains were found. Using otoliths and other skeletal parts, species and length of the majority of the fishes could be established. A total of 131 individuals was found, a mean of 3.3 fishes/pellet (table 6.7). Ruffe (*Gymnocephalus cernuus*) was the most commonest species, being present in 73% of the pellets. Cyprinids were found in 50% of the pellets. In most cases these were roaches (*Rutilus rutilus*), bream (*Abramis brama*) was only identified twice. Perch and smelt both occurred in approximately a quarter of the pellets. The length of all these fishes varied between 5 and 12 cm. Three-spined stickleback was not found in the pellets, but this can be the consequence of the species' size: after digestion possibly no parts remain. On 14 June an undigested and regurgitated stickleback was found at nest 83.

Table 6.7 Number of fish in pellets per species, number of pellets in which these were found and mean fishlength, Zeewolde 1991.
Fishlength (as total lenth) was calculated using the following formulae:
Roach: FL = 1.494*CB + 1.472, Spiering: FL = 3.4096*OL - 0.479,
Perch: FL = 2.810*OL - 0.340, Ruffe FL = 2.1448*OL - 0.362
Formulae calculated by T. Piersma (unpubl.), using small fish from the IJsselmeer. FL = fishlength, cm, OL = otolith length, mm, CB = cyringeal bone length, mm.

species	fish n	pellets n	fish-length cm	s.d.	range cm	n
Roach	18	10	7.6	2.0	6.2-11.3	11
Bream	2	2				
Cyprinid sp.	17	13				
Smelt	33	10	6.2	1.1	5.3-10.4	30
Perch	14	11	7.4	0.9	6.4- 9.2	8
Ruffe	47	29	8.5	1.1	6.5-11.2	46
Total	131	40				

In the winter 1990-91 a large-scale fish removal was carried out as part of 'Active Biological Management' in the Wolderwijd. The aim of removing the bottom-dwelling and zooplankton consuming fish was to diminish the resuspension of bottom material and to minimize the growth of phytoplankton through enhanced grazing by a.o. Daphnia. It was expected that the transparency of the water would increase, which would stimulate the ecological restoration of the lake. As a consequence of the fish removal, the fish stocks decreased from 203 kg/ha in October 1990 to 46 kg/ha in June 1991. In October 1991 the biomass had increased to 115 kg/ha, mainly because of a remarkable growth of the quantity of Ruffe (Van Nes et al. 1992). The production of cyprinids was relatively low, probably because of the cold spring. Because of the large-scale fish removal and the low reproduction of cyprinids the fish stock avaliable for the terns in spring was relatively small. On the other hand, the transparency of the water was extremely high in May and June, making the fish present easier to detect.

Smelt, not very abundant in the lake but regularly found in the pellets, lives close under the surface during daylight conditions. It can therefore be caught by the terns using their 'plunge-diving' technique. The same holds, a little less strongly, for roach. Young bream, found only twice in the pellets, lives usually at greater depth (pers. comm. E.H.R.R. Lammens). Ruffe is exclusively found near the bottom, and for the terns it is almost impossible to catch this species while plunge-diving. The large number of Ruffe in the pellets indicates the terns have been fishing around fishermen's vessels. Especially in this time of the year large amounts of Ruffe get caught in eelfikes, en after emptying these most of the fish are floating on the water. However, eelfikes have not been used in the Wolderwijd in this period. The ruffe therefore has to be caught elsewhere, presumably in the Veluwemeer.

For a more detailed account of the data and conclusions presented in this paragraph see Noordhuis et al. (1993).

6.9 Griend

Common terns breeding on Griend mainly forage within the Wadden Sea: in water above tidal flats and in gullies. Their food consists of the same species as found in the other coastal colonies: clupeids (herring and sprat), sandeel and to a lesser extent flatfish and crustaceans.

6.10 Discussion: comparison of colonies

Terns from five of the colonies were foraging on saltwater-prey exclusively: Saeftinge, Terneuzen, Zeebrugge, Westplaat and Griend. In the colonies along the Westerschelde clupeids are the main prey, while Smelt was more important on the Westplaat. On Griend, both clupeids and ammodytids are imporant prey for common terns. For the breeding birds on the Prinsesseplaat no detailed information on species composition is available, but the prey they catch in the Oosterschelde will be comparable to what was found in the other saltwater colonies. Especially in the beginning of the season however, substantial numbers of foraging birds were observed within the Zoommeer, feeding on freshwater prey. Emerging Chironomids probably were an important prey for these birds. In Zeewolde Chironomids were certainly important in the beginning of the season, later on being replaced by freshwater fish.

Two points in this overview are especially important in relation to the aim of this project. The first one is that clupeids, mainly herring, is an important prey for terns from most of the saltwater colonies. This may mask possible differences between colonies with regard to local contamination effects, as these small herring which migrate into the respective feeding areas in spring have a common background: they are born at the North Sea a few months earlier. A second important point is the fact that in freshwater habitats emerging Chironomids are an important prey in early spring. This of course is important with regard to the interpretation of possible effects of contaminants: when comparing the colonies, habitat differences occur together with food type differences.

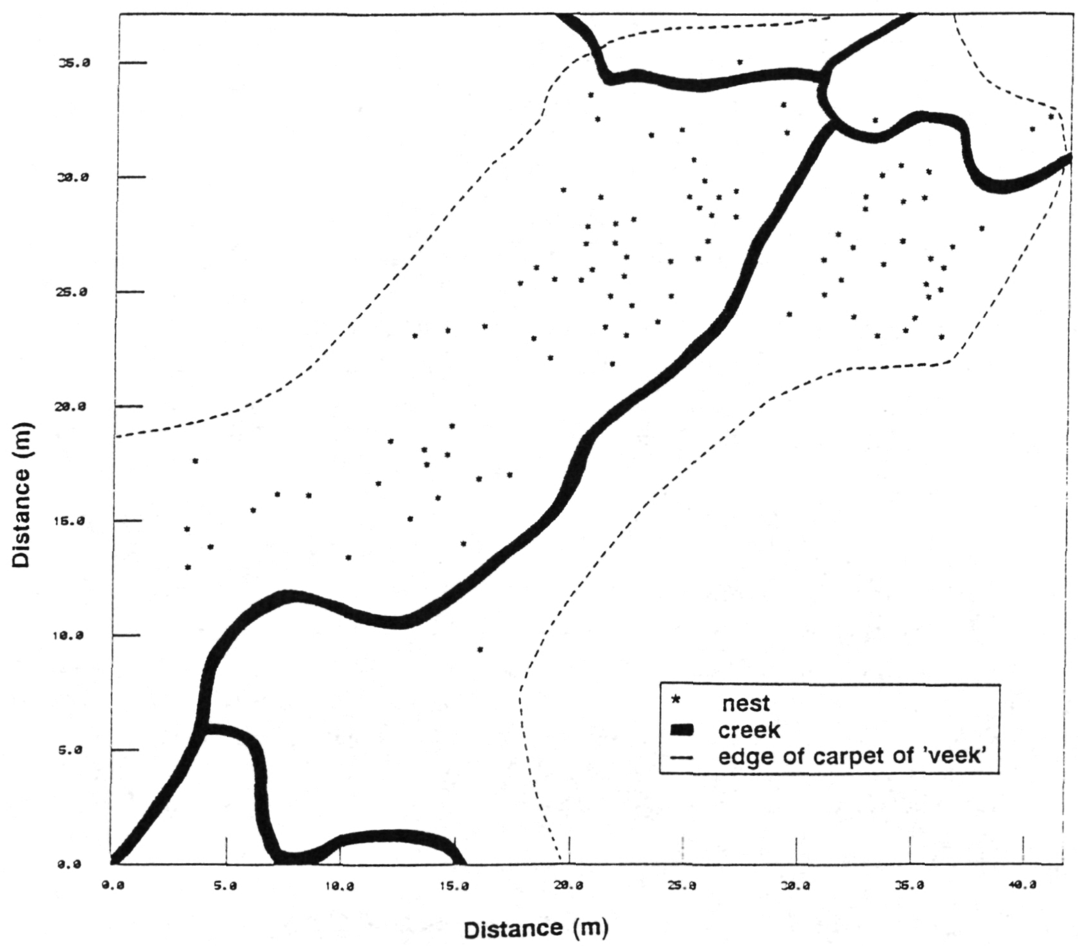


Figure 7.1 The colony of common terns on the 'Konijnenschor' with the location of the nests, the creeks and the carpet of 'veek'.

7 BREEDING BIOLOGY: EGG-LAYING, BREEDING AND HATCHING SUCCESS

7.1 The 1991 breeding season

7.1.1 Saeftinge

During the first visit (29 April) few common terns were seen in the surroundings of the area. After that date the number of birds increased as did the courtship activity. The first clutches were found on 22 May. The colony grew very rapidly with a peak on 24 May. After that date the rate at which new clutches appeared decreased very rapidly. A total of 107 clutches was reached on 3 June.

In 1991 the breeding population of common terns at Saeftinge consisted of a total of 500 pairs in three sub-colonies (figure 5.2). Only the population breeding on the 'Konijnenschor' (107 pairs) was monitored in this study (figure 5.2, colony A). The colony was situated on 'veek' covering an area of about 900 m^2 (figure 7.1). Veek is a 'carpet' of dead plant material, mainly reed and sea aster (*Aster tripolium*). The colony was intersected by several creeks (figure 7.1).

The vegetation on the edges of the 'carpet of veek' consisted mainly of sea aster and maritime club-rush.

Adjacent to the common tern colony, several pairs of black-headed gull were breeding. Although in a few cases eggs of common tern were predated, no mass predation by black-headed gulls was observed. During a very high tide on 13 June the colony was flooded, which resulted in a transposition of the colony and a mass loss of eggs. Seventy six clutches were washed away and in the remaining clutches several eggs were cooled down. Also a number of chicks just hatching drowned. Although some of the nests were transposed over a distance of 10 to 20 m, several were not abandoned.

7.1.2 Terneuzen

From the 23 April the first common terns were visiting the breeding site. After that date the number of birds seen at the colony gradually increased, as did the courtship activity. The first egg was found on 13 May. After that date the colony rapidly grew and reached a number of 77 nests on 29 May. From then on the rate at which new clutches appeared gradually decreased. A total of 145 clutches was reached on 6 June (figure 7.2).

Only two other bird species bred on the plateau: one pair of oystercatcher and one pair of kentish plover.

There was a lot of human activity in the surroundings of the colony. Passing boots, cars, opening and closing bridges created a lot of disturbance: every time a boot entered or left the nearby sluice the common terns went on the wing.

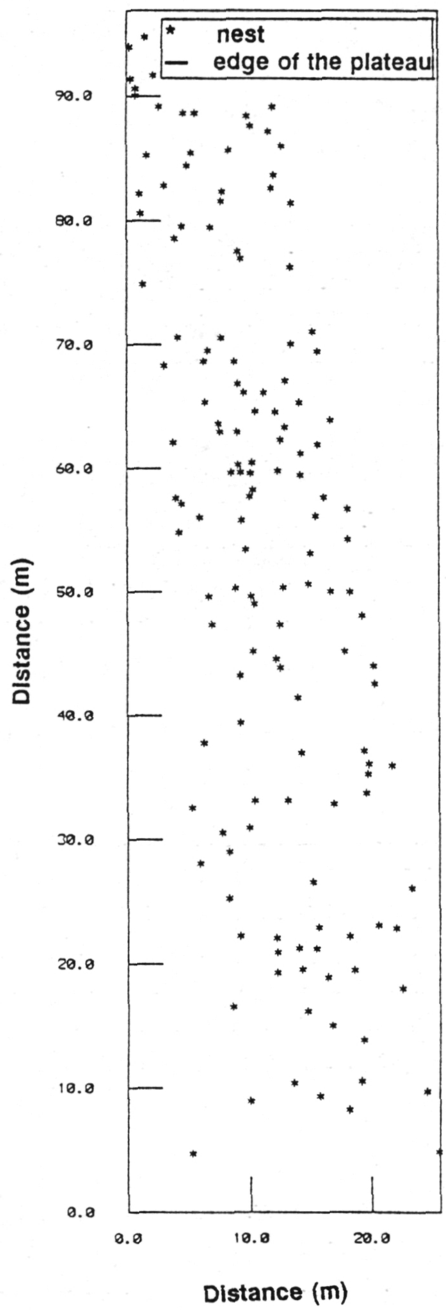


Figure 7.2 Location of the nests on the colony of Terneuzen.

The birds of this colony were very aggressive and attacked every person who came within a distance of 50 m of the nests. When a possible predator like magpie (*Pica pica*), carrion crow (*Corvus corone*), black-headed gull or herring gull came in the surroundings of the colony, it was mobbed by the whole colony and persued for several dozens of meters. Maybe as a result of this behaviour we did not observe any predation.

7.1.3 Zeebrugge

During the first visit to the area (7 May) several common terns were seen. A lot of courtship activity was observed: males carrying fish around the colony and displaying them to prospective mates ('pair-formation' phase; Nisbet 1977).

The first nests were found on 20 May. Probably more nests were already present but due to the extensiveness of the area it was impossible to find them all. From that day on the colony grew rapidly: on 30 May 212 nest were counted. On 8 June 245 nest had been marked. After that date the colony kept on growing but no supplementary nests were marked. The total population was estimated at 650 pairs.

Several other bird species were breeding in the area as well. A pioneer dune overgrown with marram (*Ammophila littoralis*) at the edge of the raised terrain held a colony of at least 600 pairs of black-headed gull, about 950 pairs of sandwich tern and 4 pairs of herring gull. More dispersed in the raised terrain about forty pairs of black-headed gull, at least 45 pairs of kentish plover, 3 pairs of oystercatcher and 1 or 2 pairs of lesser black-backed gull were breeding. A population of 134 pairs of little tern was situated in the south of the area.

Although no mass predation was observed, on several occassions eggs and nest disappeared and eggs were found broken. Common tern returning from their feeding grounds with prey often were persued by black-headed gull and herring gull (kleptoparasitism) .

7.1.4 Kleine Prinsesseplaat and Grote Prinsesseplaat

On the Kleine Prinsesseplaat the first egg was found on 15 May. More than 60 clutches were initiated in the two weeks after this date. However, from many of these clutches one or more eggs disappeared rapidly, mainly as a result of predation. Initially crows or gulls were held responsible, although often the eggs were not taken away, but were left in pieces in the nest. However, after establishing a relatively high predation rate, we began to suspect some of the oystercatchers breeding in the area. While checking clutches we noticed interactions between terns and oystercatchers, and found destroyed eggs in nearby nests afterwards. This was confirmed through observations from a hide on 27 May. Oystercatchers were indeed seen pecking in common tern nests several times. At least once an indidvidual seemed to swallow something, but the birds did so as well in nests that were known to be empty. They also 'incubated' several times on empty common tern nests.

Because only few 3-clutches were left due to the predation described, it was decided to continue the observations on the Grote Prinsesseplaat. Most of the common tern nests on the Grote Prinsesseplaat had already been marked for a breeding bird census, but no detailed breeding biology data were available. A lot of data therefore lack for many of the clutches.

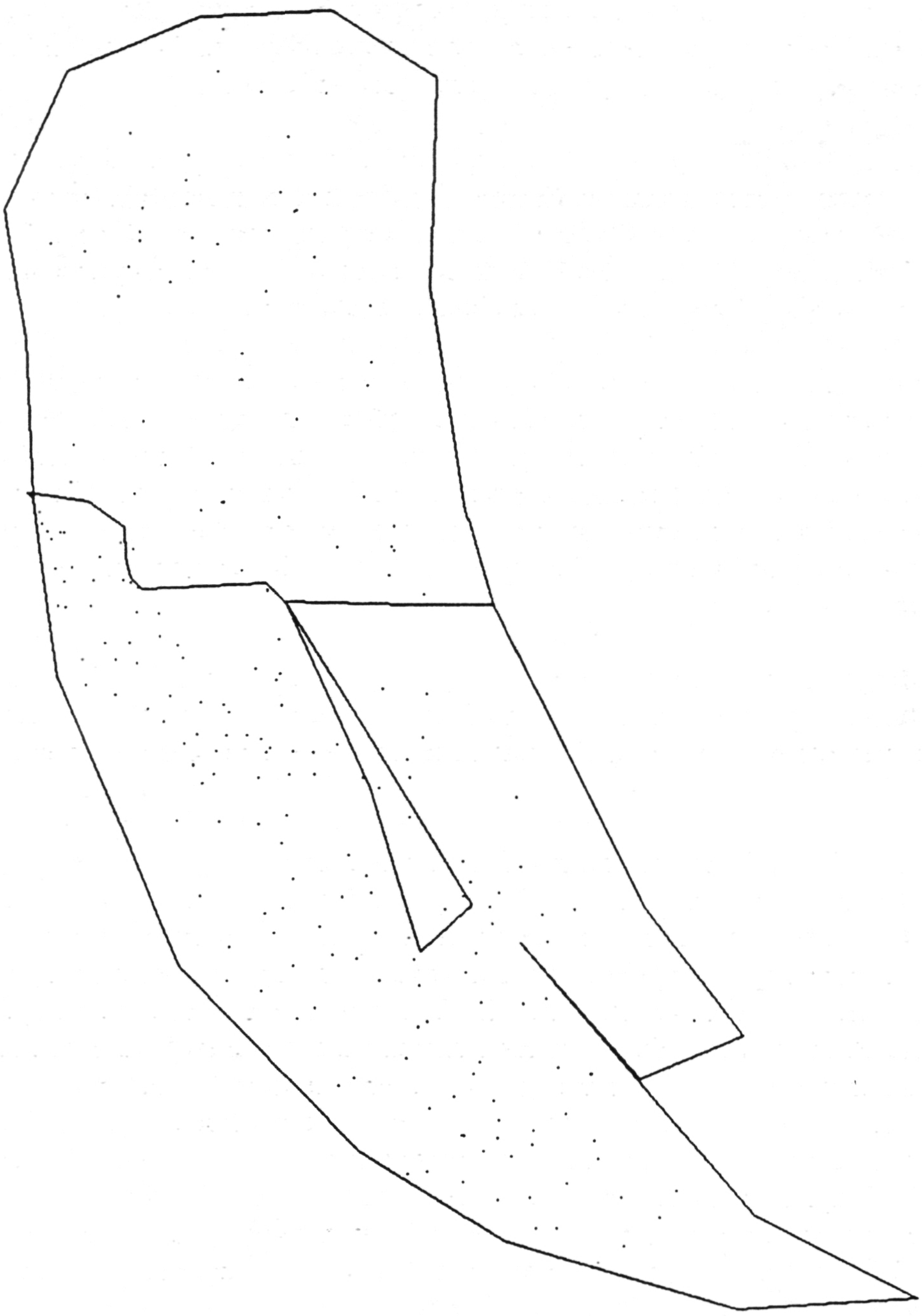


Figure 7.3 Location of the nests on the Westplaat. The southern part is the highest area on the island.

In June many chicks died during and after a period of heavy rainfall (see chapter 4). An important factor in this was the soil composition, which prevented draining of the water: a layer of 5-10 cm water was formed over a large surface in the colony.

7.1.5 Slijkplaat

The first eggs were found on 15 May. The number of clutches on the island increased rapidly. As it was impossible to mark and follow all nests (and it was not planned to do so as well) an estimate of the total number had to be made. The total estimate is 1100 nests. There were no signs of predation other than a few eggs probably taken by gulls. The rains only had direct negative influence on chicks. Because of the sandy character of the soil, the water disappeared quickly so that no water remained on the surface like on the Prinsesseplaat. Water levels did not exceed critical values for the higher parts of the island. Only on the west side of the islands some nests were washed away during a period with relatively high water levels (mid-June). A major problem, both for the researchers and some of the terns was the rapid growth of thistles. Quite some nests got completely overgrown and were difficult to find. Some nests appeared to have been deserted for this reason.

7.1.6 Westplaat

The first egg was found on 15 May. After this the colony rapidly grew to a total of 88 clutches by 31 May. In the end of June a clear second peak in laying was observed (see- 7.2). The distribution of the nests is in figure 7.3. The first clutches were laid on the highest parts of the island, while the lower parts were occupied in later stages as well.

Although some egg-predation took place (see 7.7.6), no mass predation, e.g. by gulls in periods of bad weather, was observed. Around 10 clutches were moved or washed away completely during a period of high tides in June. Some of these nests were situated on the lower parts of the island. Others disappeared because they were located too close to the western edge of the higher part of the island: several decimeters of this 'cliff' eroded into the sea.

7.1.7 Zeewolde

On 15 May the first clutches were found, but some of these must have been started as early as 10 May. In about three weeks ca. 150 clutches were started. However, many yound died within a few days after hatching. This was probably caused by the rainy and cold weather in that period (see chapter 4) and possibly also by a shortage of food. A second wave of clutches was started, which again consisted of about 150 clutches. It is tempting to believe that these were predominantly birds that laid a second clutch. The number of breeding pairs in 1991 has therefore been estaimated at 180.

Although the area is closed for the public, disturbance by visitors was established several times during the breeding season. In a few cases the numbered pegs were

Table 7.1 Colony, colony size (number of clutches studied), mean laying date, range of the period of laying, duration of the period of laying (days), range of the peak period, duration of the peak period (days) and the percentage of clutches started during the peak period (%). One Way Anova-Duncan Ranges showing significant differences in mean laying date between pairs of colonies (*) at the 0.05 level of the different colonies are given in the scheme below the table.

colony	colony size	mean laying date ±SD (days)	range of the period of laying	duration (days)	range of the peak period	duration (days)	%
Zeewolde	317 (317)	4 June (17.8)	11 May - 9 July	60	11 May - 1 June	22	45
Griend	1500 (30)	18 May (1.2)	15 May - 21 May	7	18 May - 21 May	4	67
Saeftinge	107 (107)	25 May (1.7)	22 May - 3 June	13	22 May - 25 May	4	88
Terneuzen	145 (145)	31 May (9.8)	13 May - 6 July	55	23 May - 26 May	4	37
Zeebrugge	650 (245)	25 May (4.4)	19 May - 8 June	21	19 May - 29 May	11	78
Kl.P. Plaat	64 (64)	21 May (3.5)	13 May - 27 May	15	16 May - 27 May	12	95
Gr.P. Plaat	181 (181)	1 June (12.0)	13 May - 26 June	45	19 May - 5 June	11	71
Westplaat	195 (195)	8 June (19.0)	12 May - 1 July	50	18 May - 12 June	26	64
Slijkplaat	420 (420)	26 May (10.3)	12 May - 19 June	39	15 May - 5 June	18	73

Mean laying date	colony	1	3	2	5	4
25 May	1					
26 May	3					
31 May	2	*	*			
4 June	5	*	*	*		
8 June	4	*	*	*	*	

Colonies: 1 Saeftinge, 2 Terneuzen, 3 Slijkplaat, 4 Westplaat, 5 Zeewolde.

removed from some nests. Along the edges sand was digged off, but this did not affect the common terns nor their nests. Although some nests close to black-headed gull nests seemed to suffer from predation by this species, there were no signs of severe predation pressure by e.g. crows or mammals.

7.1.8 Griend

Brenninkmeijer & Klaassen (1991) describe the common tern's season on Griend in 1991. On 16 May 1991 the first egg was found, and around 9 June the first young. On top of the generally bad weather, a storm with a high tide on 16 June caused the flooding away and/or predation of most of the eggs and young. From 22 June onwards replacement clutches were produced, but these were not very successful. Brenninkmeijer & Klaassen established a total of 1900 pairs. Breeding success of common terns on the island as a whole was estimated at 0.13 young/nest (Brenninkmeijer & Stienen 1992).

7.2 Egg-laying date

The daily number of clutches started in each colony is shown in figure 7.4. Timing of laying, duration of the period of laying, duration of the peak period, mean laying date, and the percentage of clutches laid in the peak period are summarised in table 7.1.

The timing of onset of laying was well synchronised between colonies (between 13 and 15 May) with the exceptions of the southern situated colonies of Saeftinge and Zeebrugge. On the other hand, in the duration of the period of laying some important differences can be observed. Due to the heavy predation of the eggs at the Kleine Prinsesseplaat, the observations were stopped causing an artificially short laying period in the data. As the colony of Zeebrugge was not monitored during the whole period of laying, the duration of 21 days is actually much longer. In the colony of Griend nests were marked until 23 May, after which no additional nests were checked. In the colony of Saeftinge the duration of the period of laying of 13 days was very short in comparison with the period of 60 days of the colony of Zeewolde. The duration of the periods of the other colonies is somewhat in between.

Saeftinge was the only colony breeding synchronously: 88 % (94 out of 107) of the clutches were started during the first four days after the first egg (22 May) and the egg-laying was completed on the 3 June. This in contrast to most other colonies in wich several clutches were started before the peak period. The longer period of laying in the colonies of the Westplaat and Zeewolde resulted in a less pronounced and longer peak period than in the other colonies. Remarkable is the absence of early breeders in the colony of Zeewolde in spite of the fact that it was the colony with the most prolonged period of laying. The peak of the southern colonies fell some days later than did the peaks of the more northern colonies. The duration of the peak period was also shorter in the southern colonies.

Differences in mean laying date between the colonies of Saeftinge, Terneuzen, Slijkplaat, Westplaat and Zeewolde were tested with a One Way Anova and were statistically significant ($N=1170$, $D.F.=4$, $F=41.2797$, $P<0.00001$). The Westplaat was the colony with the latest mean laying date and showed to be significantly later than the four other colonies (table 7.1).

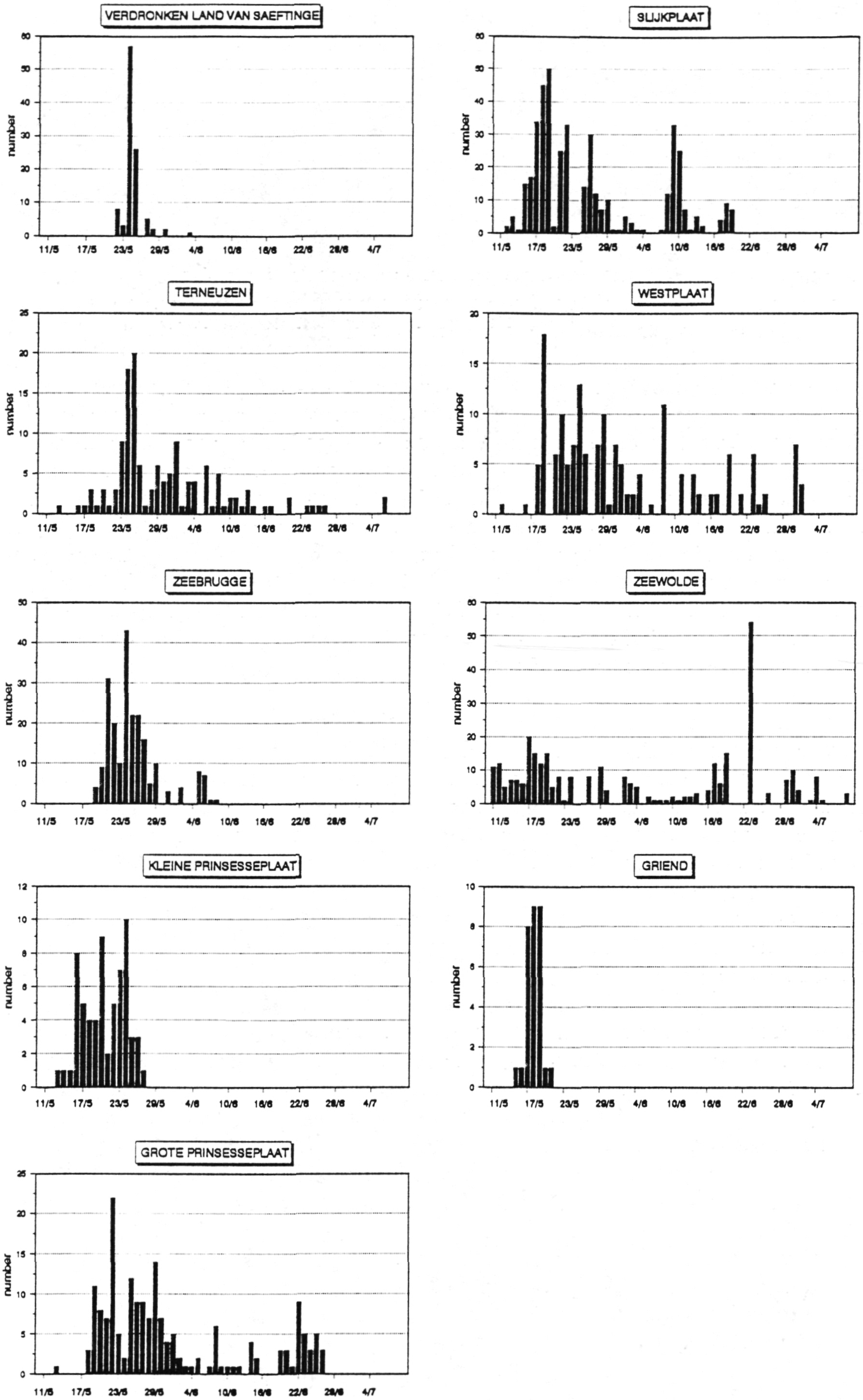


Figure 7.4 Number of clutches started during the breeding season of 1991 in the different colonies.

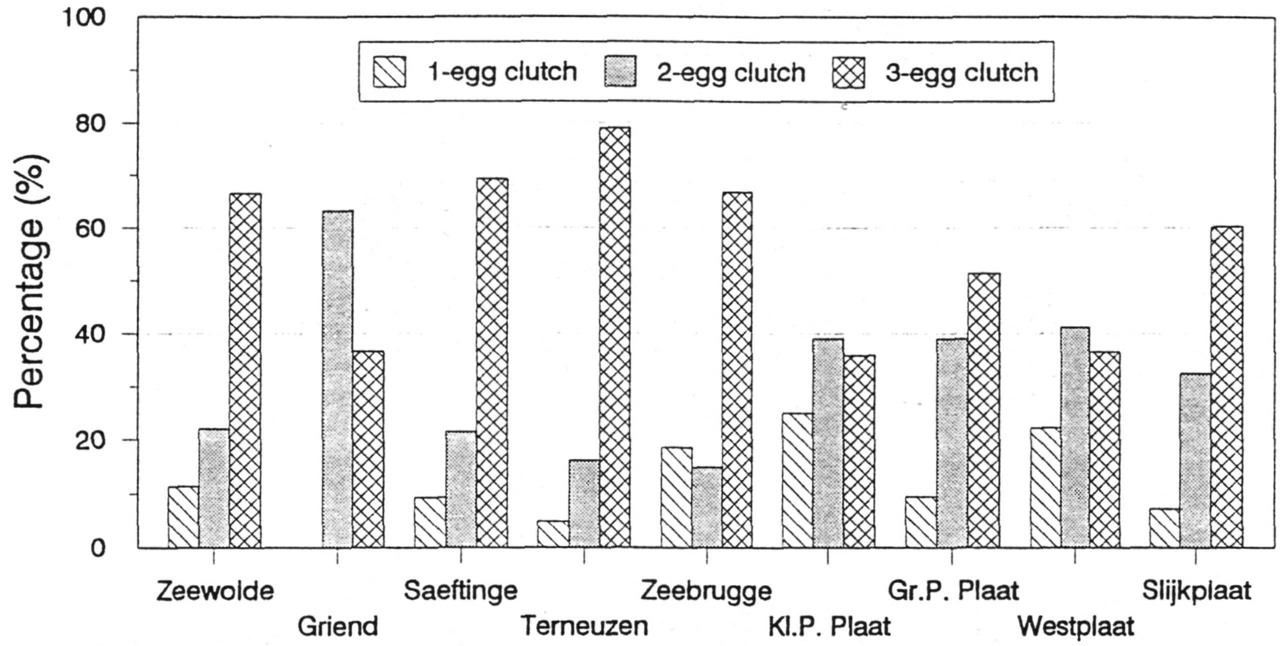


Figure 7.5 Proportion (%) of clutches of different size.

7.3 Clutch size

7.3.1 General

From figure 7.5 a clear pattern in the proportion of different clutch sizes among colonies can be seen: in the colonies of Saeftinge, Terneuzen, Zeebrugge and Zeewolde the proportion of 3 clutches is much higher than in the colonies of the Kleine Prinsesseplaat, Grote Prinsesseplaat and the Westplaat. The colony of the Slijkplaat stands somewhat in between.

The percentages of different clutch sizes and mean clutch size of the different colonies are presented in table 7.2. The distribution of clutch size was significantly different between the colonies (X^2=151.83, D.F.=21, $P<0.0001$) as was the mean clutch size (Kruskall-Wallis One Way Anova, N=1673, X^2=99.4195, $P<0.0001$). The largest mean clutch size was recorded in Terneuzen due to the high proportion of 3-clutches. The mean clutch size of this colony was significantly larger than that of other colonies with the exception of Saeftinge (Kruskal-Wallis One Way Anova-Multiple Comparisons; level of significance P=0.05).

Table 7.2. Proportion (%) of clutches of different sizes laid by terns nesting on the different colonies, mean clutch size and number of clutches studied of the different colonies.

colony	clutch size 1	2	3	4	mean clutch size	(± SD)	N
Zeewolde	11.4	22.1	66.6	0.0	2.55	(0.69)	317
Griend	0.0	63.3	36.7	0.0	2.37	(0.49)	30
Saeftinge	9.3	21.5	69.2	0.0	2.60	(0.66)	107
Terneuzen	4.8	15.9	77.9	1.4	2.76	(0.56)	145
Zeebrugge	18.4	14.7	66.5	0.4	2.49	(0.79)	245
Kl.P. Plaat	25.0	39.1	35.9	0.0	2.11	(0.78)	64
Gr.P. Plaat	9.4	38.7	50.8	1.1	2.44	(0.67)	181
Westplaat	22.2	41.2	36.6	0.0	2.14	(0.75)	194
Slijkplaat	7.1	32.4	60.0	0.5	2.54	(0.63)	420

7.3.2 Clutch size and laying period

Table 7.3 presents the mean clutch size among colonies at the different periods. In the colonies of Terneuzen, Zeebrugge, Grote Prinsesseplaat, Slijkplaat and Zeewolde the differences in clutch size between the different periods were statistically significant. Although not that clear in every colony, a trend of decreasing clutch size with time is present.

Table 7.3 Mean clutch size of the different colonies at different periods (period 3 = 10 May - 14 May; period 4 = 15 May - 19 May;...). (Kruskal-Wallis One Way Anova with level of significance P (***: P<0.0001); **: P<0.01; *: P<0.05; NS: P>0.05; Chi-Square value (X^2)).

	period 3	4	5	6	7	8	9	10	11	12	13	14	15	N	P	X^2
Zeewolde	2.9	2.8	2.5	2.9	2.7	2.8	2.4	2.5	2.3	2.3	2.3	1.7	2.7	317	***	54.77
Griend		2.4	2.0											30	NS	1.20
Saeftinge			2.6	2.6	2.3									104	NS	0.20
Terneuzen	3.0	3.2	3.0	2.9	2.4	2.9	2.9	2.7	3.0	1.7	2.0			136	**	31.35
Zeebrugge		3.0	2.7	2.4	1.3	1.4								216	***	57.52
Kl.P. Plaat	3.0	2.2	2.0	2.0										64	**	4.04
Gr.P. Plaat	3.0	2.7	2.6	2.7	2.2	2.0	2.0	2.0	2.1	2.2				181	**	31.06
Westplaat	1.0	2.1	2.3	2.3	2.1	2.0	2.1	2.3	2.2	2.3	2.0		2.0	194	NS	9.84
Slijkplaat	2.6	2.7	2.7	2.4	2.2	2.3	2.3	2.5	2.6					420	***	39.74

7.3.3 Clutch size of early, peak and late breeders

As can be seen in table 7.4 and figure 7.6 the clutch sizes of early, peak and late breeders were significantly different and showed a clear trend: clutch size decreased from early to late clutches. Although a decline from peak to late was observed in Saeftinge and the Westplaat as well, the difference was not significant.

The differences between the clutch size of the different colonies of respectively early, peak and late clutches were significant as well. The mean clutch size of the colony of Terneuzen showed to be the largest in all periods. Table 7.4a,b and c show the results of a multiple comparison of the mean clutch sizes during the early, peak and late period. From this table one can see the mean clutch size of the colony of Terneuzen to be significantly (P=0.05) larger than the sizes of most other colonies, especially during the peak and late period. The most important shifts in the ranking of the colonies occurred from the early to the peak period, probably due to the low number of cases in the early period. From peak to late only the shift of the colony of Zeebrugge is quite remarkable.

7.4 Egg volume

7.4.1 General

Table 7.5 presents the overal egg volume and the mean egg volume in relation to clutch size. The numbers included in this table are shown in figure 7.7.

In most colonies no significant difference (Oneway Anova with the exclusion of clutch 4) in egg volume between clutch size was found nor could a trend be noticed. Only in the colonies of Terneuzen and the Westplaat a significant difference was established: in both colonies the mean egg volume of the 3-clutches was significantly larger than that of the 2-clutches (on the basis of Oneway Anova-Duncan Ranges, for the 0.05 level).

On the basis of a Oneway Anova a highly significant difference between the overall egg volume among colonies was found (table 7.5). Although not all pairs of groups were significantly different at the 0.05 level, most pairs were (Oneway Anova-Duncan Ranges) (table 7.5). Especially the egg volume of the colony of Terneuzen showed to be significantly larger than the volumes of the other colonies.

7.4.2 Egg volume in relation to laying date and clutch size

In figure 7.8 the egg volumes per clutch size of the different colonies are plotted in relation to the period of laying. These figures quite clearly show differences in egg volume between periods and clutch sizes. To test the effect of the period of laying, and to test wether there was an effect of clutch size, a Two Way Anova was used. The results are summarised in table 7.6. A very clear effect of the period of laying is found. The lack of significance in the colonies of Saeftinge, Kleine and Grote Prinsesseplaat, and Griend is due to the low value of N and/or the low D.F.

Table 7.4 Mean clutch size of the different colonies at different periods (early, peak and late). (Kruskal-Wallis One Way Anova with level of significance P (***: P<0.0001; **: P<0.01; *: P<0.05; NS: P>0.05; Chi-Square value (X^2)). A posteriori test showing significant differences in mean clutch size between pairs of colonies (*) at the 0.05 level of clutches laid during the early (a), peak (b) and late (c) period. Remark: Griend was not included in the statistical analysis among colonies.

	early	peak	late	N	P	X^2
Zeewolde	3.00	2.72	2.37	317	***	29.29
Griend	2.30	2.40	-	30	NS	0.28
Saeftinge	-	2.61	2.60	104	NS	0.00
Terneuzen	3.07	2.91	2.65	136	**	11.48
Zeebrugge	-	2.62	1.38	216	***	47.45
Kl.P. Plaat	3.00	2.07	-	64	*	4.34
Gr.P. Plaat	3.00	2.53	2.14	181	***	18.26
Westplaat	1.00	2.20	2.07	194	NS	5.56
Slijkplaat	2.63	2.62	2.30	420	***	20.37
N	42	1102	488			
P	**	***	***			
X^2	22.49	99.60	62.63			

(a) Mean clutch size	colony	8	2	9	6	7	1	4
1.00	8							
2.63	9	*	*					
3.00	6	*	*					
3.00	7	*	*					
3.00	1	*	*	*				
3.07	4	*	*	*				

(b) Mean clutch size	colony	6	8	2	7	3	5	9	1	4
2.07	6									
2.20	8									
2.53	7	*	*							
2.61	3	*	*							
2.62	5	*	*							
2.62	9	*	*							
2.72	1	*	*		*					
2.91	4	*	*	*	*	*	*	*		

(c) Mean clutch size	colony	6	8	2	7	3	5	9	1	4
1.38	5									
2.07	8									
2.14	7									
2.30	9	*	*							
2.37	1	*	*							
2.60	3		*	*						
2.65	4		*	*						

Colonies: 1 Zeewolde, 2 Griend, 3 Saeftinge, 4 Terneuzen, 5 Zeebrugge, 6 Kl. P. Plaat, 7 Gr. P. Plaat, 8 Westplaat, 9 Slijkplaat

Table 7.5 Mean egg volume (ml) in relation to clutch size (1, 2, 3, 4) and mean egg volume of the total population (total). (Oneway Anova with level of significance P (**: P<0.001; *: P<0.05; NS: P>0.05), F-ratio (F) and degrees of freedom (D.F.)). One Way Anova-Duncan Ranges showing significant differences at the 0.05 level in mean egg volume of the different colonies

	1	2	3	4	total	N	P	F	D.F.
Zeewolde	19.57	20.13	19.74	-	19.78	390	NS	1.64	2
Griend	-	20.23	19.69	-	19.98	71	NS	2.35	1
Saeftinge	19.32	19.72	19.31	-	19.37	269	NS	1.45	2
Terneuzen	19.01	19.26	20.14	20.94	20.08	357	**	5.13	2
Zeebrugge	20.19	20.06	19.75	-	19.83	500	NS	2.71	2
Kl.P. Plaat	18.96	19.65	19.92	-	19.71	108	NS	2.24	2
Gr.P. Plaat	20.23	18.68	19.23	-	19.14	55	NS	1.62	2
Westplaat	18.64	18.82	19.25	-	19.05	326	*	4.59	2
Slijkplaat	20.16	19.57	19.60	19.82	19.61	359	NS	0.89	2

				N	2435				
				P	**				
				F	15.00				
				D.F.	8				

Mean egg volume	colony	8	7	3	9	6	1	5	2	4
19.05	8									
19.14	7									
19.37	3		*							
19.61	9		*	*	*					
19.71	6		*	*	*					
19.78	1		*	*	*					
19.83	5		*	*	*	*				
19.98	2		*	*	*					
20.08	4		*	*	*	*	*	*	*	

Colonies: 1 Zeewolde, 2 Griend, 3 Saeftinge, 4 Terneuzen, 5 Zeebrugge, 6 Kl. P. Plaat, 7 Gr. P. Plaat, 8 Westplaat, 9 Slijkplaat

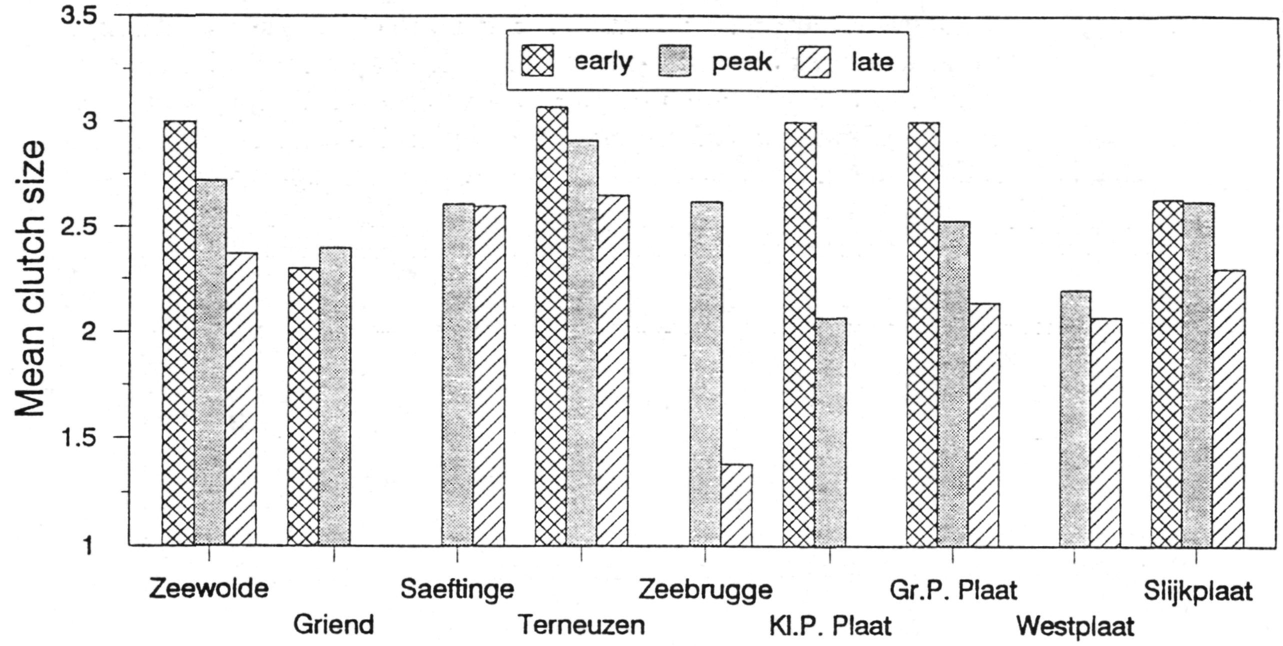


Figure 7.6 Mean clutch size of early, peak and late breeders.

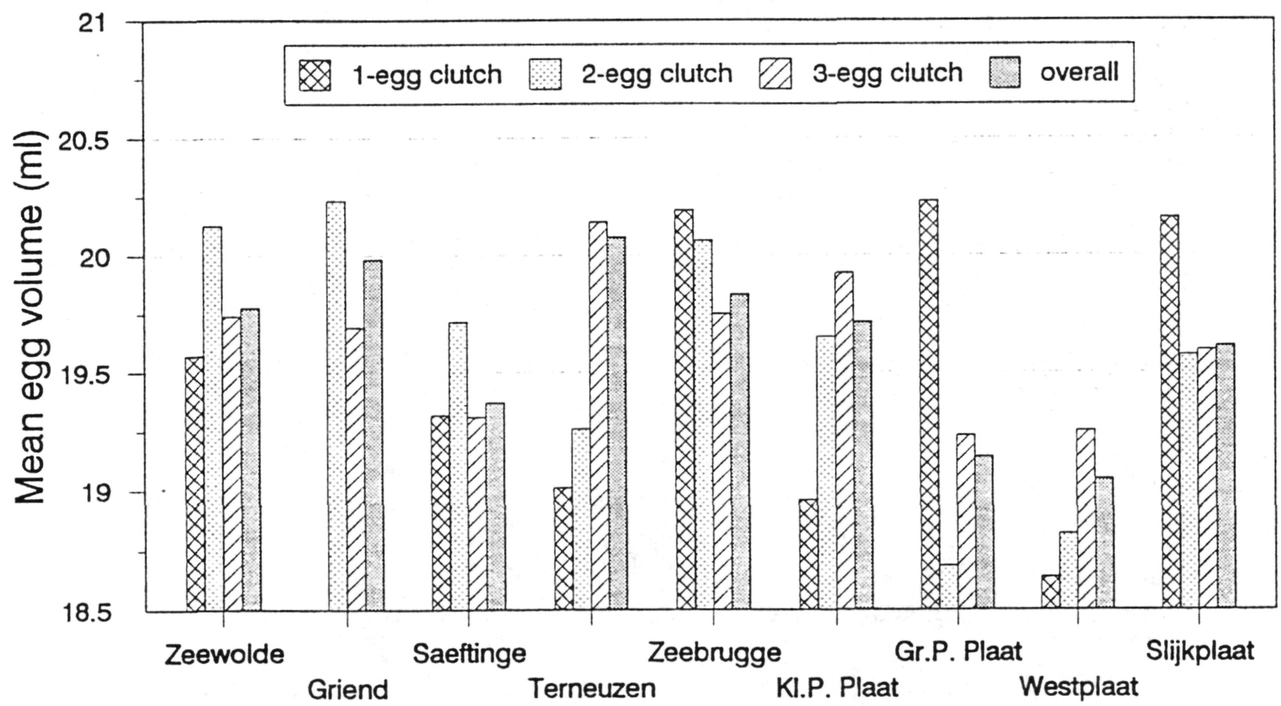


Figure 7.7 Mean egg volume in relation to clutch size and the overall mean egg volume of the different colonies.

Table 7.6 Anova table summarising the results of a Two Way Anova of the egg volume in relation of the period of laying and clutch size. (Oneway Anova with level of significance P (**: P<0.001; *: P<0.05; NS: P>0.05), F-ratio (F) and degrees of freedom (D.F.)).

interactions		Period of laying			Clutch size			2-way		
	N	P	F	D.F.	P	F	D.F.	P	F	D.F.
Zeewolde	390	**	3.90	10	*	3.88	2	NS	0.81	13
Griend	71	NS	0.53	1	NS	0.11	1	NS	0.36	1
Saeftinge	269	NS	0.86	3	NS	1.51	2	NS	0.19	4
Terneuzen	350	**	6.00	7	NS	1.84	2	NS	0.40	6
Zeebrugge	496	**	3.92	5	**	5.07	2	*	2.22	7
Kl.P. Plaat	108	NS	0.64	3	NS	1.85	2	NS	0.50	3
Gr.P. Plaat	55	NS	0.15	5	NS	1.11	2	**	3.65	6
Westplaat	326	*	2.23	10	**	6.25	2	NS	0.35	16
Slijkplaat	355	**	8.01	4	NS	0.14	2	NS	0.51	4

In the colonies of Saeftinge, Terneuzen, Zeebrugge and Griend a trend of decreasing volume was quite clear (figure 7.8), especially with the 3-clutches. In the colonies of the Grote Prinsesseplaat, Slijkplaat and Westplaat a similar trend was present only during the period in which a large number of eggs were laid (25/5-29/5, 30/5-3/6, 4/6-8/6 and 9/6-13/6). Only the colony of Zeewolde showed an increase during that period. The colony of the Kleine Prinsesseplaat did not show a trend at all.

The effect of the clutch size was less pronounced than that of the period of laying. Only at the colonies of Zeebrugge, Westplaat and Zeewolde a significant effect was found. Nevertheless the egg volumes of the different clutch sizes of most colonies showed a trend: the egg volumes of the 2-clutches were larger than the volumes of the 3-clutches in the colonies of Saeftinge, Zeebrugge, Zeewolde and Griend, while in the colonies of Terneuzen and the Westplaat the opposite was true. In the remaining colonies no trend could be seen.

Important to remark are the significant Two Way interactions in the colonies of Zeebrugge and Grote Prinsesseplaat. The significant interaction in Zeebrugge probably was caused by an increasing difference in egg volume of the 2- and 3-clutches. Whereas in the colony of the Grote Prinsesseplaat the interaction is due to the more steep decrease in egg volume of the 2-clutches than of the 3-clutches.

To test the effect of the colony on the egg volume of the different periods and clutches a Three Way Anova was calculated (Griend was excluded). A highly significant difference (N=2160; F=17.573; P<0.01; D.F.=7) between the colonies was found (see 7.4.4). The effect of the period of laying was significant as well (F=13.532; P<0.01; D.F.=6) while the clutch size did not show a significant effect (F=0.160; P=NS; D.F.=2).

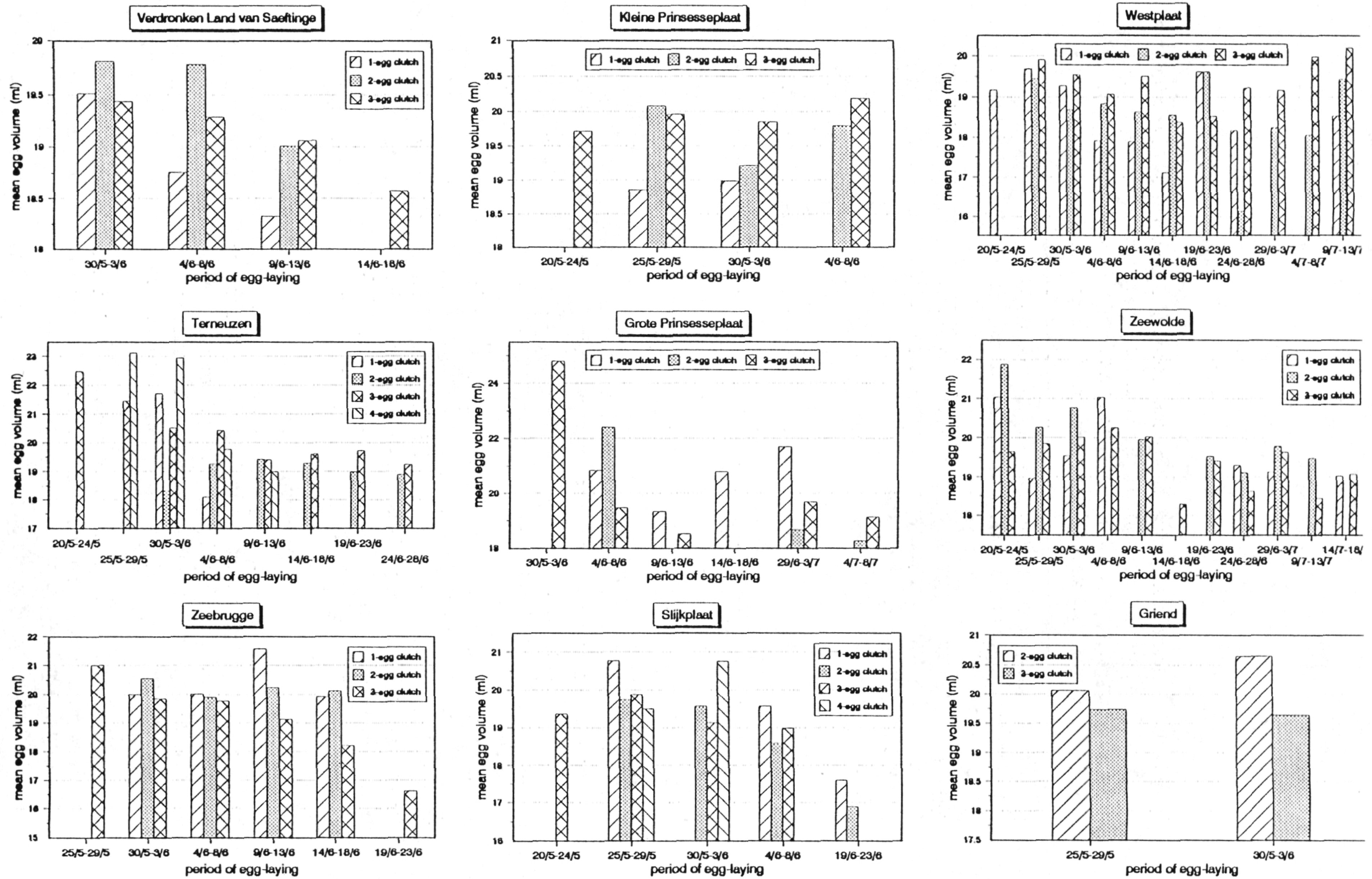


Figure 7.8 The egg volume of the different clutch sizes in relation to the period of laying in all colonies.

7.4.3 Egg volume in relation to laying date (early, peak and late) and clutch size

To simplify the interpretation of the results of the previous paragraph we analysed the egg volume of early, peak and late clutches. The same tests as in paragraph 7.4.2 were repeated. The results are summarised in table 7.7.

In figure 7.9 the egg volumes of the different clutches and the total mean egg volume are plotted in relation to the period of laying (early, peak and late). With the exception of the colonies of the Kleine Prinsesseplaat and the Westplaat, a trend of decreasing total mean egg volume was found, mainly caused by a decrease in the egg volume of the 3-clutches. This trend was significant in most colonies (table 7.7). The effect of clutch size is comparable with the results mentioned in the previous paragraph. Only the colonies of Zeebrugge, the Westplaat and Zeewolde showed a significant difference.

Table 7.7 Anova table summarising the results of a Two Way Anova of the egg volume in relation of the period of laying (early, peak and late) and clutch size. (Oneway Anova with level of significance P (**: P<0.001; *: P<0.05; NS: P>0.05), F-ratio (F) and degrees of freedom (D.F.)).

interactions		Period of laying			Clutch size			2-way		
	N	P	F	D.F.	P	F	D.F.	P	F	D.F.
Zeewolde	390	**	12.38	2	*	4.23	2	NS	0.13	2
Griend	71	NS	0.02	2	NS	2.15	1	NS	0.08	2
Saeftinge	269	*	4.43	1	NS	1.50	2	NS	0.45	2
Terneuzen	350	**	8.81	1	NS	4.31	2	-	-	-
Zeebrugge	496	*	6.39	1	**	4.64	2	*	4.57	2
Kl.P. Plaat	108	NS	1.09	1	NS	2.60	2	-	-	-
Gr.P. Plaat	55	NS	0.01	1	NS	1.23	2	NS	0.51	2
Westplaat	326	NS	0.40	2	*	4.59	2	NS	0.08	2
Slijkplaat	355	*	3.83	2	NS	1.74	2	NS	0.00	1

7.4.4 Egg volume of the different colonies

As described in the previous paragraphs the period of laying and the clutch size have at least in some colonies an effect on egg volume. To compare egg volume of the different colonies we need to exclude the effect of both period and clutch size. Therefore a Twoway analysis on egg volume between clutch size and colony for the peak period data was performed. This Anova (N=1788) showed a highly significant effect of the colony (P<0.0001; F=15.122; D.F.=8) and no effect of clutch size (P>0.05; F=0.087; D.F.=2). Nevertheless on the basis of One Way Anova's some colonies showed significant differences between the egg volumes of the different clutch sizes (table 7.8). The most striking difference in egg volume of the different clutch sizes was found in the colony of Terneuzen: as the colony of Terneuzen had the largests volumes of the 1-and 3-clutches, the volumes of the 2-clutches were the smallest. To exclude the effect of clutch size we used the volumes of the 3-clutches to compare the colonies.

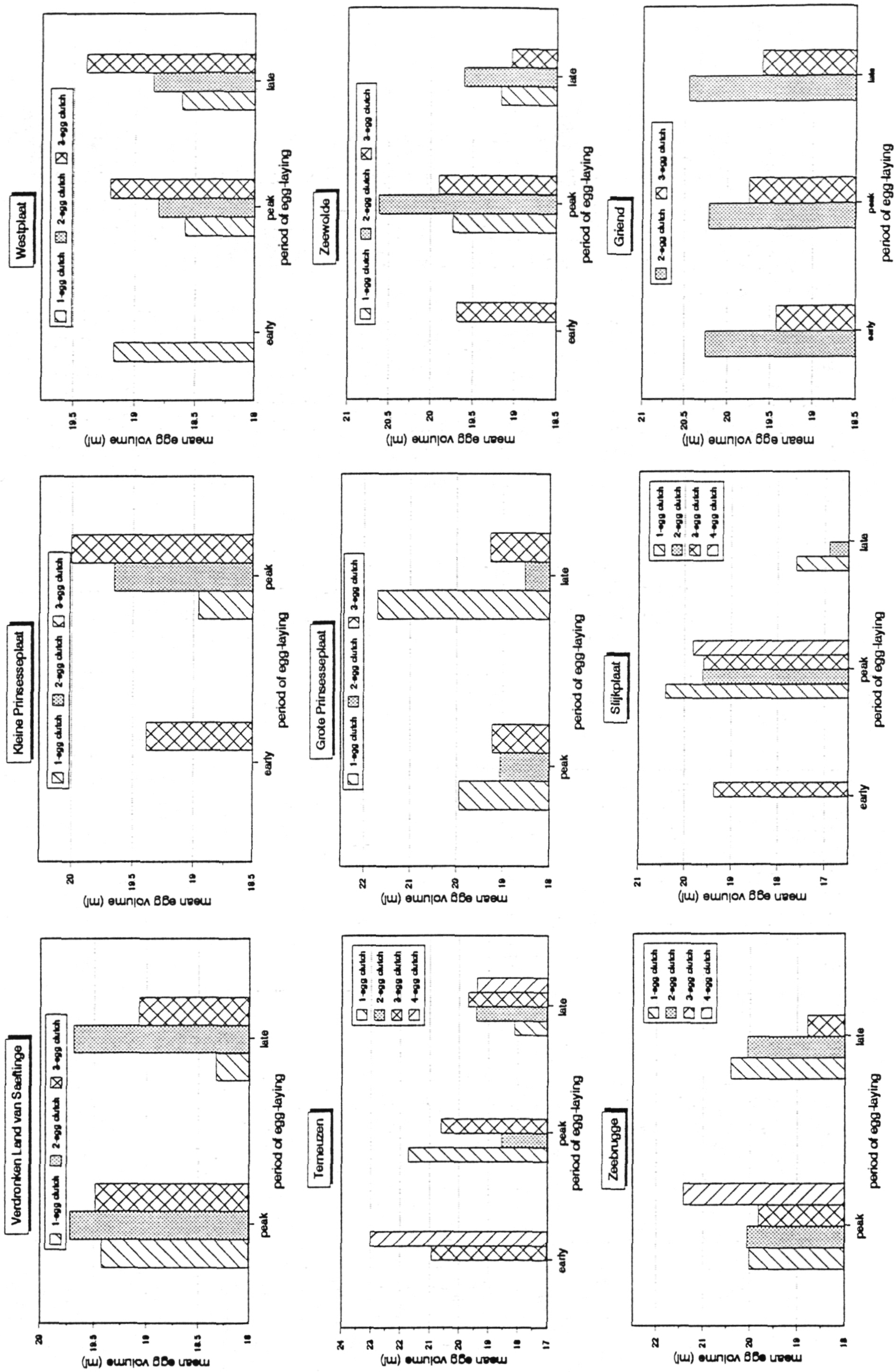


Figure 7.9 The egg volume of the different clutch sizes and the overal egg volume in relation to the period of laying (early, peak and late) in all colonies.

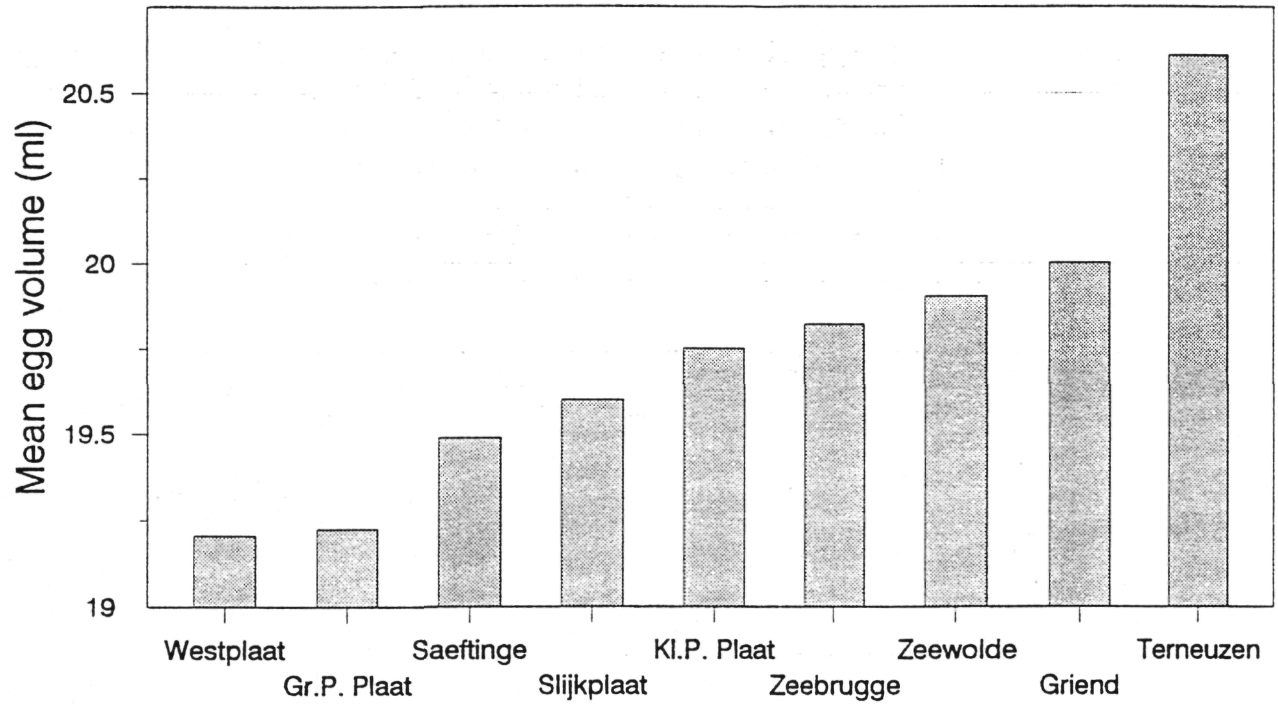


Figure 7.10 The egg volume of the 3-egg clutches laid during the peak period.

Figure 7.10 shows the egg volume of the 3-clutches laid in the peak period. On the basis of a Oneway Anova a highly significant difference between the colonies was found (table 7.8). Although not all pairs of groups were significantly different at the 0.05 level, most pairs were (Oneway Anova-Duncan Ranges) (table 7.8). From the results of table 7.8 a great variation in egg volume between the colonies is quite clear: the largest mean egg volume (Terneuzen) was about 1.5 ml larger than the smallest (Westplaat).

7.4.5 Egg volume and chick measurements

The laboratory experiment provided the possibility of relating egg-volume to some structural measurements, which seemed worthwile to present here. On an individual level eggs with a larger volume yielded heavier chicks (figure 7.11). Not only total weight was correlated with egg volume, but liverweight (figure 7.12) and gutweight (figure 7.13) as well.

Table 7.8 Mean egg volume (ml) in relation to clutch size (1, 2, 3) and mean egg volume of the total population (total) of clutches laid during the peak period. (Oneway Anova with level of significance P (**: P<0.001; *: P<0.05; NS: P>0.05), F-ratio (F) and degrees of freedom (D.F.)). One Way Anova-Duncan Ranges showing significant differences at the 0.05 level in mean egg volume of the 3-clutches laid during the peak period.

	1	2	3	total	N	P	F	D.F.
Zeewolde	19.74	20.62	19.90	19.95	277	NS	2.91	2
Griend	-	20.22	19.75	20.00	53	NS	1.39	1
Saeftinge	19.43	19.73	19.49	19.52	157	NS	0.38	2
Terneuzen	21.72	18.55	20.61	20.53	118	**	5.26	2
Zeebrugge	20.01	20.07	19.82	19.87	440	NS	0.82	2
Kl.P. Plaat	18.96	19.65	20.00	19.74	100	NS	2.50	2
Gr.P. Plaat	19.93	19.06	19.23	19.30	35	NS	0.26	2
Westplaat	18.59	18.81	19.21	19.01	252	*	3.21	2
Slijkplaat	20.41	19.61	19.60	19.63	348	NS	1.66	2
N	87	332	1367	1796				
P	**	**	**	**				
F	3.05	7.50	9.95	15.97				
D.F.	7	8	8	8				

Mean egg volume	colony	8	7	3	9	6	1	5	2	4
19.21	8									
19.23	7									
19.49	3									
19.60	9	*								
19.75	6									
19.82	1	*		*						
19.90	5	*	*	*	*					
20.00	2	*								
20.61	4	*	*	*	*	*	*	*	*	

Colonies: 1 Zeewolde, 2 Griend, 3 Saeftinge, 4 Terneuzen, 5 Zeebrugge, 6 Kl. P. Plaat, 7 Gr. P. Plaat, 8 Westplaat, 9 Slijkplaat

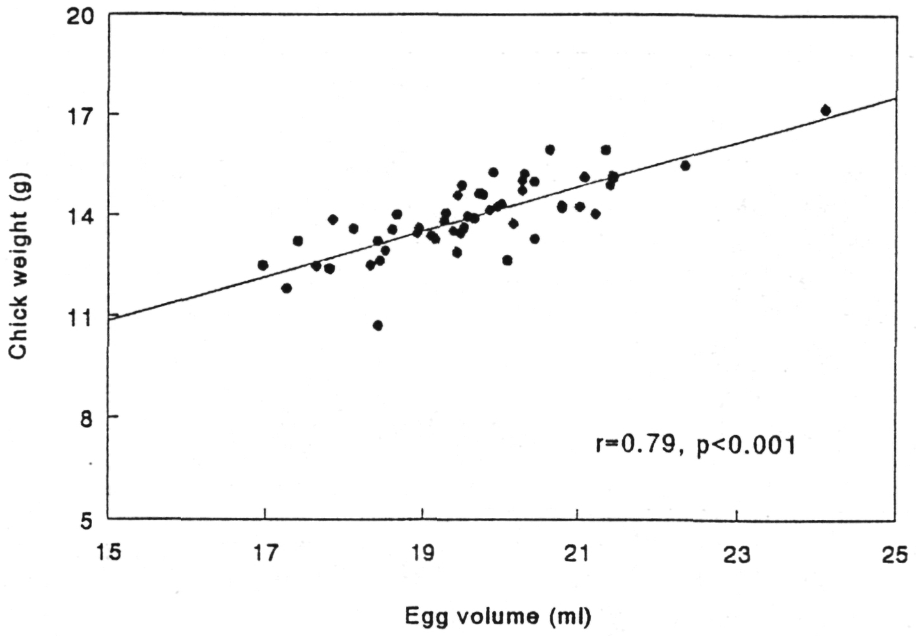


Figure 7.11 The relation between egg volume and chick weight, data of eggs from all colonies hatched in the laboratory experiment (see Murk et al. 1993).

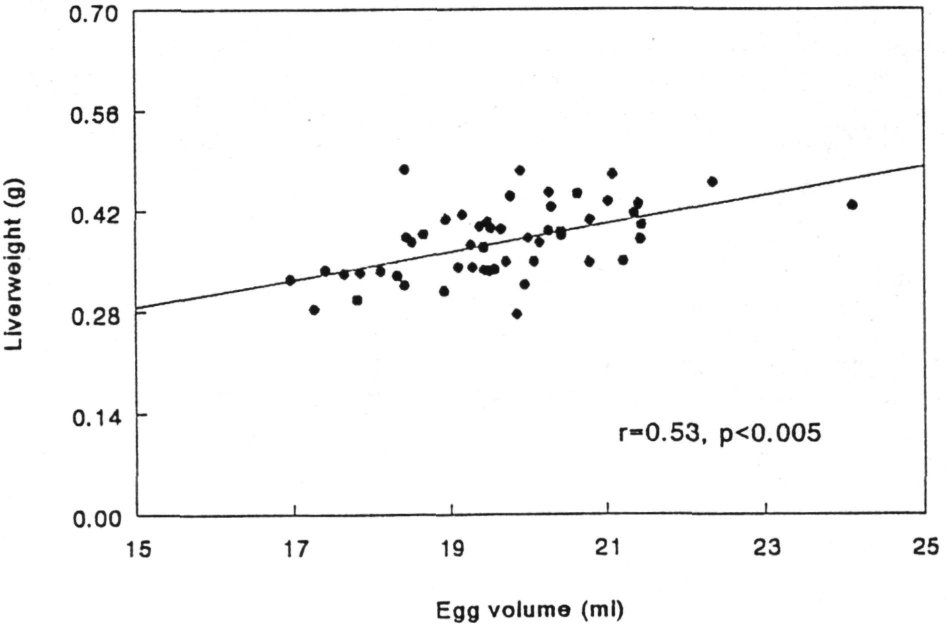


Figure 7.12 The relation between egg volume and liver weight of chicks, data of eggs from all colonies hatched in the laboratory experiment (see Murk et al. 1993).

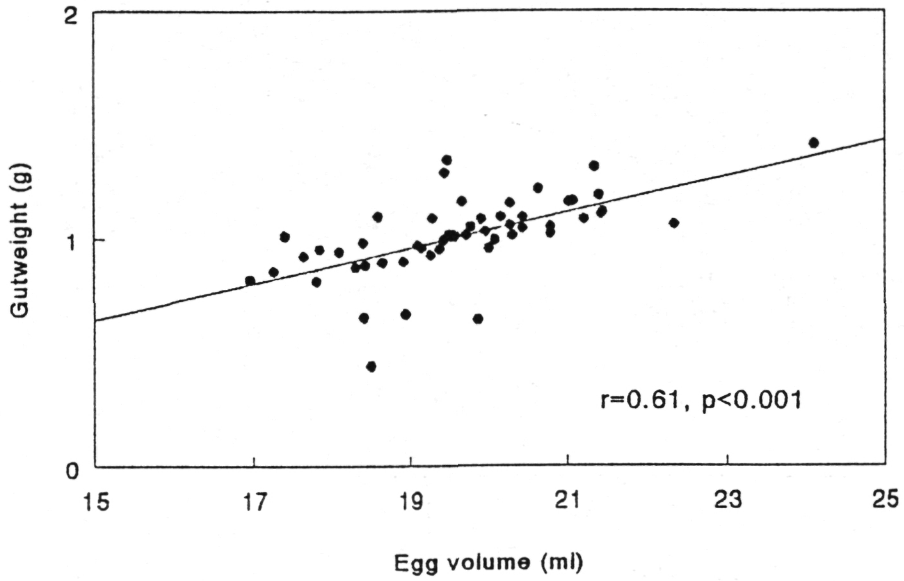


Figure 7.13 The relation between egg volume and gut weight of chicks, data of eggs from all colonies hatched in the laboratory experiment (see Murk et al. 1993).

Table 7.9. Mean egg-laying period in number of day (± SD) in relation to clutch size of the different colonies. Differences in laytime between the colonies were tested with a Kruskal-Wallis Oneway Anova (N number of cases; level of significance P (*: P<0.01; NS: P>0.05) and Chi-Square (X^2).

	Clutch 2		N	Clutch 3		N
Zeewolde	1.33	(0.58)	3	2.59	(0.51)	17
Griend	1.55	(0.52)	11	3.13	(0.35)	8
Saeftinge	2.75	(0.50)	4	3.04	(0.21)	23
Terneuzen	1.56	(0.88)	9	3.29	(0.75)	68
Zeebrugge	1.69	(0.71)	29	3.33	(1.20)	84
Kl.P. Plaat	1.80	(0.45)	5	3.00	(0.00)	1
Westplaat	1.33	(0.52)	6	3.50	(0.58)	4
Slijkplaat	1.83	(0.75)	6	3.11	(0.93)	9
N	73			214		
P	NS			*		
X^2	11.7729			19.2291		

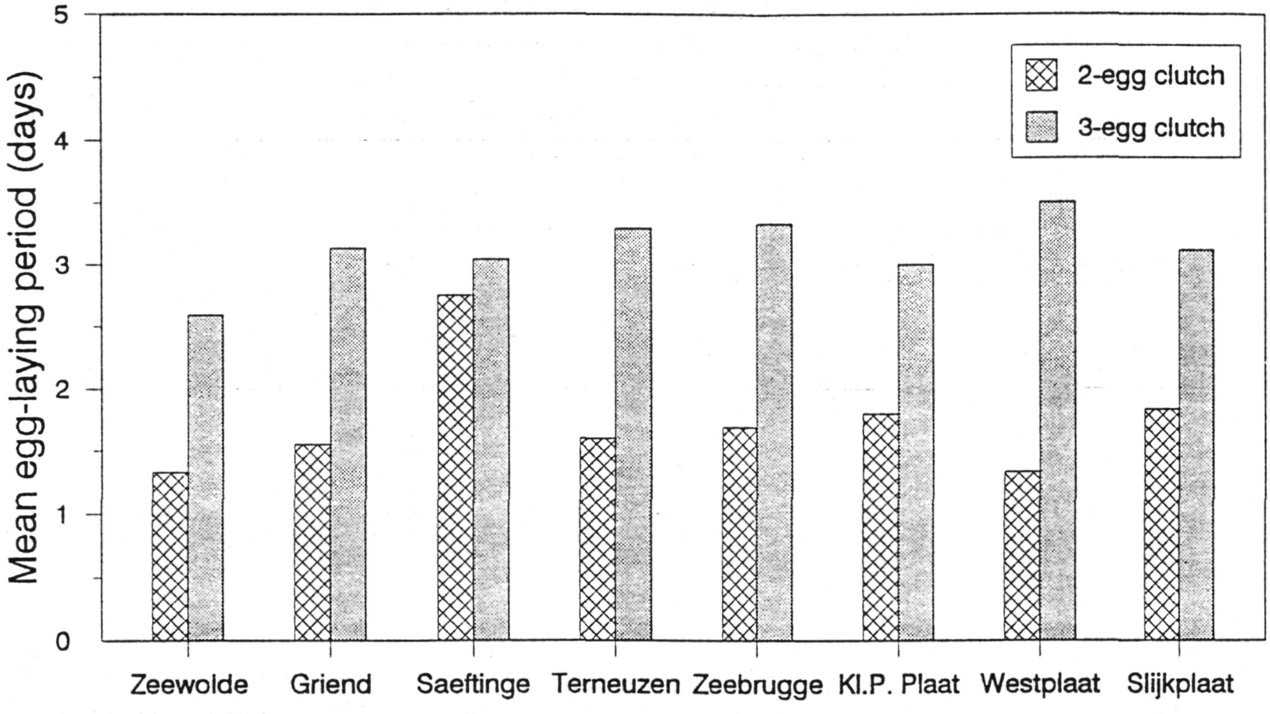


Figure 7.14 The total mean egg-laying period of the 2- and 3-egg clutches.

7.5 Egg-laying period

7.5.1 General

Table 7.9 and figure 7.14 present the mean egg-laying period in relation to clutch size. The results of the colony of the Westplaat are the most striking: the egg-laying period of the 2 clutches was the lowest, whereas of the 3 clutches was the highest. The colony of Zeewolde was the 'fastest': both 2-and 3-clutches were laid in the shortest time.

Probably due to the small number of cases no statistically significant difference between the egg-laying period of the 2-clutches of the different colonies was found. Nevertheless a statistically significant difference was found between the total mean egg-laying period of the 3-clutches of the different colonies. A multiple comparison revealed the egg-laying period of the colony of the Westplaat, Zeebrugge and Terneuzen to be significantly longer than the egg-laying period of the colony of Zeewolde (P=0.05).

7.5.2 Egg-laying period in relation to the period of laying

From the results summarised in the tables 7.10, 7.11, 7.12 and 7.13 it is clear that in most colonies the number of cases are too small to draw any conclusions. Although in some cases a statistically significant difference was found, a trend was not present.

Table 7.10. Mean egg-laying period of the 2-egg clutches of the different colonies at different periods (period 3 = 10 May - 14 May; period 4 = 15 May - 19 May;...). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05; NS: P>0.05) and Chi-Square (X^2).

	3	4	5	6	7	8	9	10	11	12	13	14	15	N	P	X^2
Zeewolde	-	1.33	-	-	-	-	-	-	-	-	-	-	-	3	-	-
Griend	-	1.55	1.50	-	-	-	-	-	-	-	-	-	-	11	NS	0.02
Saeftinge	-	-	3.00	2.00	-	-	-	-	-	-	-	-	-	4	NS	3.00
Terneuzen	-	-	1.00	2.00	2.00	1.00	-	2.00	-	-	-	1.00	-	9	NS	3.24
Zeebrugge	-	-	1.50	1.61	-	2.67	-	-	-	-	-	-	-	29	NS	4.19
Kl.P. Plaat	-	-	2.00	1.00	-	-	-	-	-	-	-	-	-	5	*	4.00
Gr.P. Plaat	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-
Westplaat	-	-	1.33	-	-	-	-	-	-	-	-	-	-	6	-	-
Slijkplaat	-	1.83	-	-	-	-	-	-	-	-	-	-	-	6	-	-

Table 7.11 Mean egg-laying period of the 3-egg clutches of the different colonies at different periods (period 3 = 10 May - 14 May; period 4 = 15 May - 19 May;...). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05 ; **: P<0.001 ; NS: P>0.05) and Chi-Square (X^2).

	3	4	5	6	7	8	9	10	11	12	13	14	15	N	P	X^2
Zeewolde	-	2.59	-	-	-	-	-	-	-	-	-	-	-	17	-	-
Griend	-	3.13	-	-	-	-	-	-	-	-	-	-	-	8	-	-
Saeftinge	-	-	3.04	-	-	-	-	-	-	-	-	-	-	23	-	-
Terneuzen	4.00	3.50	3.35	3.10	3.50	2.90	4.00	2.00	-	3.00	-	1.00	-	68	*	15.41
Zeebrugge	-	-	3.23	3.54	-	-	-	-	-	-	-	-	-	84	NS	0.15
Kl.P. Plaat	-	-	3.00	-	-	-	-	-	-	-	-	-	-	1	-	-
Gr.P. Plaat	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-
Westplaat	-	-	3.50	-	-	-	-	-	-	-	-	-	-	4	-	-
Slijkplaat	-	3.11	-	-	-	-	-	-	-	-	-	-	-	9	-	-

Table 7.12 Mean egg-laying period of the 2-egg clutches of the different colonies at different periods (early, peak and late). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05; ** : P<0.001; NS: P>0.05) and Chi-Square (X^2).

	early	peak	late	N	P	X^2
Zeewolde	-	1.33	-	3	-	-
Griend	-	1.55	-	11	-	-
Saeftinge	-	3.00	2.00	4	NS	3.00
Terneuzen	-	2.00	1.42	9	NS	0.49
Zeebrugge	-	1.58	2.67	29	*	3.73
Kl.P. Plaat	-	1.80	-	5	-	-
Gr.P. Plaat	-	-	-	-	-	-
Westplaat	-	1.33	-	6	-	-
Slijkplaat	-	1.83	-	6	-	-
N	-	62	11			
P	-	NS	NS			
X^2	-	12.68	3.84			

Table 7.13 Mean egg-laying period of the 3-egg clutches of the different colonies at different periods (early, peak and late). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05; **: P<0.001; NS: P>0.05) and Chi-Square (X^2).

	early	peak	late	N	P	X^2
Zeewolde	-	2.59	-	17	-	-
Griend	-	3.13	-	8	-	-
Saeftinge	-	3.04	-	23	-	-
Terneuzen	3.25	3.30	3.30	68	NS	0.14
Zeebrugge	-	3.33	-	84	-	-
Kl.P. Plaat	-	3.00	-	1	-	-
Gr.P. Plaat	-	-	-	-	-	-
Westplaat	-	3.50	-	4	-	-
Slijkplaat	-	3.11	-	9	-	-
N	-	179	-			
P	-	*	-			
X^2	-	20.07	-			

Table 7.14 Mean egg-laying period (± SD) of the second egg of the 2 clutches and of the second egg of the 3-egg clutches of the different colonies. Differences between eggs of the same colony were tested with a Mann-Whitney U - Wilcoxon Rank Sum W test and differences between colonies with a Kruskal-Wallis Oneway Anova. (N number of cases; level of significance P (*: P<0.05; NS: P>0.05), Z-value (Z) and Chi-Square (X^2).

	Clutch 2 egg 2		Clutch 3 egg 2		N	P	Z
Zeewolde	1.33	(0.58)	1.24	(0.44)	36	NS	-0.34
Griend	1.55	(0.52)	1.38	(0.52)	19	NS	-0.72
Saeftinge	2.75	(0.50)	1.00	(0.00)	8	*	-2.53
Terneuzen	1.56	(0.90)	1.54	(0.65)	57	NS	-0.27
Zeebrugge	1.69	(0.71)	1.42	(0.52)	118	NS	-1.89
Kl.P. Plaat	1.80	(0.45)	2.00	(0.00)	11	NS	-1.36
Gr.P. Plaat	-		-		-	-	-
Westplaat	1.33	(0.52)	1.50	(0.52)	19	NS	-0.34
Slijkplaat	1.83	(0.75)	1.38	(0.50)	30	NS	-1.52
N	73		222				
P	NS		*				
X^2	11.77		14.59				

7.5.3 Egg-laying period in relation to egg number (laying sequence)

As already mentioned in 7.5.1 the egg-laying period of the 3 clutches of the colony of the Westplaat was on average longer. This can be the result of a longer egg-laying period of the second egg and/or of the third egg. In table 7.14, the egg-laying period of the second eggs of both 2- and 3-clutches are compared and the differences were tested statistically. In most colonies no significant difference could be shown between both eggs. This is contrary to the egg-laying period of the 3-clutches showing a slight significant difference among the colonies. A multiple comparison revealed only the egg-laying period of the second egg of the colony of the Kleine Prinsesseplaat to be significantly longer than the egg-laying period of the colonies of Saeftinge, Zeebrugge, Slijkplaat and Zeewolde. Comparing the egg-laying period of the different eggs of the 3-clutches (table 7.15) a higher statistically significant egg-laying period in most colonies of the third egg is quite clear. Comparing the egg-laying period of the third egg among colonies a highly significant difference was found. A multiple comparison revealed the egg-laying period of the colonies of the Grote Prinsesseplaat, Westplaat, and Zeebrugge to be significantly longer than the egg-laying period of several other colonies (table 7.15).

Table 7.15 Mean egg-laying period (± SD) of the second and third egg of the 3-egg clutches of the different colonies. Differences between eggs of the same colony were tested with a Mann-Whitney U - Wilcoxon Rank Sum W test and differences between colonies with a Kruskal-Wallis Oneway Anova. (N number of cases; level of significance P (*: P<0.05; **: P<0.01; ***: P<0.001; NS: P>0.05), Z-value (Z) and Chi-Square (X^2). Kruskal-Wallis One Way Anova-Multiple Comparisons showing significant differences in mean egg-laying time of the third egg among colonies.

	egg 2		egg 3		N	P	Z
Zeewolde	1.24	(0.44)	1.50	(0.51)	57	*	- 1.99
Griend	1.38	(0.52)	1.80	(0.63)	18	NS	- 1.45
Saeftinge	1.00	(0.00)	3.00	(0.00)	5	*	- 2.00
Terneuzen	1.54	(0.65)	1.55	(0.72)	86	NS	- 0.09
Zeebrugge	1.42	(0.52)	1.95	(1.10)	170	***	- 5.26
Kl.P. Plaat	2.00	(0.00)	1.60	(0.55)	10	NS	- 1.50
Gr.P. Plaat	-		3.00	(0.00)	2	-	-
Westplaat	1.50	(0.52)	2.00	(0.50)	20	*	- 2.12
Slijkplaat	1.38	(0.50)	1.92	(0.68)	36	*	- 2.38
N	222		182				
P	*		***				
X^2	14.59		26.99				

Mean laying period	colony	1	4	6	2	9	5	8	3	7
1.50	1									
1.55	4									
1.60	6									
1.80	2									
1.92	9									
1.95	5	*	*							
2.00	8	*	*							
3.00	3									
3.00	7	*	*	*						

Colonies: 1 Zeewolde, 2 Griend, 3 Saeftinge, 4 Terneuzen, 5 Zeebrugge, 6 Kl. P. Plaat, 7 Gr. P. Plaat, 8 Westplaat, 9 Slijkplaat

7.6 Incubation period

7.6.1 General

The mean incubation period in relation to clutch size is summarised in table 7.16. With the exception of the colony of Terneuzen, no statistically significant differences in the incubation periods of the different clutch sizes were found. On the other hand, the differences between the colonies were highly significant. The incubation period of both 2-

Table 7.16 Mean incubation period (days ±SD) in relation to clutch size, mean incubation time and number of cases (N). Differences were tested with a Kruskal-Wallis one way anova. (N number of cases; level of significance P (*: P<0.05; **: P<0.01; ***: P<0.001; NS: P>0.05), Z-value (Z) and Chi-Square (X^2). Kruskal-Wallis One Way Anova-Multiple Comparisons showing significant differences in mean incubation time (days) of the 3-clutches among colonies.

	1	2	3	mean	N	P	X^2
Zeewolde	-	22.25 (1.89)	21.83 (1.18)	21.86 (1.22)	64	NS	0.03
Griend	-	21.67 (0.50)	21.11 (0.88)	21.29 (0.81)	28	NS	3.78
Saeftinge	-	-	22.89 (0.93)	22.89 (0.93)	9	-	-
Terneuzen	25.50 (0.71)	24.00 (1.16)	23.38 (1.31)	23.49 (1.33)	144	*	6.63
Zeebrugge	-	-	21.88 (0.94)	21.88 (0.94)	186	-	-
Kl.P. Plaat	-	-	-	-	-	-	-
Gr.P. Plaat	-	21.00 (0.00)	22.00 (0.00)	21.67 (0.58)	3	NS	2.00
Westplaat	-	21.60 (0.99)	22.39 (1.50)	22.15 (1.40)	48	NS	3.53
Slijkplaat	-	21.67 (0.89)	22.00 (1.67)	21.93 (1.55)	56	NS	0.1
N	-	51	485				
P	-	***	***				
X^2	-	20.47	123.87				

Mean incubation time	colony	2	1	5	6	8	7	3	4
21.11	2								
21.83	1	*							
21.88	5	*							
22.00	6								
22.00	8	*							
22.39	7	*	*	*					
22.89	3	*	*	*		*			
23.38	4	*	*	*		*	*		

Colonies: 1 Zeewolde, 2 Griend, 3 Saeftinge, 4 Terneuzen, 5 Zeebrugge, 6 Kl. P. Plaat, 7 Gr. P. Plaat, 8 Westplaat, 9 Slijkplaat

and 3-clutches among colonies were significantly different. In case of the 2-clutches a multiple comparison showed only the incubation period of the colony of Terneuzen to be significantly longer than the incubation periods of all other colonies. Whereas in case of the 3-clutches more pairs of colonies were significantly different (table 7.16).

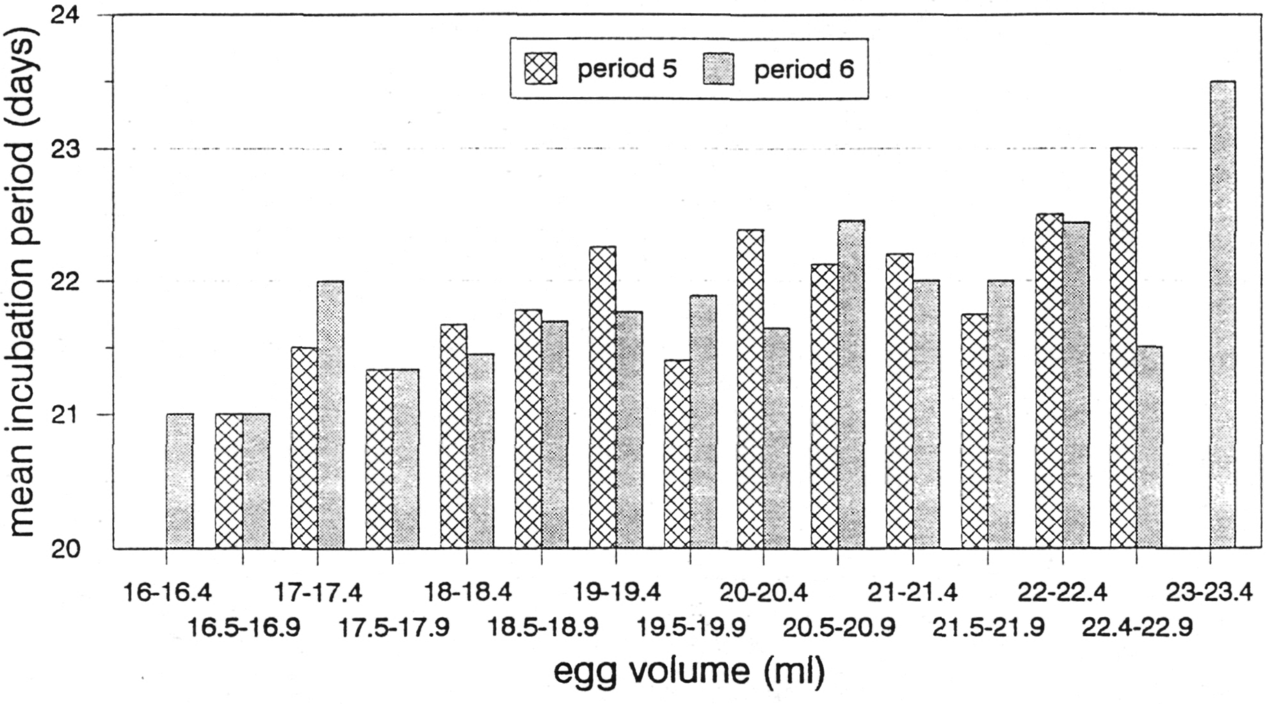


Figure 7.15 Colony of Zeebrugge: mean incubation period in relation to the egg volume and period of laying. The egg volumes were classified in several categories.

7.6.2 Incubation period in relation to egg volume

The effect of the egg volume on the incubation period was tested with a Kruskal-Wallis one way analysis of variance for every period of laying and clutch size. No statistically significant differences were found, nor was there a clear trend. Only in the colony of Zeebrugge a slight trend of increasing incubation period with increasing egg volume could be seen (figure 7.15).

To overcome the problem of a low number of cases in the different periods, the effect of the egg volume was only tested during the peak period. The egg volumes of the different clutches were divided into two categories: eggs below the mean egg volume and a category of eggs with a volume above the mean. The results are summarised in table 7.17.

From table 7.17 it is quite clear that larger eggs need a longer incubation period. Only the 2-clutches of the colony of Terneuzen and the 2-and 3-clutches of the colony of the

Table 7.17 Mean incubation period (days ±SD) of clutches laid during the peak period in relation to egg volume. Category 1 represents the incubation period of 'small eggs', i.e. eggs smaller than the mean egg volume; category 2 represents the incubation period of eggs larger than the mean egg volume.

	clutch 2		clutch 3		total	
	1	2	1	2	1	2
Zeewolde	21.00 (0.00) -	23.50 (2.12)	21.76 (1.26) -	21.96 (1.05)	21.74 (1.25) -	22.04 (1.17)
Griend	21.50 (0.71) -	21.71 (0.49)	21.00 (1.00) -	21.25 (0.71)	21.08 (0.95) -	21.47 (0.64)
Saeftinge	-		22.40 (0.55) -	23.50 (1.00)	22.40 (0.55) -	23.50 (1.00)
Terneuzen	25.00 (1.00) -	23.57 (0.98)	23.21 (1.33) -	23.63 (1.26)	23.30 (1.32) -	23.67 (1.34)
Zeebrugge	-		21.71 (0.87) -	22.07 (0.98)	21.71 (0.87) -	22.07 (0.98)
Kl. P. Plaat	-		-		-	
Gr. P. Plaat	-		-		-	
Westplaat	21.33 (1.03) -	21.88 (0.99)	22.18 (1.63) -	22.63 (1.36)	21.96 (1.56) -	22.36 (1.25)
Slijkplaat	22.25 (0.50) -	21.43 (0.98)	22.45 (1.93) -	21.94 (1.39)	22.42 (1.77) -	21.79 (1.28)

Table 7.18 Mean incubation period of the 2-egg clutches of the different colonies at different periods (period 3 = 10 May - 14 May; period 4 = 15 May - 19 May;...). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05); **: P<0.001; NS = not significant (P>0.05)) and Chi-Square (X^2).

	3	4	5	6	7	8	9	10	N	P	X^2
Zeewolde	-	22.3	-	-	-	-	-	-	4	-	-
Griend	-	21.6	21.8	-	-	-	-	-	9	NS	0.20
Saeftinge	-	-	-	-	-	-	-	-	-	-	-
Terneuzen	-	-	25.0	23.5	25.0	23.0	-	23.0	10	NS	5.98
Zeebrugge	-	-	-	-	-	-	-	-	-	-	-
Kl.P. Plaat	-	-	-	-	-	-	-	-	-	-	-
Gr.P. Plaat	-	-	-	21.0	-	-	-	-	1	-	-
Westplaat	-	-	21.6	22.0	-	-	-	-	15	NS	0.14
Slijkplaat	-	21.8	21.0	-	-	-	-	-	12	NS	1.86

Slijkplaat showed an opposite trend. The trend of an increasing incubation period with increasing egg volume was only significant in the colony of Zeebrugge (Mann-Whitney U; N=181; Z=-2.9960; P<0.01).

7.6.3 Incubation period in relation to the period of laying

In this paragraph the effect of the period of laying on the duration of the incubation will be analysed. As in all but one colony no significant effect of egg volume was found, differences in egg volume do not need to be taken into account.

The tables 7.18 and 7.19 summarise the mean incubation period in relation to the period of laying of the 2- and 3-clutches. The differences were tested with a Kruskal-Wallis one way analysis of variance. From the results a trend of a decreasing incubation period towards the end of the period of egg laying is quite clear. This trend was most pronounced in 3-clutches (table 7.19) and in several cases it was significant as well.

7.6.4 Incubation period in relation to clutch size

In the previous paragraph a clear effect of the period on clutch size was shown. In order to evaluate the effect of clutch size on the incubation period, the effect of the period of laying needs to be controlled for. To do so the incubation periods in relation to clutch size were analysed within each period of laying. In none of the colonies a significant difference between the incubation periods of the different clutches was established nor was there a trend present.

Table 7.19 Mean incubation period of the 3-egg clutches of the different colonies at different periods (period 3 = 10 May - 14 May; period 4 = 15 May - 19 May;...). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05; ***: P<0.001; NS: P>0.05) and Chi-Square (X^2).

	3	4	5	6	7	8	9	10	N	P	X^2
Zeewolde	-	21.8	21.7	-	-	-	-	-	60	NS	0.65
Griend	-	21.4	20.9	-	-	-	-	-	19	NS	0.32
Saeftinge	-	-	22.0	23.0	-	-	-	-	9	NS	1.69
Terneuzen	26.0	24.2	23.5	23.3	23.9	22.0	23.1	23.6	132	*	17.53
Zeebrugge	-	-	22.0	21.9	20.8	-	-	-	186	*	8.82
Kl.P. Plaat	-	-	-	-	-	-	-	-	-	-	-
Gr.P. Plaat	-	-	-	22.0	-	-	-	-	2	-	-
Westplaat	-	-	22.4	22.3	-	-	-	-	33	NS	0.64
Slijkplaat	-	22.5	20.6	-	-	-	-	-	44	***	12.18

Table 7.20 Mean incubation period of all clutches of the different colonies at different periods (early, peak and late). (Kruskal-Wallis Oneway Anova with N number of cases; level of significance P (*: P<0.05; **: P<0.01); ***: P<0.001); NS: P>0.05) and Chi-Square (X^2). Multiple comparison showing significant differences at the 0.05 level in mean incubation time of clutches laid during the peak period.

	early	peak	late	N	P	X^2
Zeewolde	-	21.9	-	17	-	-
Griend	-	21.4	20.5	28	*	5.32
Saeftinge	-	23.5	22.7	9	NS	0.11
Terneuzen	24.1	23.8	23.1	147	***	16.62
Zeebrugge	-	21.9	20.8	186	**	8.05
Kl.P. Plaat	-	-	-	-	-	-
Gr.P. Plaat	-	21.7	-	3	-	-
Westplaat	-	22.2	-	4	-	-
Slijkplaat	-	21.9	-	-	-	-
N	20	437	84			
P	-	***	***			
X^2	-	100.18	21.69			

Mean incubation period	colony	2	6	1	5	8	7	3	4
21.42	2								
21.67	6								
21.86	1								
21.91	5								
21.93	8								
22.15	7								
23.50	3								
23.80	4	*		*	*	*	*		

1 Zeewolde, 2 Griend, 3 Saeftinge, 4 Terneuzen, 5 Zeebrugge, 6 Gr.P.Plaat, 7 Westplaat, 8 Slijkplaat.

7.6.5 Incubation period of the different colonies

In order to compare the incubation periods of the different colonies only the period of laying needs to be taken into account. To do so the incubation periods of clutches laid during the same 'breeding phases' were compared.

Table 7.20 shows the mean incubation periods of early, peak and late clutches. Differences in incubation period during the peak period tested with a Kruskal-Wallis one way analysis of variance were highly significant (N=437; $P<0.0001$; $X^2=100.1836$) as were those of the late breeders (N=84; $P<0.0001$; $X^2=21.6890$). A multiple comparison among colonies revealed (in case of the peak period) only the incubation period of the colony of Terneuzen to be significantly longer than the period of most of the other colonies (table 7.20).

7.7 Hatching success

7.7.1 Categories of hatching success, data selection

Eggs were classified into four categories with regard to hatching success. Because there were some inevitable differences between colonies in the proportion of eggs which could be observed accurately around the time of hatching, these categories and the criteria of data-selection for further analysis will be dealt with in some details here.

The four categories in which the eggs were classified were:

1. not hatched (including all possible causes of failure, see 3.2.6)
2. hatched
3. egg disappeared in the period it should (have) hatch(ed)
4. no observations on the clutch were made in the period the egg should (have) hatch(ed)

Total number of eggs in each category is given in table 7.21 for eggs from 3-clutches starting in period 8 or earlier. Category 1 and 2 need no further comment: the outcome of the breeding period for these eggs was established with certainty. Category 3 however is a potential problem in the interpretation of the data. The main concern is whether the hatching of these eggs was disproportionally as compared to the hatching of eggs of known fate. If this would be the case, a difference in proportion of eggs in category 3 between colonies would lead to errors in the comparison of hatching success between colonies.

Before answering this question, the possible effects of such errors were investigated by computing mean hatching success in three possible scenarios, including the two extremest possible:

1. the 'category 3 eggs' hatched in the same proportions as the eggs whose fate was established: hatching success was calculated without these eggs.
2. none of 'category 3 eggs' hatched, and all were therefore classified as category 1.
3. all 'category 3 eggs' hatched, and were therefore classified as category 2.

Table 7.21 Number of eggs according to hatching status in 3-clutches, started in or before period 8, for all colonies.
1: hatched; 2: not hatched; 3: egg disappeared in the period it should (have) hatch(ed); 4: no observations on the clutch were made in the period the egg should (have) hatch(ed)

	category				
colony	1	2	3	4	total
Zeewolde	70	250	90	12	422
Griend	11	21	1		33
Saeftinge	180	39			219
Terneuzen	38	235	3		276
Zeebrugge	25	249	11	139	424
Kl. Prinsessepl.	46	2		21	69
Gr. Prinsessepl.	53	116	70	8	247
Westplaat	47	81	10		138
Slijkplaat	71	302	181	61	615
total	541	1295	366	241	2443

Table 7.22 Comparison of hatching rate (proportion of eggs hatching, 3-clutches, started in or before period 8) in 3 possible scenarios (see also text).
1: the 'category 3 eggs' hatched in the same proportions as the eggs whose fate was established: hatching success was calculated without these eggs.
2: none of the 'category 3 eggs' hatched, and all were therefore classified as category 1.
3: all 'category 3 eggs' hatched, and were therefore classified as category 2.

	scenario					
	1		2		3	
colony	mean	n	mean	n	mean	n
Zeewolde	0.78	320	0.61	410	0.83	410
Griend	0.66	32	0.64	33	0.67	33
Saeftinge	0.18	219	0.18	219	0.18	219
Terneuzen	0.86	273	0.85	276	0.86	276
Zeebrugge	0.91	274	0.87	285	0.91	285
Kl. Prinsessepl.	0.04	48	0.04	48	0.04	48
Gr. Prinsessepl.	0.69	169	0.49	239	0.78	239
Westplaat	0.63	128	0.59	138	0.66	138
Slijkplaat	0.81	373	0.55	554	0.87	554

The results of these calculations are in table 7.22. It can be seen that the difference between scenario 1 and 3 is relatively small for most colonies, and that almost no changes in the rank order of hatching success of the colonies occur. However, large differences can be seen when scenario 2 is compared to 1 and 3 respectively. These differences are the logical consequence of the fact that, in most colonies, the majority of eggs do hatch: when a varying, but relatively large, proportion of non-hatchers is introduced, the total proportion of non-hatchers changes accordingly.

The main question to answer therefore is whether there are reasons to believe that a majority of Category 3 eggs did not hatch. There were several reasons why the hatching success of these eggs remained unknown. Some visits had to be postponed because of the bad weather conditions in the period of hatching. On some sites the vegetation had grown so fast that clutches and young were very hard to find. Normally these eggs were seen a few days before hatching was expected, often when (an) other egg(s) had hatched already, and were not found (as egg or young) during the next visit. It seems unlikely that the majority of these eggs did not hatch and nevertheless disappeared completely (= without signs of predation) from the nest. More likely, these eggs hatched and the young hided, died or were predated after hatching. Given the relatively small difference between the scenarios 1 and 3 as described above, further calculations are made with the eggs of which hatching success is known, i.e. scenario 1.

Category 4 eggs were left out of the analysis. This seems justified, as it is unikely that this is a biased part of the data: these are eggs from clutches which were overlooked, or which were in a part of the colony which was not always visited.

The comparison between clutches has been restricted to clutches of which all the eggs were scored as either category 1 or 2, i.e. of which the result of hatching was known.

7.7.2 Hatching success: overall comparison between colonies

In table 7.23 the proportions of eggs hatching in all colonies are given for all eggs, eggs from 2- and eggs from 3-clutches respectively. The data of the 3-clutches were analysed by a Oneway ANOVA (after a log10 + 1 transformation), which was significant (n=1879, F=96.87, D.F.=8, p<0.001). The results of a pairwise comparison using the Oneway ANOVA - Duncan procedure are in the table as well. The highest hatching rate per egg from 3-clutches was established in Zeebrugge. Several other colonies had a high hatching rate as well: Terneuzen, Slijkplaat and Griend. Three colonies were intermediate (Zeewolde, Gr.Prinsesseplaat and Westplaat), while Saeftinge and Kl.Prinsesseplaat had very low rates.

The results of the same calculations on clutch level are in table 7.24. The Oneway ANOVA (after a log10 + 1 transformation) was significant (n=428, F=33.30, D.F.=8, p<0.001). The rank order of the colonies was almost the same as in the calculations on egg level, but less pairs of colonies were significantly different in the Oneway ANOVA - Duncan procedure.

Table 7.23 Hatching rate (proportion of eggs hatching) for all eggs, eggs from 2- and from 3-clutches. Oneway ANOVA (Duncan ranges) showing significant differences between pairs of colonies (*) at the 0.05 level are given in the scheme below the table for the data from 3-clutches.

	all eggs			eggs from 2-clutches			eggs from 3-clutches		
colony	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n
Zeewolde	0.69	0.46	427	0.60	0.50	57	0.74	0.44	353
Griend	0.80	0.40	46	0.80	0.41	20	0.81	0.40	26
Saeftinge	0.16	0.37	260	0.05	0.21	44	0.19	0.39	206
Terneuzen	0.86	0.35	360	0.78	0.42	32	0.88	0.33	315
Zeebrugge	0.96	0.19	259				0.96	0.19	259
Kl. Prinsessepl.	0.02	0.14	97	0.00	0.00	39	0.05	0.22	42
Gr. Prinsessepl.	0.62	0.49	262	0.49	0.50	83	0.70	0.46	166
Westplaat	0.58	0.49	258	0.65	0.48	93	0.63	0.48	135
Slijkplaat	0.84	0.37	500	0.85	0.36	107	0.86	0.35	377

mean	colony	4	1	7	5	8	9	6	2	3
.05	col. 4									
.19	col. 1	*								
.63	col. 7	*	*							
.70	col. 5	*	*							
.74	col. 8	*	*	*						
.81	col. 9	*	*	*						
.86	col. 6	*	*	*	*	*				
.88	col. 2	*	*	*	*	*				
.96	col. 3	*	*	*	*	*		*	*	

Colonies: 1 Zeebrugge, 2 Saeftinge, 3 Terneuzen, 4 Kl. Prinsesseplaat, 5 Gr. Prinsesseplaat, 6 Slijkplaat, 7 Westplaat, 8 Zeewolde, 9 Griend.

7.7.3 Hatching success and date of laying

In table 7.25 the mean hatching rate of eggs according to the period in which the clutch was started are given for all colonies. The same data for the relative periods (early, peak and late) are in table 7.26. In a comparable way, data on hatching success per clutch are presented in tables 7.27 and 7.28.

Mean hatching rate decreases significantly in five colonies throughout the season (table 7.25). In three of the four remaining colonies only three periods with data on more than five eggs are available, indicating that the bulk of the data was limited to a few periods. Only for the Slijkplaat the mean hatching rate seems rather constant over a longer period of time. Due to smal sample sizes the data on hatching success (eggs hatching / clutch) resulted in fewer significant trends (table 7.27). However, for all thecolonies where a non-significant result was calculated for the mean hatching rate the trend in hatching success was not significant either. This means that the results were not contradicting.

Table 7.24 Hatching success (eggs hatching / clutch) for all clutches and 2- and 3-clutches. Oneway ANOVA (Duncan ranges) showing significant differences between pairs of colonies (*) at the 0.05 level are given in the scheme below the table for the data from 3-clutches.

	all clutches			2- clutches			3-clutches		
colony	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n
Zeewolde	1.73	1.65	123	1.13	0.99	24	2.24	1.69	82
Griend	1.89	0.93	9	1.40	0.89	5	2.50	0.58	4
Saeftinge	0.43	0.89	90	0.09	0.43	22	0.64	1.02	58
Terneuzen	2.39	0.97	113	1.56	0.81	16	2.62	0.79	90
Zeebrugge	2.88	0.33	72				2.88	0.33	72
Kl. Prinsessepl.	0.00	0.00	45	0.00	0.00	18	0.00	0.00	11
Gr. Prinsessepl.	1.27	1.27	81	1.00	0.97	39	1.88	1.34	32
Westplaat	1.07	1.11	102	1.26	0.90	43	1.76	1.30	29
Slijkplaat	1.84	1.10	103	1.71	0.61	38	2.46	0.95	50

mean	colony	4	1	7	5	8	6	9	2	3
0.00	col. 4									
0.64	col. 1	*								
1.76	col. 7	*	*							
1.88	col. 5	*	*							
2.24	col. 8	*	*							
2.46	col. 6	*	*	*	*					
2.50	col. 9	*	*							
2.62	col. 2	*	*	*	*	*				
2.88	col. 3	*	*	*	*	*				

Colonies: 1 Zeebrugge, 2 Saeftinge, 3 Terneuzen, 4 Kl. Prinsesseplaat, 5 Gr. Prinsesseplaat, 6 Slijkplaat, 7 Westplaat, 8 Zeewolde, 9 Griend.

From the comparison according to the relative periods in which the clutches were started (early, peak and late) approximately the same conclusions can be drawn: clutches started earlier generally have a higher hatching rate and hatching success. Again, not in all colonies significant trends were found. The difference between early and peak mostly is much smaller than the difference between late and either of the two other periods.

7.7.4 Hatching success and clutch size

In all colonies with n > 100 eggs a significant effect of clutch size on hatching rate of eggs was found (table 7.29). Hatching rates of eggs in 1-clutches were always very low. Those of eggs in 3-clutches were highest in most, but not all, colonies. Within a given colony, the differences between the hatching rates of eggs from 2-clutches and eggs from 3-clutches were normally relatively small. No effect of colony on the hatching rate of eggs from1-clutches was found: they had low rates everywhere. However, for eggs from both 2- and 3-clutches a significant effect of colony was found.

Table 7.25 Mean hatching rate of eggs according to the period in which the clutch was started. Values are given only where n>5. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.).

colony	period 3	4	5	6	7	8	9	10	11	12	13	N	P	F	D.F.
Zeewolde	0.95	0.82	0.76	0.76	0.62	0.60	0.90	0.13	0.06		0.00	423	**	17.624	12
Griend		0.78	0.84									46	NS	0.282	1
Saeftinge			0.06	0.21	0.17							255	*	2.931	3
Terneuzen		1.00	0.87	0.97	0.83	0.85	0.79	0.80	0.88			354	**	6.993	11
Zeebrugge			0.96	0.97	0.87							259	NS	1.327	3
Kl. Pr. plaat		0.06	0.00	0.00								97	NS	1.385	3
Gr. Pr. plaat		0.94	0.75	0.67	0.38	0.67			0.25	0.00		262	**	5.898	9
Westplaat		0.66	0.67	0.71	0.67	0.33	0.44	0.00	0.23	0.20	0.00	258	**	4.767	10
Slijkplaat		0.86	0.84	0.75	1.00	0.67	0.85					500	NS	1.599	7

Table 7.26 Mean hatching rate of eggs according to the relative period in which the clutch was started (early, peak, late). Values are given only where n>5, Griend excluded. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.).

colony	period early	peak	late	N	P	F	D.F.
Zeewolde	0.96	0.81	0.35	423	**	54.547	2
Saeftinge		0.13	0.21	255	NS	2.762	1
Terneuzen	0.93	0.95	0.83	354	*	5.362	2
Zeebrugge		0.97	0.88	259	NS	3.448	1
Kl. Prinsessepl.	0.29	0.00		97	**	17.443	2
Gr. Prinsessepl.	0.86	0.65	0.24	262	**	9.536	2
Westplaat		0.64	0.13	258	**	17.300	2
Slijkplaat		0.84	0.83	500	NS	0.202	2
N	73	1790	545				
P	**	**	**				
F	7.205	137.088	40.480				
D.F.	5	7	7				

Table 7.27 Mean hatching success per clutch according to the period in which the clutch was started. Values are given only where n>5. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.).

colony	period 3	4	5	6	7	8	9	10	11	N	P	F	D.F.
Zeewolde	2.52	2.20	1.96	1.71	1.14			0.17	0.00	123	**	6.737	11
Griend		1.88								9	NS	0.059	1
Saeftinge			0.44	0.44						88	NS	0.141	2
Terneuzen		2.83	2.70	2.81	1.94	2.29	2.22			111	**	5.566	10
Zeebrugge			2.85	2.92						72	NS	0.846	1
Kl. Prinsessepl.		0.00	0.00							44	-	-	3
Gr. Prinsessepl.		2.38	1.59	1.25	0.60				0.40	81	*	2.944	9
Westplaat		1.20	1.20	1.41	1.09	0.40			0.80	102	NS	1.449	9
Slijkplaat		1.98	1.90	1.29			1.75			103	NS	0.885	6

Table 7.28 Mean hatching success per clutch according to the relative period in which the clutch was started (early, peak, late). Values are given only where n>5, Griend excluded. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.).

colony	early	period peak	late	N	P	F	D.F.
Zeewolde	2.86	2.08	0.41	123	**	27.976	2
Saeftinge		0.42	0.71	88	NS	0.487	1
Terneuzen	2.78	2.78	2.09	111	**	7.672	2
Zeebrugge		2.88		72	-	-	-
Kl. Prinsessepl.	0.00	0.00		45	-	-	1
Gr. Prinsessepl.		1.40	0.20	81	*	5.641	2
Westplaat		1.17	0.36	102	NS	3.005	2
Slijkplaat		1.86	1.70	103	NS	0.000	1
N	21	581	123				
P	**	**	**				
F	40.908	63.234	19.093				
D.F.	4	7	5				

Table 7.29 Mean hatching rate of eggs in relation to clutch size. Values are given only where n>5. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.). Griend excluded in the vertical oneway tests.

colony	clutch size 1 egg	2 eggs	3 eggs	N	P	F	D.F.
Zeewolde	0.12	0.60	0.74	427	**	17.235	2
Griend		0.80	0.81	46	NS	0.041	1
Saeftinge	0.00	0.05	0.19	260	*	3.868	2
Terneuzen	0.40	0.78	0.88	352	*	5.720	2
Zeebrugge			0.96	259	-	-	-
Kl. Prinsessepl.	0.00	0.00	0.05	96	NS	1.333	2
Gr. Prinsessepl.	0.00	0.49	0.70	258	**	13.739	2
Westplaat	0.13	0.65	0.63	258	**	15.215	2
Slijkplaat	0.13	0.85	0.86	497	**	31.098	2
N	102	455	1853				
P	NS	**	**				
F	1.658	34.617	110.777				
D.F.	6	6	7				

Table 7.30 Mean hatching success per clutch in relation to clutch size. Values are given only where n>5. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.). Griend excluded in the vertical oneway tests.

colony	clutch size 1 egg	2 eggs	3 eggs	N	P	F	D.F.
Zeewolde	0.12	1.13	2.24	123	**	24.608	2
Griend		1.40	2.50	9	NS	3.071	1
Saeftinge	0.00	0.09	0.64	90	*	5.221	2
Terneuzen	0.40	1.56	2.62	111	**	23.583	2
Zeebrugge			2.88	72	-	-	-
Kl. Prinsessepl.	0.00	0.00	0.00	45	-	-	2
Gr. Prinsessepl.	0.00	1.00	1.88	80	**	10.568	2
Westplaat	0.13	1.26	1.76	102	**	22.621	2
Slijkplaat	0.13	1.71	2.46	103	**	51.277	2
N	102	200	424				
P	NS	**	**				
F	1.658	17.794	37.667				
D.F.	6	6	7				

The same trends were found even stronger for the data on hatching success (table 7.30). This is not surprising, as hatching success can be seen as hatching rate times clutch size, and hatching rates are positively related to clutch size.

7.7.5 Hatching success and egg volume

The hatching rate of eggs in relation to their volume is in table 7.31. In two of the colonies a significant effect of egg volume could be established. Especially in Terneuzen larger eggs apparently have higher hatching rates. In the seven other colonies no significant effects of egg volume were found.

7.7.6 Hatching success: causes of egg loss

Eggs failing to hatch wereclassified into 15 different categories (see 3.2.6). In the analysis presented here these categories have been combined to the following groups of categories (numbers 1-15 referring to the original categories):

- A predation (6)
- B damaged, cause unknown (1, 2) or very rare (7, 2 eggs in total)
- C disappeared, displaced, cause unknown (5, 10)
- D washed away, covered with sand, nest disappeared (9, 14, 15)
- E failed to hatch (8, 11, 12)
- F sampled or damaged by researchers (3, 4, 13)
- G unknown

The total number of eggs in these categories in the 9 colonies is given in table 7.32. Eggs in category F (119 sampled for laboratory experiment and 11 damaged during fieldwork in all colonies) and G (17 in all colonies, max. 5 per colony) were omitted from the analysis. For the remaining categories proportions (as percentages of the total of all categories included) are given in table 7.32 as well. These figures are given for all eggs and eggs from three clutches separately.

Some remarks have to be made before these figures can be interpreted. In Zeebrugge only 3-clutches were monitored. The data in the two parts of table 7.32 are therefore identical. In this colony the hatching rate was high, resulting in a very low sample of eggs not hatching. On Griend data of a relatively small number of control clutches were gathered as compared to the other colonies. (More data probably are available, and will be incorporated in the next version of this text). The high predation on the Kleine Prinsesseplaat and the effects of flooding on Saeftinge mentioned before are clear from this table as well, and prevent a further analysis for causes of not hatching in these colonies.

With regard to possible effects of contaminants the eggs in category E (failed to hatch) are the most relevant ones. Therefore, the number in this category was compared with the number of eggs in the categories A, B, C and D together, for all colonies except the three mentioned above (Saeftinge, Kl. Prinsesseplaat and Griend). The Slijkplaat had the

Table 7.31 Mean hatching rate of eggs according to egg volume category. Values are given only where n>5. Oneway ANOVA for all cases, with level of significance (P; **: p<0.001; *: p<0.05; NS = not significant), F-ratio (F) and degrees of freedom (D.F.).

	egg volume																	
colony	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	N	P	F	D.F.
Zeewolde			1.00	1.00	0.82	0.90	0.95	0.76	0.74	0.76	0.80	0.75	0.75			271	NS	1.307	16
Griend						0.83		0.83		1.00	0.83					46	NS	1.460	11
Saeftinge		0.10	0.27	0.21	0.04	0.19	0.08	0.24	0.18	0.19	0.00	0.29				259	NS	0.923	16
Terneuzen		1.00	0.86	0.80	0.70	0.83	0.83	0.86	0.98	0.94	0.88	0.87	1.00	1.00	1.00	333	*	1.707	17
Zeebrugge			1.00	1.00	0.95	0.93	1.00	0.97	0.97	0.93	0.88	1.00	1.00			259	NS	0.543	16
Kl. Prinsessepl.						0.25	0.00	0.00	0.00	0.00	0.00					77	NS	1.323	14
Gr. Prinsessepl.							0.38									28	*	3.425	12
Westplaat	0.71	0.50	0.25	0.60	0.54	0.69	0.74	0.53	0.57	0.79	0.45					242	NS	1.291	17
Slijkplaat				0.67	0.73	0.77	0.75	0.86	0.88	0.95	0.71	0.92	0.80			229	NS	0.846	15

highest figure (42.3%), followed by Terneuzen (33.3%). Between these two colonies there is a gap of 9%, while all other colonies are within another 9% under the value of Terneuzen. This might indicate a relatively high egg mortality in the Slijkplaat colony. However, no statistically significant difference could be found (X^2=11.35, DF=6, p>0.05).

Expressing the number of eggs failing to hatch as a proportion of all eggs not hatched, as done above, provides insight in the relative importance of this cause for not hatching. However, the figure should be expressed as a proportion of the total number of eggs as well, to get insight in the absolute importance as a mortality factor. These figures are given in table 7.33. Saeftinge has by far the highest proportion of eggs failing to hatch, but this probably is a delayed effect of flooding. The lowest figure has been established in the Kleine Prinsesseplaat, but in this colony predation as a mortality factor was so dominant that eggs did not reach the stage in which they might fail to hatch. Of the other colonies, the Westplaat reached the highest proportion of eggs failing to hatch (8.2%), followed by Zeewolde, Slijkplaat, Grote Prinsesseplaat and Terneuzen (5.3%). Although there are differences between colonies, it can be concluded that in none of these colonies the failing of hatching was a major cause of egg mortality.

7.8 K-factor analysis

In the paragraphs above data from all colonies have been presented for different phases of the breeding period. In order to establish the effect of mortality in a certain phase on the total breeding success, and to compare between colonies, these data have to be combined. K-factor analysis is a useful technique to do so (Varley & Gradwell 1960, Dempster 1975), and has been used in similar research before (Dirksen et al. 1988). This analysis uses a so called "age specific life table", in which the survival of a certain cohort is followed. De values of each stage are transformed to their logarithm. The difference between the logarithms of succeeding stages is the k-value of the intervening phase. The calculated values are in table 7.34, and in figure 7.16.

Some remarks have to be made. Because no data on fledging success are incorporated here, the number of phases and therefore the number of k-values per colony is limited. In order to be able to incorporate the loss caused by laying smaller clutches in some colonies it was necessary to use a maximum (mean) clutch size to be achievable, which was set at 3 eggs. The absolute value is not essential here while comparing colonies: because of the log-transformation the differences in k are independent of the value chosen. Within a colony, comparing the importance of mortality in different phases, this does nto hold, and should this k be treated with care. The data of Griend have been omitted from the analysis. For Zeebrugge data on hatching success are available for 3-clutches only, therefore no k-vakue for the egg phase could be calculated. For the Kleine Prinsesseplaat the hatching success per clutch (0.00) has been replaced by the product of hatching rate and mean clutch size (0.04), to be able to calculate a k-value.

Table 7.32 Number and percentage of eggs according to category of cause for not hatching. Percentages are calculated using the total of eggs in categories A, B, C, D, and E. Data are given for all and 3-clutches respectively.

category	A predated		B damaged, cause unknown		C disappeared, displaced, cause unkn.		D washed away, sand-covered, nest away		E failed to hatch		F sampled or damaged for/ by research	G not repor-ted	total not hatched	hatched	TOTAL
code(s)	6		1, 2, 7		5, 10		9, 14, 15		8, 11, 12		3, 4, 13				
all eggs	n	%	n	%	n	%	n	%	n	%	n	n	n	n	n
Zeewolde	14	11.1	9	7.1	75	59.5	0	0.0	28	22.2	15	5	146	296	442
Griend	4	44.4	0	0.0	0	0.0	0	0.0	5	55.6	15	0	24	37	61
Saeftinge	2	0.9	1	0.5	112	51.1	36	16.5	68	31.1	16	0	235	41	276
Terneuzen	7	14.0	13	26.0	11	22.0	0	0.0	19	38.0	18	0	68	310	378
Zeebrugge	1	11.1	1	11.1	1	11.1	0	0.0	6	66.7	15	1	25	249	274
Kl. Pr. plaat	38	42.2	0	0.0	50	55.6	0	0.0	2	2.2	6	5	101	2	103
Gr. Pr. plaat	12	12.2	5	5.1	67	68.4	0	0.0	14	14.3	7	2	107	162	269
Westplaat	12	11.2	6	5.6	53	49.5	15	14.0	21	19.7	16	2	125	149	274
Slijkplaat	7	8.8	8	10.0	35	43.8	1	1.3	29	36.3	22	2	104	418	522
eggs in 3-clutches	n	%	n	%	n	%	n	%	n	%	n	n	n	n	n
Zeewolde	11	12.5	6	6.8	48	54.6	0	0.0	23	26.1	15	5	108	260	368
Griend	1	20.0	0	0.0	0	0.0	0	0.0	4	80.0	6	0	11	21	32
Saeftinge	0	0.0	1	0.6	90	53.9	27	16.2	49	29.3	16	0	183	39	222
Terneuzen	6	15.4	13	33.3	7	18.0	0	0.0	13	33.3	17	0	56	276	332
Zeebrugge	1	11.1	1	11.1	1	11.1	0	0.0	6	66.7	15	1	25	249	274
Kl. Pr. plaat	11	29.7	0	0.0	24	64.9	0	0.0	2	5.4	6	3	46	2	48
Gr. Pr. plaat	7	14.3	4	8.2	26	53.0	0	0.0	12	24.5	7	0	56	117	173
Westplaat	2	4.0	2	4.0	23	46.0	10	20.0	13	26.0	15	0	65	85	150
Slijkplaat	2	3.8	6	11.5	21	40.4	1	1.9	22	42.3	21	1	74	324	398

Table 7.33 Percentage of eggs of all clutches in three groups of causes for not hatching (see Table 7.32) as a proportion of all eggs. Total eggs includes all hatched eggs, but is exclusive the eggs in category F and G.

all clutches	failed to hatch E	predated A	all other causes B, C, D	total eggs
	%	%	%	n
Zeewolde	6.6	3.3	19.9	422
Saeftinge	26.2	0.8	57.3	260
Terneuzen	5.3	1.9	6.7	360
Kl. Pr. plaat	2.2	41.3	54.3	92
Gr. Pr. plaat	5.4	4.6	27.7	260
Westplaat	8.2	4.7	28.9	256
Slijkplaat	5.8	1.4	8.8	498

The k-values of the egg phase can be combined with the data on causes of hatching failure from table 7.32. This has been done by multiplying the k values with the proportions of the three groups of hatching failure mentioned in the figure: A, B/C/D and E. The results of these calculations can be found in table 7.35 and figure 7.17.

7.9 Griend: a comparison with 1989-90 data

Because the Griend-colony was not investigated in the same way as the other colonies in 1991 it seems useful to summarize the most important results given by Klaassen & Veen (1992) on reproductive success parameters for common terns on Griend. The most important data from their table 1 are in table 7.36. When comparing these data with the data in previous paragraphs for the other colonies

The colony on Griend had a breeding success of 0.3 young fledging per pair in 1989-1990 (Klaassen & Veen 1992), which the authors attribute to both predation and a lack of sufficient food brought to the young.

Table 7.34 Results of k-factor analysis. See text and figure 7.16.

colony	Zeewolde	Saeftinge	Terneuzen	Zeebrugge	Kl. Pr.pl.	Gr. Pr.pl.	Westplaat	Slijkplaat
clutch size	3	3	3	3	3	3	3	3
log number	0.4771	0.4771	0.4771	0.4771	0.4771	0.4771	0.4771	0.4771
k clutch size	0.0706	0.0621	0.0362	0.0809	0.1528	0.0897	0.1467	0.0723
mean clutch size	2.55	2.60	2.76	2.49	2.11	2.44	2.14	2.54
log number	0.4065	0.4150	0.4409	0.3962	0.3243	0.3874	0.3304	0.4048
k egg phase	0.1685	0.7815	0.0625		1.7222	0.2836	0.3010	0.1400
mean hatching success	1.73	0.43	2.39		0.04	1.27	1.07	1.84
log number	0.2380	-0.3665	0.3784		-1.3979	0.1038	0.0294	0.2648

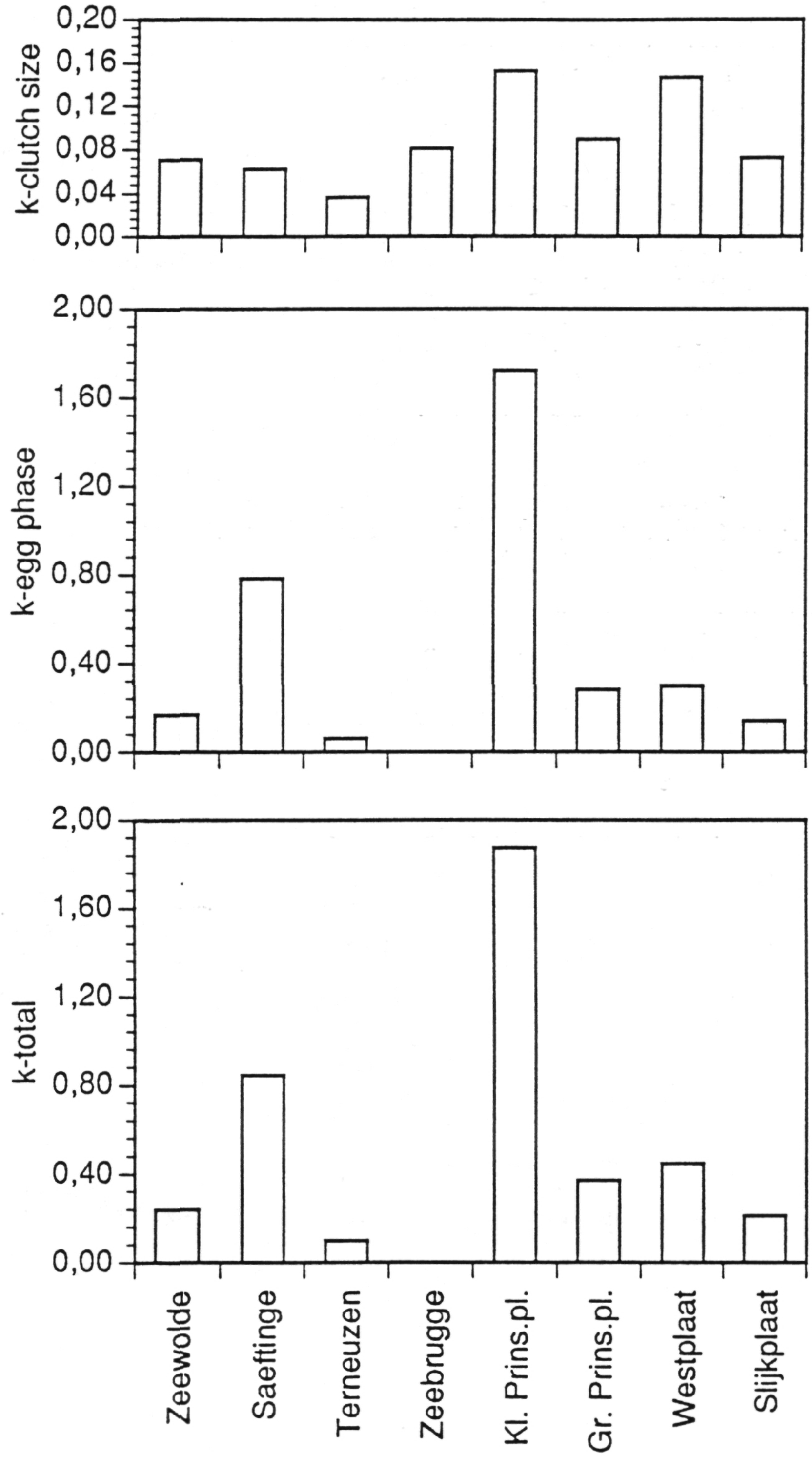


Figure 7.16 K-analysis on survival of eggs in common tern colonies; see text.

Table 7.35 K egg phase partitioned according to the three groups of causes for eggs not hatching. See text, Table 6.32 and Figure 7.17.

all clutches code(s)	k egg phase	failed to hatch E	predated A	all other causes B, C, D
Zeewolde	0.1685	0.0374	0.0187	0.1123
Saeftinge	0.7815	0.2427	0.0071	0.5317
Terneuzen	0.0625	0.0238	0.0088	0.0300
Kl. Pr. plaat	1.7222	0.0383	0.7272	0.9568
Gr. Pr. plaat	0.2836	0.0405	0.0347	0.2084
Westplaat	0.3010	0.0591	0.0338	0.2082
Slijkplaat	0.1400	0.0508	0.0123	0.0770

Table 7.36 Summary of reproductive success parameters (up til hatching stage) for Griend, 1989 and 1990, from a sample of 100 clutches. Data from Klaassen & Veen (1992).

clutch size	2.49	eggs/clutch
hatching success	61.4	% eggs hatching
1-day old chicks/pair	1.53	

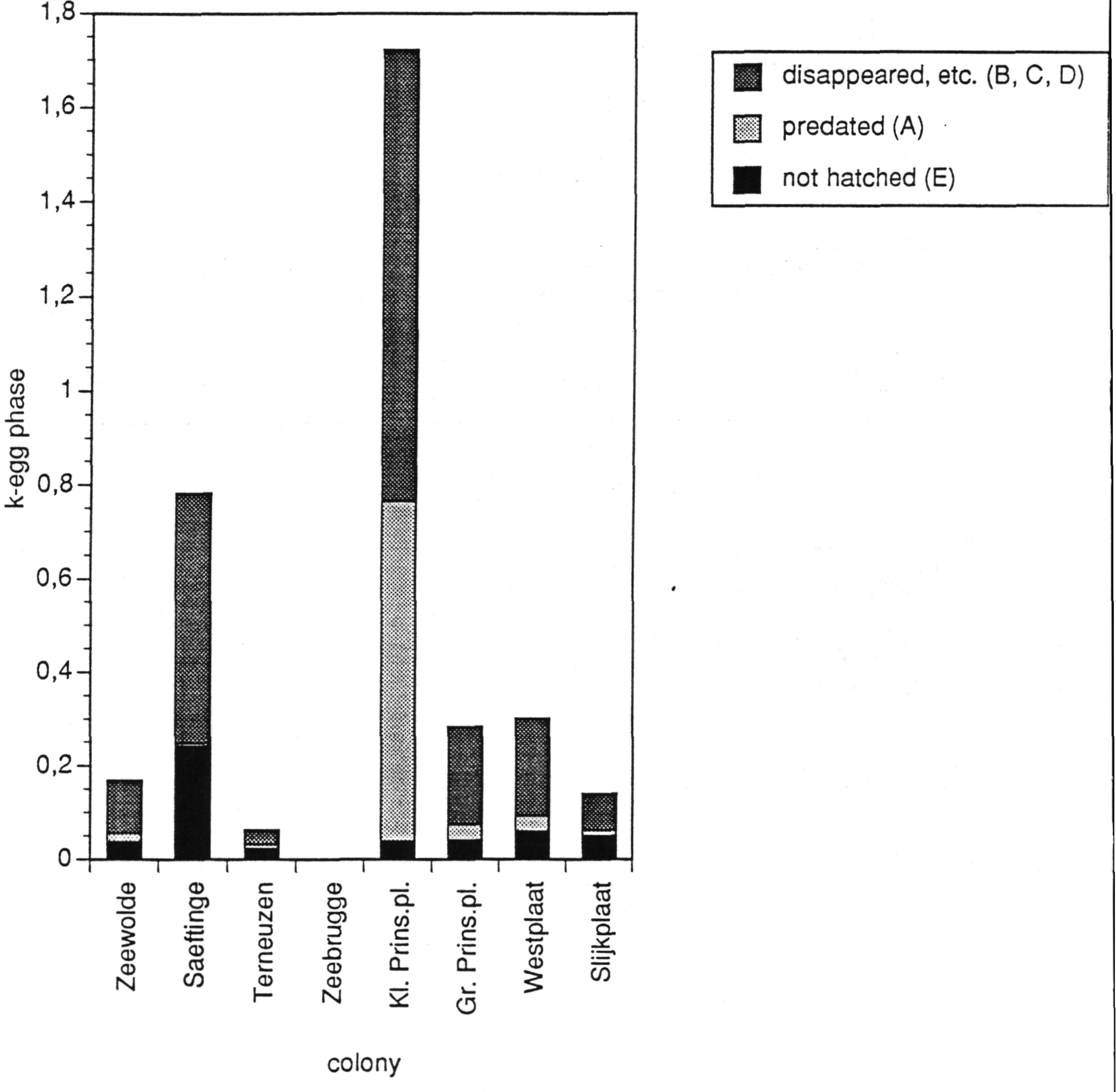


Figure 7.17 K-analysis; k-egg phase divided according to cause of not hatching; see text.

Table 8.1 Egg-laying dates of the first egg of several colonies.

place	date (year)	source
Workumerwaard (IJselmeer-Nederland)	30/4-16/5 (1974-1981)	Guldemond & Roog, 1982
Philipsdam (Oosterschelde-Nederland)	07/5-13/5 (1988)	Geelhoed, 1988
Neeltje Jans (Oosterschelde-Nederland)	28/5-03/6 (1988)	Geelhoed, 1988
Markiezaat (Oosterschelde-Nederland)	14/5-20/5 (1988)	Geelhoed, 1988
DOW-Chemical (Westerschelde-Nederland)	07/5-13/5 (1988)	Geelhoed, 1988
USA (east coast)	01/5-22/5 (1979,1982, 1985)	Burger & Gochfeld, 1991
SW Finland	01/5-14/5	Lemmetyinen, 1974

8 DISCUSSION

8.1 Egg-laying date

First egg-laying dates vary within years among colonies and for any given colony, among years. Nevertheless, there is less variability among years in date of first egg-laying than in date of arrival on the colony site (Burger & Gochfeld 1991).

Several factors seem to influence the start of the egg-laying. Older, more experienced birds arrive earlier in season, establish their territories and start the egg-laying sooner than the younger, less experienced birds (Austin 1947, Hays 1978, Nisbet 1978). Differences in breeding phenology among colonies are also caused by differential colony size: larger colonies tend to have longer egg-laying periods (Burger & Gochfeld 1991) and situate the first wave of egg-laying earlier in season (Burger & Lesser 1979).

Table 8.1 summarises reported egg-laying dates of the first egg for several colonies. From these data it is clear that most colonies start egg-laying in May. The start of the egg-laying period in the nine colonies studied is comparable.

The length of the egg-laying period varied between 13 and 60 days, which is comparable with the lenghts of 15 to 70 days mentioned by Burger & Gochfeld (1991). The mean date of egg-laying among colonies was always closer to the beginning of egg-laying than to the end. That is, the egg-laying period is skewed and extends beyond the peak of egg-laying.

To compare the start of egg-laying among colonies (see table 7.1), the egg-laying dates of the first egg can be used. From the results summarised in table 7.1 it is clear that most colonies started laying at approximately the same date (11-13 May). In the colony of Zeebrugge egg-laying probably started before 9 May, but due to the extensiveness of the area these eggs might have been overlooked.

Several authors (e.g. Emlen & Demong 1975, Burger 1979) used the standard deviation of clutch initiation as a measure of synchrony, where a low standard deviation indicates high synchrony. From the results of table 7.1 synchrony is most pronounced in Saeftinge. The same conclusion can be drawn from figure 7.4. However, if a colony has attracted later breeders, the synchrony may be masked (Burger & Gochfeld 1991). This was clearly the case in the Grote Prinsesseplaat, showing a second wave of nesting probably consisting of renesting birds from the Kleine Prinsesseplaat. To minimise the effect of later nesting birds on the analysis of breeding synchrony, one should only use the nests started during the first wave.

To analyse the breeding synchrony among colonies, the date on which the peak of the first wave is situated, probably is a better measure than the date of the first egg. From figure 7.4 two groups can be distinguished: a group of colonies with a peak situated between 22 and 25 May (Saeftinge, Terneuzen, Zeebrugge, Kleine and Grote

Prinsesseplaat), and a second group with a peak situated somewhat earlier (17-19 May) (Slijkplaat, Westplaat, Zeewolde and Griend).

Former studies already (e.g. Guldemond & Roog 1982) revealed the effect of the geographical position of the colony: northern colonies start later in season than southern colonies. From figure 7.4 a similar effect is not that clear as the northern colonies started breeding earlier than the colonies situated in the south. However, this trend may also be influenced by the effect of colony size.

8.2 Clutch size

The mean clutch sizes in several studies in Europe ranged from 2.55 to 2.88 (review in Cramp 1985). Nevertheless, Burger & Gochfeld (1991) present sizes of 2.42-2.46 as a realistic mean value for temperate zone common terns. Most values of table 6.2 can thereby be considered as normal. Only the colony of the Westplaat showed to have a low mean clutch size due to the high proportion of one- and two-egg clutches.

Several factors affect clutch size. The amount of food, which the males can provide during the 'honeymoon' period, can be a factor limiting the number and size of the eggs (Nisbet 1979). Although no observations were done with regard to the courtship-feeding rates, we have reasons to believe that the feeding conditions of the colony of Terneuzen were better than in the other colonies. In Terneuzen most foraging took place in the sluice complex at a distance of approximately 300 m (see 6.3) from the colony and the patches of prey were spatially restricted. This might explain the high mean clutch size in this colony.

According to Nisbet (1975) and Becker (1981) the egg-laying date can also affect clutch size as early clutches are larger than clutches started later in season. A similar trend was found in most colonies as clutch size decreased with time (tables 7.3 and 7.4). This effect was most pronounced in the colony of Zeebrugge. Birds starting to breed late in season might have smaller clutches due to food shortage and/or due to a higher predation pressure as the colony was used as a resting place by groups of black-headed gull.

Another factor affecting clutch size is colony size. Larger colonies generally have higher mean clutch sizes (Burger & Lesser 1978). This effect can be due to the presence of a larger percentage of older birds (see Hayes 1978 and Ryder 1980), or to the concentration of more experienced birds near areas of abundant food (Burger & Gochfeld 1991). In order to analyse the effect of colony size the effect of laying date was minimised by comparing clutch size among colonies during the same phenological period (peak period). Although clutch sizes were significantly different (see table 7.4), a trend of a higher mean clutch size with increasing colony size is not that clear.

Clutches of common terns normally contain no more than three eggs. In some cases however, four or more eggs may be found (see Burger & Gochfeld 1991). According to

Geelhoed (1988) these supernormal clutches (see Conover 1984) probably result from several females depositing eggs in the same nest. The occurrence of supernormal clutches might also be related to the effects of chemical pollutants, as suggested by Fry & Toone (1981).

8.3 Egg volume

Dirksen & Boudewijn (1990) found the egg volumes of colonies in the Delta area to range between 19.06 and 20.12 ml. These values are comparable with the volumes found in this study. Nevertheless, the differences among colonies were statistically significant. Only the value of 19.05 ml (Westplaat) seems to be quite low and is about 1.03 ml smaller than mean volume of Terneuzen.

As with several species, male common terns provide the female with some of the food needed to alleviate the problem of food shortage at the time of egg formation (Perrins & Birkhead 1983). Nisbet (1973, 1977) found that the more food the male terns brought their mates, the earlier egg-laying occurred, and the larger the eggs and clutches. Thus, clutches started early in the season are on average larger (see 8.2) and contain larger eggs.

From the results of the tables 7.6 and 7.7 and the figures 7.9 and 7.10 an effect of the period of laying is quite clear as in most colonies the egg volume showed a decrease throughout the season. This effect was most pronounced with the 3-egg clutches. However, not all colonies showed a trend as clear as in the colonies of Saeftinge, Terneuzen and Zeebrugge. The Kleine Prinsesseplaat showed an opposite trend with an increase of egg volume. The Grote Prinsesseplaat and the Westplaat showed a clear decrease followed by an increase during the second wave of laying. The increase during the second wave may be indicative that the second wave consisted of second clutches of older birds and not of first clutches of younger birds. In Zeewolde finally, the effect of a second wave also is quite clear, although the volumes of the first wave did not show a decrease.

According to Nisbet (1973,1977) one also expect the egg volumes of clutches started during the same period to be positively correlated with clutch size. However, the effect of clutch size was less pronounced than the effect of the period of laying. Although in most colonies the egg volumes of 3-egg clutches tended to be larger than the volumes of the 1-egg and 2-egg clutches, a clear trend was absent: in the colony of Zeebrugge the opposite can be seen.

In order to compare the egg volumes among colonies, the period of laying and clutch size needs to be taken into account. For this purpose only eggs laid during the same phenological period can be used. From table 7.8 it is clear that no important changes occurred: only the colonies of Zeebrugge and Zeewolde shifted places, and the range in egg volume increased from 1.03 to 1.50 ml.

The egg volume is an important parameter as in many species the dimensions of the egg are positively correlated with the chick size at hatching (Parsons 1970, Lloyd 1979, Paulussen 1981, Grant 1991, Sydeman et al. 1991). The hatching weight of the chicks is on his turn positively correlated with the survival of the chicks (Nisbet 1978, Lundberg & Väisänen 1979).

8.4 Egg-laying period

The egg-laying period for any pair of terns lasts only about four days. Eggs may be laid on successive days or on alternate days (Burger & Gochfeld 1991). Nisbet & Cohen (1975) found an average of 3.6 days between laying of the first and third egg in a three-egg clutch.

Several factors may account for variability in the egg-laying period. According to Lemmetyinen (1974), the interval of laying increases when food becomes scarce. From this, one might expect the egg-laying period to increase throughout the season. However, in most colonies the number of cases were too low to test this assumption. Only the colony of Zeebrugge showed an significant increase in case of the 2-egg clutches (table 7.12). Terneuzen on the other hand, showed a decrease in case of the 2-egg clutches and a slight increase in case of the 3-egg clutches.

From table 7.9 it is quite clear that although the birds of the Westplaat laid the 2-egg clutches in a short period, they needed a substantial longer period to lay the 3-egg clutches. This longer egg-laying period of the 3-egg clutches was not caused by a longer laying period of the second egg, as these second eggs were laid as fast as the second eggs of the 2-egg clutches (table 7.14). Only the birds of Saeftinge needed about one supplementary day to lay a 2-egg clutch. However, comparing the egg-laying periods of the different eggs of the 3-egg clutches, it is clear that in most colonies the birds needed a longer period to lay the third egg (table 7.15). This effect was more pronounced in the Westplaat. An explanation can be found in the low proportion of the 3 clutches in the colony of the Westplaat (see table 7.2). Possibly the birds had difficulties in producing a third egg, which resulted in a longer egg-laying period of the 3-clutches.

8.5 Incubation period

Incubation requires three to four weeks depending on the degree of disturbance (Burger & Gochfeld 1991). Austin (1933) reported incubation periods of 23-28 days and a modal incubation period of 26 days in a partially disturbed colony (Austin 1932). According to Glutz von Blotzheim & Bauer (1982) the mean incubation period amounts 23 days and ranges between 20 and 26 days. Nisbet & Cohen (1975) reported a range of 21-22 days in undisturbed nests and 27-28 days in areas with disturbance. In case of nocturnal disturbance the incubation period can increase considerably, up to 32 days (Nisbet 1975). Our mean values for the different colonies ranged from 21 to 23.5 days what can be considered as normal. Nevertheless, the mean incubation period of 23.5 days of the colony of Terneuzen showed to be quite high in comparison with the other values. A possible explanation can be found in both the frequent disturbances (see 5.3) and the high number of visits for this study.

The duration of the incubation period can be influenced by several factors. For example in waterfowl the incubation period depends largely on the size of the eggs (Owen & Black 1990). This trend was confirmed in this study, but was not significant in most colonies. However, among colonies a similar trend was not present.

Possible differences in incubation period may also be expected according the timing of laying. As older, more experienced birds start breeding earlier in season than younger, less experienced birds, one might expect the incubation period to increase throughout the season. However, from the tables 7.18, 7.19 and 7.20 the opposite is quite clear.

8.6 Hatching success

Reproductive success is normally expressed as the number of young fledging per pair or clutch, or as the proportion of eggs resulting in a fledging young. As in terns mortality other than predation tends to concentrate in the period after hatching, the period before hatching often is not treated in a detailed way in reports on common tern research. However, as effects of organochlorine pollutants specifically affect the egg stage, this phase was of highest interest within the present study and more time and effort was devoted to this than to the chick rearing period. This has led to a situation in which good data are available to compare between the colonies investigated here, but with less data available from the literature to compare with.

Hatching success, and consequently breeding success, of common terns is rather variable between sites and between years. Firstly, common terns often breed in habitats where the nest has a large risk to get flooded during the breeding season. Secondly, in spite of the protective value of colony-breeding predation can sometimes be catastrophical rather than incidental (Cramp 1985, Burger & Gochfeld 1991, Stienen & Brenninkmeijer 1992).

In southern Finland Lemmetyinen (1973) found that 33% of egg losses were due to eggs failing to hatch, while hatching rates were between 0.67 and 0.86. When predated and flooded eggs are neglected, hatching rate was about 0.9 in Jade Busen (Germany) between 1980-1987 (Becker 1991). According to Cramp (1985) hatching rate typically is over 0.9, where there are no adverse factors. Even when predated and flooded eggs are included in the calculations, hatching rates normally are above 0.7 in many areas (Stienen & Brenninkmeijer 1992).

Not surprisingly, in the data on hatching success presented here large differences between colonies have been established (7.7, 7.8). Hatching rate values from almost zero (Kleine Prinsesseplaat) to over 0.9 (Zeebrugge) were found.

For the colonies with a very low hatching success the main factor causing the mass losses could well be established. On the Kleine Prinsesseplaat most eggs got predated. A few oystercatchers probably were responsible for most of these. Although not regularly occurring, the phenomenon of oystercatchers predating upon tern eggs is known from the literature. Veen (1977) cites Rutten (1931) who already described the phenomenon. According to Veen oystercatchers generally took sandwich tern eggs incidentally. The exceptions to this were a few specialists, which seemed to take advantage of the disturbance caused by researchers in the colony, eating 25 eggs during only four visits. Burger & Gochfeld (1991) in their book on common terns state:" Some tern colonies have suffered extensive egg predation by american oystercatchers (*Haematopus palliatus*), however, the oystercatchers nest comfortably in the midst of terns and as a rule they are not mobbed." Apparently some specialists have been at work on the Kleine Prinsesseplaat as well. From the similarity of the observations with the description by Veen (1977) in his study on sandwich terns a negative effect of research activity can not be excluded in this case.

The colony in Saeftinge was largely flooded during a very high tide. Most nests were washed away or at least replaced over some distance. Eggs that subsequently were found not to hatch in this colony were almost certainly deserted after this flood.

In the colonies where no 'catastrophic' predation or flooding took place the hatching rate was between 0.58 (Westplaat) and 0.96 (Zeebrugge). This is generally in agreement with the conclusion mentioned above of Stienen & Brenninkmeijer (1992) for a range of areas. However, the colony of Griend is one of these, and Stienen & Brenninkmeijer also present data in support of the view that the breeding (fledging) success in this colony is not high enough to guarantee a stable colonysize without immigration. This means that the differences in hatching rate between the remaining colonies can be of significant value, and it is worthwile to discuss these in some more detail as well.

In the analysis of causes of not hatching, eggs that disappeared were kept separate and not added to the 'most likely to be'-category of causes (7.7.6). Burger & Gochfeld (1991) however, in their account of over 20 years of research, considered all missing eggs to be predated unless there was evidence for alternative disturbance. If this line of reasoning is adopted for the data presented in 7.7.6 and 7.8, the differences in hatching success between the remaining colonies are largely caused by predation and/or flooding. There are only few eggs that did not hatch after having been in the nest throughout the incubation period that is needed before hatching: 5.3% (Terneuzen) to 8.2% (Westplaat) of all eggs (7.7.6). There is no (cor)relation between this figure and the total number of eggs predated upon (including the disappeared eggs). Thus, in all colonies over 90% of the eggs would have hatched if predation and flooding is ruled out - which is in agreement with Cramp (1985) and Becker (1991).

9 CONCLUSIONS

Data on various factors which influence breeding biology parameters have been presented in the previous chapters. There are some which may be described as 'general breeding biology'-factors: processes which, under normal circumstances, are operating on each individual of the species. Others are more specific. These can be site- and/or year-specific. Because the main goal of this project is to establish possible effects of organochlorine pollution, it will be evaluated now which of these different factors (that have been established to be related to breeding biology parameters in this particular study) might be related to organochlorine pollutants.

Organochlorine pollution can induce different types of adverse effects on birds, of which many are related to reproduction. Several of these can be recognized in field research, especially if the levels of the pollutant(s) involved are high enough to affect a measurable proportion of the breeding pairs within an area. A short overview of the effects on breeding biology and reproductive success will be given below.

* Delay of the start of egg-laying.
In laboratory experiments it was shown by Koval et al. (1987) that several bird species delayed the start of egg-laying as a consequence of high levels of PCBs. This may be relevant because of the reduction in breeding success which is the consequence of a later start of egg-laying. No evidence from field studies is available yet. However, in research on cormorants an indication was found: cormorants in the colony in the most polluted area, where breeding success was shown to be reduced because of organochlorine contaminants, started their clutches about two weeks later than cormorants in relatively clean areas (Dirksen et al. 1989).

* Eggshell thinning and subsequent breaking of eggs.
Reproductive failure because of eggshell thinning and subsequent breaking of eggs has been described for many fish-eating and predatory bird species, and there is sufficient evidence to relate this to DDE (Ratcliffe 1967, 1970, Anderson et al. 1969, Anderson & Hickey 1972, Koeman et al. 1972, Cooke 1979, Pearce et al. 1979, Moriarty et al. 1986, Lundholm 1987). In cases where whole colonies or populations of birds fail because of contamination with DDE and related pesticides, the levels are probably high enough for some embryos to die because of direct toxic effects as well.

* Mortality of embryos and chicks.
As a consequence of high levels of PCBs and related compounds, embryos and chicks are known to die, especially in the period just before and after hatching (Fox 1976, Morris et al. 1976, Vermeer & Peakall 1977, Gilbertson 1983, Kubiak et al. 1989).

* Morphological aberrations.
Chicks surviving after hatching can have several types of morphological aberrations which are likely to be caused by PCBs and related compounds (Hays & Risebrough 1972, Gochfeld 1975, Gilbertson et al. 1976, 1989, in press). These include: loss of

wing- and tailfeathers, crossed bills, shorter upper or lower mandibles, eye defects, feet defects, hip displasia.

* Effects on adult breeding behaviour
The breeding behaviour of birds can be adversely influenced by PCBs (and/or related compounds, see Kubiak et al. 1989). The attentiveness at the nest can be reduced (Peakall & Peakall 1973, Peakall & Fox 1987), and the nests built can be of poor quality (Scholten et al. 1989). Field data on this type of effects are scarce, although the egg change experiments performed by Kubiak et al. (1989) clearly showed that part of the reduction in breeding success they found in their study on Forster's terns was caused by a behavioural factor.

At the start of the project there were several indications that in the colonies and areas concerned (some of) these types of negative effects could indeed be established. Eggs of common terns from Saeftinge had PCB levels high enough to exceed effect levels (Stronkhorst et al. in prep.). In the Slijkplaat colony one young was found in 1991 showing hip displasia (Dirksen & Boudewijn 1990), a developmental aberration possibly caused by organochlorine pollutants. As these two colonies are within the most heavily polluted estuaries of the Netherlands (Bijlsma & Kuipers 1989) in which negative effects of pollutants on biota have been assessed on various trophic levels, it seemed likely to expect that fish-eaters like common terns would suffer from these as well.

The crucial question therefore to answer now is whether there are any indications for the occurrence of these types of effects in the common tern colonies of which breeding biology data have been reported above.

In spite of the expectations based on the preliminary research on common terns, and the effects found in other fish-eating birds in the same or comparable areas in the Netherlands (Dirksen et al. 1991, in prep., Van der Gaag et al. 1991, Van den Berg et al. in prep), no reduction in hatching success because of pollutant inducted effects could be established: neither breakage of eggs nor dying of embryos and young because of pollutants could be found. In colonies where many eggs disappeared other factors could be assessed with certainty to be responsible: predation and flooding. Also, not a single chick examined showed morphological aberrations, even on the Slijkplaat, where one chick was found with hip displasia in 1990. The number of eggs that did not hatch after having completed the incubation period necessary for hatching was between 5 and 8.5% in all colonies. These are relatively low figures (Stienen & Brenninkmeijer 1992), and they are within the range of other sites where extreme effects of organochlorine pollutants are lacking (Becker 1991, Burger & Gochfeld 1991). Also, there was no correlation between these figures and the estimated relative pollution grade of these colonies.

In addition to this general conclusion there are some features in the breeding biology data worthwile mentioning here, because they might indicate effects of pollutants on a smaller scale.

In 7.6.2 the incubation period was analysed in relation to egg volume. Although only statistically significant for Zeebrugge, larger eggs took a longer incubation period in 6 out of 7 colonies. Only on the Slijkplaat birds incubated longer on smaller eggs than on larger ones. If this would be a 'real' difference, which remains uncertain because of the low sample size involved, there would be a site-specific difference with regard to incubation effectiveness of pairs laying smaller eggs.

The position of the Westplaat with regard to some parameters related to egg laying is somewhat exceptional. In this colony the mean clutch-size is relatively low, egg volume is the lowest of all colonies (in spite of the low number of smaller 3-eggs!) and the laying interval between the 2-egg and the 3-egg is the longest of all colonies. Apparently the adults in this colony had problems in producing eggs, both in number and in content. Again this is a site-specific difference. It may be food-related, but a relation with pollutants can not be excluded.

In conclusion: no reduction of breeding success because of organochlorine pollutants could be established, although some features in the breeding biology in a few colonies might indicate that these compounds do have some (relatively small) impact. This should be analysed further in combination with the chemical and toxicological data. These can be combined with ecological data on colony-level, but also at individual clutch-level. Only after this analysis it is possible to evaluate the extent to which common terns in the study areas are under chemical pressure at the moment, and whether it is a useful species for monitoring purposes.

10 REFERENCES

Anderson, D.W., J.J. Hickey, R.W. Risebrough, D.F. Hughes, & R.E. Christensen 1969. Significance of chlorinated hydrocarbon residues to breeding pelicans and cormorants. Can. Field Nat. 83: 91-112.

Anderson, D.W. & J.J. Hickey 1972. Eggshell changes in certain North American birds. Proc. XVth Int. Orn. Congress: 514-540.

Austin, O.L. 1932. Further contributions to the knowledge of the Cape Cod Sterninae. Bird Banding 3: 123-139.

Austin, O.L. 1933. The status of Cape Cod terns in 1933. Bird Banding 4: 190-198.

Austin, O.L. 1947. A study of the mating of the Common tern (*Sterna h. hirundo*). Bird Banding 18: 1-16.

Becker, P.H. 1981. Der Einfluß der Silbermöwe auf den Bruterfolg einer Flußseeschwalbekolonie auf Mellum. Verh. Dt. zool. Ges.: 159.

Becker, P.H. 1991. Population and contamination studies in coastal birds: the Common Tern *Sterna hirundo*. pp. 433-460 in: Perrins, C.M., J.D. Lebreton & G.J.M. Hirons (eds.): Bird population studies: relevance to conservation and management. Oxford University Press, Oxford.

Bijlsma, L. & J.W.M. Kuijpers 1989. River water and the quality of the Delta Waters. pp.3-26 in: Hooghart, J.C. & C.W.S. Posthumus (eds.). Hydro-ecological relations in the Delta Waters of the South-West Netherlands. TNO-CHO, The Hague.

Brenninkmeijer, A. & E.W.M. Stienen 1992. Griend, vogels en bewaking 1992. Rapport. Arnhem.

Burger, J. 1979. Colony size: A test for breeding synchrony in herring gull *Larus argentatus* colonies. Auk 96: 694-703.

Burger, J. & M. Gochfeld 1991. The Common Tern. Its Breeding Biology and Social Behavior. Columbia University Press, New York.

Burger, J. & F. Lesser 1978. Selection of colony sites and nest sites by Common Terns Sterna hirundo in Ocean County, New Jersey. Ibis 120: 433-449.

Burger, J. & F. Lesser 1979. Breeding behavior and success in salt marsh Common tern colonies. Bird Banding 50: 322-337.

Conover, M.R. 1984. Occurrence of supernormal clutches in the Laridae. Wilson Bulletin 96: 249-267.

Connover, W.J. 1980. Practical non-parametric statistics. John Wiley & Sons, New York.

Cooke, A.S. 1979. Egg shell characteristics of Gannets *Sula bassana*, Shags *Phalacrocorax aristotelis* and Great Black-backed Gulls *Larus marinus* exposed to DDE and other environmental pollutants. Environ. Pollut. 19: 47-65.

Craane, B.L.H.J., A. Brouwer, S. van Mourik, S. Dirksen, T.J. Boudewijn & M. van den Berg 1990. A comparative laboratory breeding study with Cormorants (*Phalacrocorax carbo*) from two Dutch colonies with adifferent degree in contamination. pp. 207-210. In: Hutzinger O. & H.Fiedler (eds.): DIOXIN '90. Eco-informa Press, Bayreuth.

Cramp, S. (ed.) 1985. The Birds of the Western Palearctic, Vol. IV. Oxford University Press, Oxford.

Devos, K. & P. Meire 1991. Het avifaunistisch belang van de voorhaven van Zeebrugge en de mogelijke effecten van de bouw van een containerkaai. Rapport Instituut voor Natuurbehoud, Hasselt (in prep.).

Dirksen, S. & T.J. Boudewijn 1990. Visdieven en de verontreiniging van het Haringvliet. Oriënterend onderzoek naar mogelijke effecten van organische microverontreinigingen op de reproductie. Ecoland-rapport 90-4. Bureau Ecoland, Utrecht.

Dirksen, S., T.J. Boudewijn & L.K. Slager 1989. Voedselkeus van Aalscholvers in zeven Nederlandse broedkolonies in 1987/1988. Ecoland-rapport 89-9. Bureau Ecoland, Utrecht.

Dirksen, S., T.J. Boudewijn, L.K. Slager & R.G. Mes 1991. Breeding success of Cormorants (*Phalacrocorax carbo sinensis*) in relation to the contamination of their feeding grounds. pp. 232-243 in: M.R. van Eerden & M. Zijlstra (eds.). Proceedings workshop 1989 on Cormorants Phalacrocorax carbo. Rijkswaterstaat Directie Flevoland, Lelystad.

Emlen, S.T. & N.J. Demong 1975. Adaptive significance of synchronized breeding in a colonial bird: a new hypothesis. Science 188: 1029-1031.

Fox, G.A. 1976. Eggshell quality: its ecological and physiological significance in a DDE-contaminated Common Tern population. Wilson Bull. 88: 459-477.

Fry, D.M. & C.K. Toone 1981. DDT-induced feminization of gull embryos. Science 213: 922-924.

Geelhoed, S. 1988. Enkele broedbiologische gegevens van Bontbek-, en Strandplevier, Visdief en Dwergstern in het Delta-gebied. Rijkswaterstaat, Dienst Getijdewateren, studentenrapport 5-88, Middelburg.

Gilbertson, M. 1983. Etiology of chick edema disease in Herring Gulls in the Lower Great Lakes. Chemosphere 12: 257-370.

Gilbertson, M., R.D. Morris & R.A. Hunter 1976. Abnormal chick and PCB residue levels in eggs of colonial birds on the lower Great Lakes (1971-73). Auk 93: 434-442.

Gilbertson, M., T.J. Kubiak, J. Ludwig & G.A. Fox 1989. Abstract of presentation on chick-edema disease in colonial fish-eating birds. pp. 12-13 in: Gilbertson, M. (ed.), Proceedings of the Workshop on Cause-Effect Linkages, International Joint Commission, Council of Great Lakes Research Managers, Windsor.

Gilbertson, M., T.J. Kubiak, J. Ludwig & G.A. Fox in press. Great Lakes embryo mortality, edema and deformities syndrome (GLEMEDS) in colonial fish-eating birds: similarity to chick-edema disease. J. Toxicol. & Environ. Health.

Gochfeld, M. 1975. Developmental defects in Common Terns of Western Long Island, New York. Auk 92: 58-65.

Glutz von Blotzheim, U.N. & K.M. Bauer 1982. Handbuch der Vögel Mitteleuropeas. Band 8/2. Akademische Verlagsgesellschaft, Wiesbaden.

Guldemond, A. & M. Roog 1982. De broedbiologie van de visdief in twee verschillende biotopen op de Workumerwaard in verband met het beheer. Verslag LH/Nb 606. Landbouwhogeschool, Wageningen.

Hays, H. 1978. Timing and Breeding success in three- to seven-year-old Common terns. Ibis 120: 127-128.

Hays, H. & R.W. Risebrough 1972. Pollutant concentrations in abnormal young terns from Long Island Sound. Auk 89: 19-35.

Hoffmann, D.J., B.A. Rattner, L. Sileo, D. Docherty & T.J. Kubiak 1987. Embryotoxicity, teratogenicity and aryl hydrocarbon hydroxylase activity in Forster's Terns on Green Bay, Lake Michigan. Environ. Res. 42: 176-184.

Hoyt, D.F. 1979. Practical methods of estimating volume and fresh weight of bird eggs. Auk 96: 73-77.

ICONA 1992. Noordzee-atlas voor het Nederlands beleid en beheer. Stadsuitgeverij Amsterdam.

Klaasen, M. & J. Veen 1992. De relevantie van "The naive proficient" voor het natuurbeheer. [In Dutch]. Appendix in: M. Klaassen. The naive Proficient. Metabolic responses of chicks to problems of climate and food availability. Thesis, Univ. Groningen.

KNMI 1991a. Maandoverzicht neerslag & verdamping in Nederland 60(5), mei 1991.

KNMI 1991b. Maandoverzicht neerslag & verdamping in Nederland 60(6), juni 1991.

KNMI 1991c. Maandoverzicht neerslag & verdamping in Nederland 60(7), juli 1991.

KNMI 1991d. Maandoverzicht van het weer in Nederland 88(5), mei 1991.

KNMI 1991e. Maandoverzicht van het weer in Nederland 88(5), juni 1991.

KNMI 1991f. Maandoverzicht van het weer in Nederland 88(5), juli 1991.

Koeman, J.H., T. Bothof, R. de Vries, H. van Velzen-Blad & J.G. de Vos 1972. The impact of persistent pollutants on piscivorous and molluscivorous birds. TNO-nieuws 27(10): 561-569.

Koval P.J., T.J. Peterle & J.D. Harder 1987. Effects of polychlorinated biphenyls on Mourning Dove reproduction and circulating progesterone levels. Bull. Environ. Contam. Toxicol. 39: 663-670.

Kubiak, T.J., H.J. Harris, L.M. Smith, T.R. Schwartz, D.L. Stalling, J.A. Trick, L. Sileo, D.E. Docherty & T.C. Erdman 1989. Microcontaminants and reproductive impairment of the Forster's Tern on Green Bay, Lake Michigan - 1983. Arch. Environ. Contam. Toxicol. 18: 706-727.

LAC 1990. Biomonitoring van stofconcentraties en effecten. Signaleren, controleren en voorspellen. Ministerie van Landbouw, Natuurbeheer en Visserij, 's Gravenhage.

Leemans, J. & B. Verspaandonk 1972. Saeftinghe. Vegetatiekaart 1 : 10.000. Uitgave 1980, Stichting Het Zeeuwse Landschap.

Lemmetyinen, R. 1973. Breeding success in *Sterna paradisea* Pontopp. and *S. hirundo* L. in southern Finland. Ann. Zool. Fennici 10: 526-535.

Lemmentyinen, R. 1974. Comparative breeding ecology of the Arctic and the Common Tern with special reference to feeding. Reports from the department of ecology, Univ. of Turku: 5-19.

Ling, R. 1967. Breeding ecology of the Common and Arctic Tern. In: Kumari, E. (ed.). Lääne-Eesti meraarte linnustik, Ornitoloogiline kogumik IV: 90-113, Tartu.

Lloyd, C.S. 1979. Factors affecting breeding of Razorbills *Alca torda* on Skokholm. Ibis 121: 165-176.

Lok, C.M. & L. Bakker 1988. Seizoengebonden terreinkeuze van Aalscholver *Phalacrocorax carbo* op Voorne. Limosa 61: 7-12.

Lundholm, E. 1987. Thinning of eggshells in birds by DDE: mode of action on the eggshell gland. Comp. Biochem. Physiol. 88C, 1-22.

Lundberg, C.A. & R.A. Väisänen, 1979. Selective correlation of egg size with chick mortality in the Black-headed gull (*Larus ridibundus*). Condor 81: 146-156.

Maebe, J. 1991. Verdronken Land van Saeftinghe. Broedvogelinventarisatie 1990. Zeeuws Landschap 2: 6-9.

Meininger P.L., C.M. Berrevoets & R.C.W. Strucker 1992. Kustbroedvogels in het Deltagebied in 1991 met een samenvatting van dertien jaar monitoring 1979-1991. Rapport DGW-92.024. Dienst Getijdewateren, Middelburg.

Moerland, G. 1987. Het Schelde-estuarium. In: Westerschelde studies: studierapport Nr. 9, deel 1 (73 pp.) en deel 2 (71 pp.).

Moriarty, F., A.A. Bell & H. Hanson 1986. Does p,p'-DDE thin eggshells? Environ. Pollut. 40A: 257-286.

Morris, R.D., R.A. Hunter, & J.F. McElman 1976. Factors affecting the reproductive success of Common Tern (*Sterna hirundo*) colonies on the lower Great Lakes during the summer of 1972. Can. J. Zool. 54: 1850-1862.

Murk, A.J., A. Spenkelink, A. Brouwer, M. van Kampen, A.T.C. Bosveld, J. Gradener, M. van den Berg 1993. Effects of PCBs, PCDDs and PCDFs on reproductive success, and morphological, physiological and biochemical parameters in chicks of the Common tern (*Sterna hirundo*). Part 2: laboratory study. Report DGW-93.011, Rijkswaterstaat - Tidal Waters Division, University Wageningen, University Utrecht.

Nisbet, I.C.T. 1973. Courtship-feeding, egg-size and breeding succes in Common terns. Nature 241: 141-142.

Nisbet, I.C.T. 1975. Selective effects of predation in a tern colony. Condor 77: 221-226.

Nisbet, I.C.T. 1977. Courtship-feeding and clutch size in Common Terns *Sterna hirundo*. In: Stonehouse, B. & Perrins C. (Eds.). Evolutionary Ecology. The Macmillan Press Ltd.

Nisbet, I.T.C. 1978b. Dependence of fledging success on egg-size, parental performance and egg-composition among Common and Roseate terns, *Sterna hirundo* and *S. dougallii*. Ibis 120: 207-215.

Nisbet, I.T.C. 1983. Territorial feeding by Common terns. Colonial Waterbirds 6: 64-70.

Nisbet, I.T.C. & W.H. Drury 1972. Measuring breeding success in common and roseate terns. Bird-Banding 43: 97-106.

Nisbet, I.C.T. & M.E. Cohen, 1975. Asynchronous hatching in common and roseate terns, *Sterna hirundo* and *S. dougallii*. Ibis 117: 374-379.

Nisbet, I.C.T., J. Burger, C. Safina & M. Gochfeld 1990. Estimating fledging success and productivity in Roseate Terns (*Sterna dougallii*). Colonial Waterbirds 13: 85-91.

Noordhuis, R., E.C.L. Marteijn, S. Dirksen & T.J. Boudewijn 1993. Voedseltekort voor de Visdieven van Zeewolde in 1991? Limosa, in press.

Norusis, M.J. 1986. SPSS/PC+. SPSS Inc., Chicago.

Neubauer, W. 1969. Zu einige Fragen der Brutbiologie und des Verhaltens der Flusseeschwalbe (*Sterna h. hirundo* L.). Beitr. Vogelkd. 14: 238-341.

Owen, M. & J.M. Black 1990. Waterfowl Ecology. Blackie, Glasgow and London.

Parson, J. 1970. Relationship between egg size and post-hatching chick mortality in the Herring gull (*Larus argentatus*). Nature 228: 1221-1222.

Paulussen, J. 1981. Broedbiologie, postnatale groei en energiebehoefte van jonge kokmeeuwen *Larus ridibundus* Linnaeus (Aves: Laridae). Proefschrift, Katholieke Universiteit Leuven. 259 pp.

Peakall, D.B. & M.L. Peakall 1973. Effect of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. J. Appl. Ecol. 10: 863-868.

Peakall, D.B. & G.A. Fox 1987. Toxicological investigations of pollutant-related effects in Great Lakes gulls. Environmental Health Perspectives 71: 187-193.

Pearce, P.A., D.B. Peakall & L.M. Reynolds 1979. Shell thinning and residues of organochlorines and mercury in seabird eggs, Eastern Canada, 1970-76. Pestic. Monit. J. 13: 61-68.

Ratcliffe, D.A. 1967. Decrease in eggshell weight in certain birds of prey. Nature 215: 208-210.

Perrins, C. M. 1970. The timing of birds breeding season. Ibis 112: 242-253.

Perrins, C.M. & T.R. Birkhead 1983. Avian Ecology. Blackie, Glasgow and London.

Ratcliffe, D.A. 1970. Changes attributable to pesticides in egg breakage frequency and eggshell thickness in some British birds. J. Appl. Ecol. 7: 67-115.

Richards, M.H. & R.D. Morris 1984. An experimental study of nest site selection in Common terns. J. Field Ornithol. 55: 457-466.

Ryder, J.P. 1980. The influences of age on the breeding biology of colonially nesting seabirds. In: Burger, J., B.L. Olla & H.E. Winn (eds.). Marine Birds. Plenum, New York.

Scholten, M.C.T., E.M. Foekema, W.C. de Kock & J.M. Marquenie 1989. Reproduction failure in Tufted Ducks, feeding on mussels, from polluted lakes. pp. 365-371 in: Proc. 2nd Eur. Symp. on Avian Medicine and Surgery. Dutch Ass. of Avian Veterinarians.

Stienen, E.W.M. & A. Brenninkmeijer 1992. Ecologisch profiel van de Visdief (*Sterna hirundo*). RIN-rapport 92/18. DLO-Instituut voor Bos- en Natuuronderzoek, Arnhem.

Swelm, N.D. van 1990a. De broedvogels van het Westplaat-sluftergebied 1988. Stichting Ornithologisch Station Voorne, Oostvoorne.

Swelm, N.D. van 1990b. De broedvogels van het Westplaat-sluftergebied 1989. Stichting Ornithologisch Station Voorne, Oostvoorne.

Swelm, N.D. van 1990c. De broedvogels van het Westplaat-sluftergebied 1990. Stichting Ornithologisch Station Voorne, Oostvoorne.

Teixeira, R.M. (ed.) 1979. Atlas van de Nederlandse Broedvogels. Vereniging tot Behoud van Natuurmonumenten in Nederland, 's Graveland.

Ten Brink, B.J.E. & S.H. Hosper 1989. Naar toetsbare ecologische doelstellingen voor het waterbeheer: de AMOEBE-benadering. H_2O 22: 612-617.

Van Buel, H. 1991. Broedvogels van het Krammer-Volkerak en Zoommeer 1991. Rapportnummer 635/10000-1. Heidemij Adviesbureau, Lelystad.

Van der Gaag, M.A., M. van den Berg, A. Brouwer, S. Dirksen, T. Boudewijn & G. van Urk 1991. Impaired breeding success of some Cormorant populations in the Netherlands: the net tightens around compounds with a dioxin-like effect. pp. 71-77 in: J.A.W. de Wit, M.A. van der Gaag, C. van der Guchte, C.J. van Leeuwen & J. Koeman (eds.): The effect of micropollutants on components of the Rhine ecosystem. Publikaties en rapporten van het project 'Ecologisch Herstel Rijn' nr. 35.

Van Nes, E.H., M.-L. Meijer, A.W. Breukelaar, P. Hollebeek, E.H.R.R. Lammens, H. Coops & E.C.L. Marteijn 1992. Wolderwijd-Nuldernauw 1991. Gevolgen van uitdunning van de visstand. Notanr. 92.063. Rijkswaterstaat - RIZA, Lelystad.

Van Schaik, A. & D.J. de Jong 1988. De vegetatie van buitendijkse terreinen langs de Westerschelde. Rijkswaterstaat, Dienst Getijdewateren, Middelburg.

Vermeer, K. & D.B. Peakall 1977. Toxic chemicals in Canadian fish-eating birds. Mar. Pollut. Bull. 8: 205-210.

Veen, J. 1977. Functional and causal aspects of nest distribution in colonies of the sandwich tern (*Sterna s. sandvicensis* Lath.). Behaviour, Suppl. 20: 1-193.

Veen, J. & J. van de Kam 1988. Griend vogeleiland in de Waddenzee. Vereniging tot Behoud van Natuurmonumenten in Nederland, 's Graveland / Terra, Zutphen.

Veerkamp, M.T., R. Beringen & R.G. Mes 1988. Beheersplan Haringvliet. Grasgorzen Haringvliet, Slijkplaat, Ventjager, Spuigorzen. Deel I: Inventarisatie. Ecoland-rapport 88-3. Bureau Ecoland, Utrecht.

Ysebaert, T. & P. Meire 1989. Uitkomstsucces en foerageergedrag van kokmeeuwen in drie kolonies gelegen langs de Westerschelde. Rapport W.W.E. 6. Rijksuniversiteit Gent.

Zijlstra, M. & M.R. van Eerden 1991. Development of the breeding population of Cormorants *Phalacrocorax carbo* in the Netherlands till 1989. pp. 53-60 in: M.R. van Eerden & M. Zijlstra (eds.). Proceedings workshop 1989 on Cormorants Phalacrocorax carbo. Rijkswaterstaat Directie Flevoland, Lelystad.