

Daily Hay Fever Forecast in The Netherlands

Radio Broadcasting of the Expected Influence of the
Weather on Subjective Complaints of Hay Fever Sufferers

FRITS TH.M. SPIEKMA

Department of Allergology, University Medical Centre, Leiden, The Netherlands

The literature on local pollen counts and their significance for hay fever is reviewed and a system for forecasting hay fever is described. Such forecasts have been broadcast by radio in The Netherlands since 1977. The hay fever forecast takes the form of a prognosis (in terms of three grades) of the influence of the expected weather situation on tomorrow's course of the subjective complaints of hay fever sufferers. It is not a forecast of the pollen count.

When the subjective complaints of about 150 hay fever patients were used as reference for evaluation, the forecasts proved to have been correct in 72, 85, and 88% of the cases in 1977, 1978, and 1979, respectively.

The practical usefulness and the limitations of the system are briefly discussed, with emphasis on the principle that not the local pollen count but the weather should be taken as the main determinative factor for the expected subjective experiences in a group of hay fever sufferers in a certain region.

Key words: forecast; hay fever; pollen count.

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The severity of hay fever complaints in individuals who are allergic to pollen allergens is related to the degree of exposure to the airborne pollen grains; and the concentration of airborne pollen grains is determined, apart from the flowering characteristics, by the weather conditions. With the considerable increase in aerobiological monitoring in recent decades, more insight has been gained into the seasonal course of the airborne pollen concentrations, particularly of grass in Western Europe, of birches in Scandinavia, and of ragweed in Northern America.

These developments have led in some countries or regions to the publication of daily pollen counts and sometimes even forecasts, as a service to hay fever sufferers (10). The release of this kind of information to the public is based on the assumption of a more or less simple relationship between the pollen count

and the severity of hay fever complaints, and between meteorological parameters and the pollen count. However, these relationships have proved to be far from simple and to be influenced or obscured by a large number of variables.

A forecast of tomorrow's airborne-pollen concentration, as proposed by Dingle (8), Davies & Smith (7), Stix (36), Bringfelt (2), and Weeke (41), and as reported by Frankland (10) and Raynor & Hayes (31), is considered to be too unreliable for a large area and to provide inadequate information to hay fever patients. On the other hand, observations in the seasons between 1970 and 1978 (for an example, see Fig. 1), have made it clear that there is a positive relationship between certain meteorologic parameters such as sunshine, rising temperature, and absence of precipitation on the one hand and the

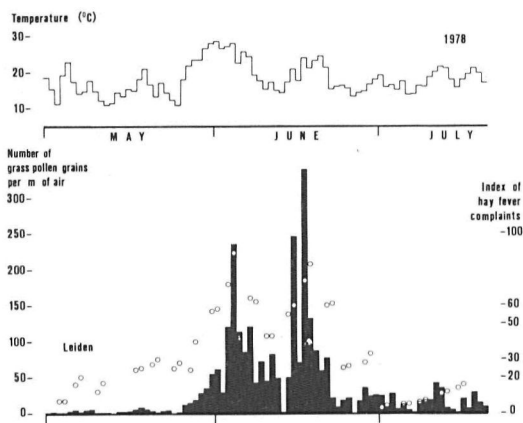


Fig. 1. Hay fever complaints in relation to pollen grain counts and temperature.

Indices of hay fever complaints of 156 patients (open circles) show a limited relationship with airborne grass pollen concentrations (solid columns). Within the May-June-July season there is a striking relationship between the indices of complaints and maximum daytime temperature of the outdoor air (top curve) measured at De Bilt (about 60 km east of Leiden).

subjective hay fever complaints on the other. This relationship is particularly clear very early in the hay fever season, even when hardly any grass pollen grains are collected at the sampling site (see also the graphs published by van den Assem (1) and Fuckerieder (11).

Further analysis of this relationship was not undertaken, but in 1975 an attempt was made retrospectively to relate the weather forecasts to the complaints reported by a group of hay fever patients. After this relationship had been incorporated into a working scheme, it was applied to forecast hay fever intramurally in 1976 to evaluate the accuracy. When the degree of reliability reached in 1976 was judged to be sufficiently high, radio broadcasting of the hay fever forecast was started in 1977.

The forecast represents a prediction of whether the expected weather conditions will be beneficial or adverse for hay fever patients; in other words, it gives a relative prognosis of what the patients can expect to experience as to improvement or worsening of their complaints due to the weather situation. It is not a forecast of the pollen count.

MATERIAL AND METHODS

Pollen count

A Hirst automatic volumetric spore trap (14) has been in operation since 1969. Until 1976, it was on a low flat roof (about 4 m above street level) surrounded by higher buildings of the University Hospital. In 1977, it was shifted to a higher roof (about 12 m above street level). The trap is equipped with an external membrane vacuum pump. Since 1977, a Burkard seven-day trap has also been in operation on the same roof at a distance of about 5 m from the Hirst trap.

Descriptions of the traps and methods used for the preparation of the slides can be found in Ogden et al. (30) and in Leuschner (22). Safranin is added to the embedding medium for selective staining of the pollen grains.

For the volumetric value of the daily pollen count, three bands, each 1/3 mm wide, were scanned, which corresponds with 1 m³ of air passing through the trap between 0.00 and 24.00 h, Middle European Time.

Scoring the weather forecast

The weather forecast for The Netherlands is prepared by the Royal Dutch Meteorological Institute (KNMI); it is revised every 2 h, and given to the public in hourly newscasts by radio, by an automatic telephone service, (and in the daily newspapers and after the news on television). Starting at noon, it includes the weather development expected for the next day, expressed in a more or less typical jargon. The forecast gives information on four aspects: the amount of sunshine and/or degree of cloudiness; the intensity and/or duration of precipitation; minimum and maximum temperatures; and the force and direction of the wind. To adapt the information on the first two aspects for the study of the relationship to hay fever, two independent scoring lists were devised, with scales from 1 to 10 (Table 1). On the basis of these lists, the expected type of weather is expressed as a score by taking the average of the scores in the two lists and, if

Table 1
Scoring lists for expected weather

Score	Sun	Clouds	Rain	Score
1	dismal	heavily clouded	prolonged rain	1
2	no sun	overcast	rains	2
3	occasional sun	increasingly cloudy	rainy periods	3
4	short sunny spells	half clouded; changing cloudiness	occasional rains; showers	4
5	sunny spells	bright intervals	occasional showers	5
6	increasingly sunny	clearing sky	some local showers	6
7	pretty sunny	clear sky	locally a shower	7
8	sunny	almost cloudless	perhaps a single shower	8
9	sunny and warm	cloudless	mostly dry	9
10	sunny and very warm		dry	10

The expected type of weather, as forecast by the Royal Dutch Meteorological Institute (KNMI), is expressed by a single score representing the average of two scores, one for the amount of sunshine and/or degree of cloudiness (left) and the other for the intensity and/or duration of precipitation (right).

necessary, rounding off upward. For example, "mainly dry, with a clearing sky and some sunny spells", is recorded as $(9+6)/2=8$, and "increasing cloudiness, with some local rain" becomes $(3+3)/2=3$.

Index of the hay fever complaints

Since 1970, in the months of April through July, all hay fever patients visiting the out-patient clinic for hyposensitization treatment are interviewed very briefly by the nurse and asked about the presence and severity of typical signs of hay fever on the two preceding days. Since these patients come on Monday and Friday mornings, information about their state on Saturday and Sunday and on Wednesday and Thursday is collected (patients starting treatment come twice a week; later, less frequently but at least once a month).

The subjective appraisal of the severity of the complaints is scored by the nurse according to a simple plus-and-minus sign system: no complaints: —; weak or faint complaints: $\pm$; clear and unmistakable complaints: +; serious or severe complaints: ++.

In the 9 years since 1970 the number of hay fever patients whose subjective complaints

have been scored and evaluated has ranged per year from 118 to 156. The number of visitors per day ranged between 15 and 60, and is usually around 40. The "index" of the hay fever complaints is obtained by adding all plus signs for one day, dividing the sum by the number of patients seen on that day, and multiplying the results by a hundred:

$$\frac{\text{sum of plus signs}}{\text{number of patients seen}} \times 100 = \text{index of complaints}$$

No attempt was made to collect symptom scores by having the patients keep a diary (27, 39), since in this study it was preferred to record the subjective experience of as many patients as possible and thus to avoid selection of patients willing and able to keep a symptom diary for more than 3 months with the required diligence.

The diagram in Fig. 1 gives an example of the indices of hay fever complaints reported by 156 patients in 1978. The large size of the groups of patients coming from Leiden and its surroundings and its composition including males and females of different ages, makes it extremely likely that the course of these indices is representative for the vast majority of hay fever patients in the area.

The scale of the indices, which very rarely exceed 100 is divided into three overlapping sections: 0–30, 21–60, > 50. Index values lower than 30 are considered to correspond with a characterization of the complaints in the group as light or absent. This is the normal situation outside the hay fever season in The Netherlands, i.e., before the end of April and after the end of July. When the index is under 30 during the hay fever season, the situation is apparently beneficial for the hay fever patients, and the weather condition is therefore considered favourable. Index values lying between 21 and 60 represent a moderate level of complaints, indicating a situation called not very favourable. Values higher than 50 represent serious and severe complaints, i.e. a situation that is adverse or unfavourable for the majority of the hay fever patients.

Relation of the weather-forecast score to the complaint index

The basis for this method of forecasting conditions for hay fever patients is the relationship between the score indicating the expected weather situation and the section of the scale of indices of complaints experienced by a large group of hay fever patients.

Empirically, the data for both weather and complaints collected in 1975 were matched as closely as possible and were later adjusted according to those for 1976. A reasonable and useful relationship was obtained when the hay fever season was divided into periods. In agreement with Noland & Duchaine (26), three periods were distinguished: the start, the peak period, and the end of the season. In addition, an earlier period had to be considered. After the maximum temperature was taken into account, the scheme shown in Table 2 was constructed. The first period runs from the end of April to the first week of May, when very few or no grass pollen grains are found at the sampling sites. However, a sunny, dry, and warm type of weather gives rise to the first hay fever complaints in a certain

proportion of the patients: weather scores of 7, 8, and 9, with maximum temperatures above 17°C, correspond to the middle section of the index scale (21 to 60). This weather situation is called not very favourable. However, this fine type of weather is more the exception than the rule at this time of the year in The Netherlands and normally there are hardly any hay fever complaints.

The second period is characterized by grass pollen counts that are initially low but rise toward the end of May. During the last 3 weeks of May the index may lie in the middle section of the index scale (21–60) when the weather is rather sunny and even when there are occasional showers. If temperatures rise over 20°C (which rarely occurs), the majority of the hay fever patients start to have more severe complaints, which pushes the index to values higher than 50.

In the first 3–4 weeks of June, the highest numbers of grass pollen grains occur and the hay fever patients suffer most. During this third period, the index of complaints can be expected to be low only when clouds cover the sky, when rain falls for long periods, and when temperatures are low. This type of weather is called favourable for hay fever patients.

During the last period, the grass pollen count decreases and the relationship between the weather and the complaint index resembles that of the second period, albeit under a different temperature influence.

The transition from one period to another is determined by two factors, i.e. the level of the daily grass pollen counts and the apparent shift in the relationship between the weather score and the index of complaints.

RESULTS

The quality of this kind of hay fever forecasting is assessed by comparing the *predicted* section of the index scale with the *scored* indices of complaints reported by the hay fever patients. For the evaluation of this comparison, one factor in particular is of decisive interest: the quality of the weather forecast. This is judged

Table 2
Scheme for formulation of the relationship between weather-forecast score and index of complaints

No. pollen grains	No	Low; rising	High	Falling	Section of index scale	Weather conditions for hay fever pat.
Period	April 27—May 7	May 8—May 31	June 1—June 25	June 26—July 20		
Score for weather	$\begin{array}{l} 1,2,3,4,5,6 \\ t \leq 17^\circ \\ \hline 7,8,9 \\ t > 17^\circ \\ \hline 10 \end{array}$	$\begin{array}{l} t \leq 15^\circ \\ \hline 1,2,3,4,5 \\ t > 15^\circ \\ \hline 6 \end{array}$ $\begin{array}{l} t \leq 20^\circ \\ \hline 7,8,9 \\ t > 20^\circ \\ \hline 10 \end{array}$	$\begin{array}{l} t \leq 15^\circ \\ \hline 1,2 \\ t > 15^\circ \\ \hline 3,4 \\ t > 20^\circ \\ \hline 5 \end{array}$ $\begin{array}{l} t \leq 20^\circ \\ \hline 5 \\ t > 15^\circ \\ \hline 6 \end{array}$ $\begin{array}{l} t \leq 15^\circ \\ \hline 3,4 \\ t > 15^\circ \\ \hline 5 \end{array}$ $\begin{array}{l} t \leq 20^\circ \\ \hline 6 \\ t > 15^\circ \\ \hline 7,8,9,10 \end{array}$	$\begin{array}{l} t \leq 17^\circ \\ \hline 1,2,3,4 \\ t > 17^\circ \\ \hline 5,6 \\ \hline 7 \\ \hline 8,9,10 \end{array}$	0-30 21-60 > 50	favourable not very favourable unfavourable

The weather forecast score (derived from Table 1) located in the actual period and (where indicated) related to the expected maximum day time temperature, determines the appropriate section of the scale of indices of complaints (right). The three sections of the index scale correspond with the expected effects of weather conditions for the complaints of hay fever sufferers (far right) in the terms used in the message given in the daily radio broadcast.

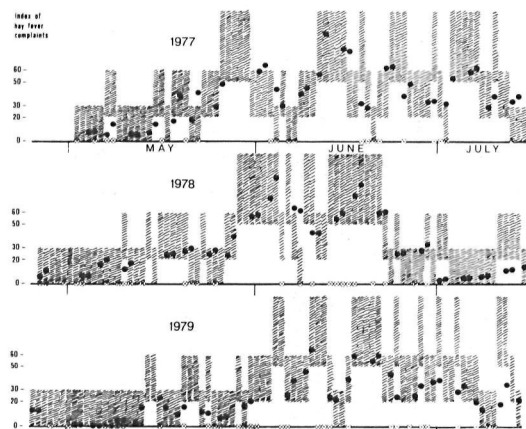


Fig. 2. Forecast and reported hay fever complaints in three seasons. Predictions of the section of the scale of indices of complaints for tomorrow (hatched vertical bars) and indices of complaints reported by about 150 hay fever patients (black dots). Days with a bad or poor quality weather forecast are indicated (open crossed circles). (For numbers and percentages of days with correct or incorrect hay fever forecasts, see Table 3.).

daily by comparing actual data (e.g. precipitation, temperature) with the expected conditions, and is rated bad, poor, reasonable, and good. It is self-evident that a prediction of the effect of the weather for hay fever sufferers that is based on a weather forecast of poor or bad quality has very little chance of being correct. Therefore, the quality of the weather forecast must be taken into consideration here.

Fig. 2 shows the results of comparison between the predicted sections of tomorrow's index scale and the indices reported by the patients for 1977, 1978, and 1979.

Table 3 summarizes these results numerically, giving the numbers and percentages of days for which the prediction appeared to be correct, underestimated, or overestimated, both with and without the days with inaccurate or poor weather forecasts. Although the presentations in Fig. 2 and Table 3 speak for themselves, the results for 1979 need special comment. The distribution of the incorrect predictions over underestimation and overestimation is extremely unequal (0 to 9), probably due to the exceptional weather situation during that year, when a very long

and severe winter was followed by a relatively cold and wet spring and summer. Retrospectively, this combination of meteorological events should have led to a reduction of the weather scores in the scheme shown in Table 2.

DISCUSSION

Most of the studies on the relationship between hay fever symptoms and exposure to allergenic pollen have made use of the Durham gravity slide, the Hirst volumetric pollen trap, or a similar instrument to obtain pollen counts over 24 h periods, but observations of the flowering characteristics, the time of shedding of the pollen, and the airborne-pollen levels have shown that most plants release their pollen within limited periods (hours) rather than throughout the day (18, 19, 24, 28, 35).

Moreover, because changing meteorological conditions determine the duration and the direction of the transport of the pollen grains through the air, the concentration at any given monitoring spot will fluctuate widely and irregularly (1, 8, 11, 13, 15, 17, 32, 37, 38, 40).

An example of these fluctuations in time is given in Fig. 3, which shows the average grass pollen concentrations in one cubic metre of air during periods of 4 h and also the concentration averaged over 24 h, on the basis of observations made with a Hirst volumetric pollen trap in the city of Leiden between June 10th and 22nd in 1975. These findings, which closely resemble those of Gurney & Cryst (13), show how extremely different the course of the airborne-pollen concentration can be on 2 separate days with approximately the same 24 h average (i.e., with the same "pollen count").

There are also marked differences in airborne-pollen concentrations between places several kilometres apart (3, 6, 11, 12, 17, 37, 40), and even considerable differences at distances of a few metres (23, 33, 34). An example of this divergence is given in Fig. 4, which shows the daily pollen counts determined with two similar volumetric pollen

Table 3
Evaluation of the accuracy of hay fever forecasts

		1977				1978				1979			
		All hay fever forecasts made		Hay fever forecasts for days with correct weather forecast		All hay fever forecasts made		Hay fever forecasts for days with correct weather forecast		All hay fever forecasts made		Hay fever forecasts for days with correct weather forecast	
Quality of hay fever forecast		Days	%	Days	%	Days	%	Days	%	Days	%	Days	%
Correct		23	58	21	72	34	79	22	85	34	79	23	88
Underestimation		8	20	4	14	3	7	1	4	0	0	0	0
Overestimation		9	22	4	14	6	14	3	11	9	21	3	12

Numbers and percentages of days with correct and incorrect hay fever forecast, predicting the section in which the indices of the reported complaints of about 150 hay fever patients will come to lie.

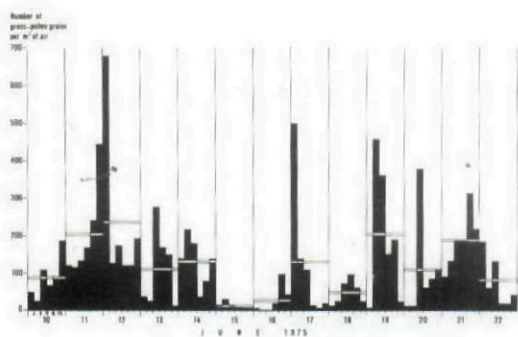


Fig. 3. Daily irregular fluctuations of airborne pollen concentrations. Grass pollen concentrations/ m^3 of air averaged for 4-h periods (solid columns) and over 24 h (open horizontal bars). Observations made in Leiden with a Hirst volumetric pollen trap.

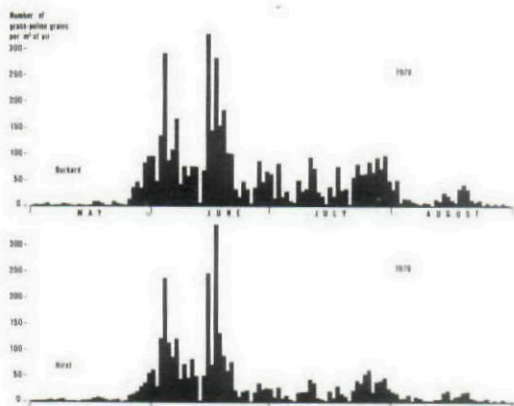


Fig. 4. Pollen counts with two similar instruments. Grass pollen concentrations/ m^3 of air sampled in Leiden with a Hirst volumetric pollen trap and a Burkard 7-day volumetric pollen trap, placed about 5 m apart.

traps (a Hirst and a Burkard) situated approximately 5 m apart. Not only the size of the catch, but also the course of the daily pollen counts differed within this short distance. The results of such studies indicate that pollen grains are transported through the air in more or less discrete clouds and that considerable time and distance are required before a homogeneous distribution is reached.

Nevertheless, the general seasonal pattern for the pollen types found in relatively high concentrations shows a great similarity, at least between places within a region with the same climate (3, 11, 37, 40). This similarity becomes much more distinct when the daily pollen

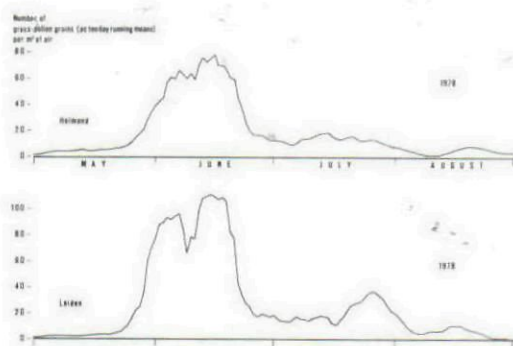


Fig. 5. Pollen counts for two cities.

Ten-day running means of grass pollen concentrations/ m^3 air sampled with two Hirst volumetric pollen traps, one in Leiden and one in Helmond (about 100 km apart).

count is transformed into a "10-day running mean" presentation. As an example, the seasonal patterns of the grass pollen concentrations for two Dutch cities, Leiden and Helmond, are shown in Fig. 5. Leiden is situated in the western part of the country, about 10 km from the North Sea coast; Helmond about 100 km inland. Over this distance in the delta making up the greater part of The Netherlands, there is no difference in climate. From these observations the conclusion may be drawn that the general pattern of the average daily-pollen concentration is very much the same within a region with a similar climate, but hourly variation may be extreme within short distances, and the hourly-pollen count at a given monitoring spot may not reflect or be a measure of the hourly exposure of hay fever patients to the pollen allergen.

Nevertheless, there are many reports on the overall positive relationship between the airborne-pollen concentration and hay fever complaints, for ragweed, grass, and birch (1, 4, 9, 11, 15, 16, 20, 21, 25, 26, 27, 36, 39).

A closer look at the graphs presented by the various authors reveals, however, a number of deviations from this general relationship. In some studies a relatively elevated symptom score in relation to the pollen count, was found during the last weeks of the hay fever season (20, 25, 39), but other authors have reported a

relatively very high symptom level at the very beginning of the season (15, 26, 36). An unequivocal absence of an hour-to-hour relation between pollen count and symptoms has also been found (13, 15).

The conclusion to be drawn from all these sometimes seemingly conflicting observations is that there is only a very rough and general relationship between pollen count and hay fever complaints. But, as Noland & Duchaine (26) have also concluded, this relation is different during the early part of the season, in the peak period, and the end of the season.

It is evident that these conclusions are in conflict with the view that there is a general and fixed threshold value of the pollen count above which almost all patients experience symptoms, e.g., 30 ragweed pollen grains/m³ (29), 50 grass pollen grains/m³ (Frankland & Davies, unpublished observations: see 5), or initially 80 and later in the season 30 birch pollen grains/m³ air (39).

CONCLUSION

If the percentages of correct predictions on days with a reasonably accurate or good weather forecast are taken as the most relevant criterion for evaluation of the hay fever forecast, it is clear that the values of 72% in 1977, 85% in 1978, and 88% in 1979 are high enough to justify continued use of the method described here. In the years to come, however, a more critical consideration of all of the factors involved should include the subjectivity and averaging of the complaints of a group of patients, the variability of both the weather situation and the patient's condition, and so forth. These factors are not relevant solely for the principles of the present forecasting system but are also of great significance for other systems in use or in preparation elsewhere.

It is to be expected that in the near future more data will become available from studies now in progress, which should lead to improvement of the quality and accuracy of hay fever predictions. The system described here is almost completely empirical, and the

results of each season contribute to adjustments in the system for the next season.

The practical usefulness of this particular procedure for forecasting hay fever is restricted to local conditions. It would unquestionably be impossible to apply exactly this procedure, which has been used successfully in The Netherlands, in other countries or regions where other plants may be the main cause of hay fever complaints and where the climate is different. This paper points to the value of the principle by which the local pollen count is not taken as the main determinative factor for the expected subjective complaints in a group of hay fever sufferers in a certain region. It demonstrates the possibility of predicting adverse or favourable influences of the expected weather on hay fever with an acceptable degree of accuracy based partially on objective observations, and partially on empirical relationships.

Practical procedure

1. Take tomorrow's weather forecast given by the automatic telephone service at 4.30 p.m.
2. Transform the information about sunshine, cloudiness, and rain, into two scores (Table 1) and take the average, which is the weather forecast score.
3. On the basis of the scheme in Table 2, relate this weather forecast score in the actual period to the section of the scale of indices of complaints. This corresponds with the estimation of tomorrow's weather for hay fever patients expressed as favourable, not very favourable, and unfavourable.
4. Put this estimate, using additional relevant weather-forecast information such as changes in time and/or place (e.g., sun in the morning, rain in the afternoon; sun in the south, rain in the north) in a message and communicate this message to the radio station at 5.00 p.m., so that it can be broadcast at 5.30 p.m.
5. Collect and score the subjective data on complaints as frequently as possible (twice a

week for the 2 preceding days), and compare these scored indices with the forecast sections of the scale of indices, to judge whether the forecast was correct or incorrect.

6. Do a daily pollen count, using a volumetric pollen sampler, and use these data and those for the complaints to determine the time of transition from one period to the next.

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Address:

F. Th. M. Spijkstra, Ph.D.
 Afdeling Allergologie
 Academisch Ziekenhuis
 Rijnsburgerweg 10
 2333 AA Leiden
 The Netherlands

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