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Foraging strategy in the spoonbill (*Platalea leucorodia*).

by

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CONTENTS.

SUMMARY

The aim of this study was to find factors that made the spoonbill colony in the Zwanenwater decrease so drastically. Three to four hundred pairs of, the spoonbill Platalea leucorodia bred in the Zwanenwater around 1930 against 60 pairs in the last years.

Foodintake rate is determined in five different areas of the spoonbill in the north of the province of Noordholland. Five different types of prey can be distinquished with different weight and density. This study shows that weight of prey is much more important for high foodintake rate than density of prey.

The stickleback is the most important prey for the spoonbill of the Zwanenwater. There is much variation in size between fish of different stickleback populations. The areas with populations with big sticklebacks are the ones that are visited most by the spoonbill (Wieringerwaard). The exclusion of migrating 3-spined sticklebacks from the polders might have caused the decline in number of spoonbills in the last fifty years.

CHAPTER 1.

FOODINTAKE RATE.

1.1 INTRODUCTION

The spoonbill Platalea leucorodia migrates from Africa and the south of Spain to Holland in early spring. In different colonies the birds breed from march until the end of june. Then they leave the colony to return to the south in August. (Poorter 1969, 1979) In 1930 about 300 pairs of spoonbills visited the Zwanenwater, a nature reserve in the dunes near Callantsoog (figure 1.2.: Z). From that time the number decreased to about 60 pairs (figure 2.6). There are a few possible reasons for this decline. For example, the colony might supply to few nest places or might be not protected enough against predators (f.e. fox). There might be to few places with shallow water for the spoonbill to search for food. Maybe the foodsituation or the foraging strategy of the spoonbill is the bottleneck (Krebs, Cowie 1976). From a previous study on the spoonbill food seemed to be the most likely restriction for a large spoonbill population. To get more insight in the food situation a quantitative analysis and comparison of the foodintake rate in different foraging areas of the spoonbill was carried out. The foodintake rate was estimated by catch frequency and prey weight. In addition to a comparison between foraging areas, the most profitable food situation for the spoonbill was determined. A similar study was carried out by Lowe (1981) for the Royal spoonbill Platalea regia in Westernportbay, Victoria, Australia. On these mudflats, covered with seagrass, the main prey is the striped prawn Macrobrachium intermedium.

1.2 MATERIALS AND METHODS.

The foodintake rate is computed according the following equation.

$F = C * W$ with F: Foodintake rate.
C: Catch frequency.
W: Average weight of the prey.

1.2.1 Recording the foraging behaviour (C).

The places where the spoonbills were foraging were located by driving around by car in the study area. To increase the probability of finding spoonbills most attention was paid to places where the birds were numerous in 1984. In addition, local birdwatchers gave information about actual observations. Especially when a spoonbill finds little

ACTIVITY	TIME (Sec.)
sweep	0
catch	6
chase	29
catch	45
look	46
sweep	50
catch	75
catch	96
look	101

Table 1.1. Example of a protocol linked to a time scale.

	Average frequency (actions / minute)
catch	9.6 ± 3.2
look	5.6 ± 1.5
chase	2.3 ± 2.3

Table 1.2.a Catch/look and chase frequency (minute).

	Average chare (%) to the total activities per minute.
sweeping	88.8 ± 5.6
look	6.1 ± 1.2
chase	5 ± 5.7

Table 1.2.b Percent wise chare of sweeping/look and chase.

	Average catch frequency (minute) (compensated)
catch	10.2 ± 3.2

table 1.2.c The amount of catches per minute, compensated for the time the spoonbill did look.

food he is easy to disturb and will fly away. Therefore most behaviour protocols were made from the car. Birds were observed with a Bausch & Lomb, 60 mm zoom telescope (15 - 60 times). With such a telescope, behaviour protocols can be made up to a distance of 400 meter, under good weather conditions (i.e. cold and clear). For the recording a portable cassette recorder was used. In describing the foraging behaviour of the spoonbill four different activities were distinguished.

1) SWEEPING: The spoonbill sweeps its bill through the water from side to side. This is the main behaviour of a sweeping- bird. But in the definition of sweeping all other activities, in which the bill is in the water to locate prey are included.

2) CATCH: Finding a prey the spoonbill throws it from the spoon into its throat.

3) CHASE: Prey is found but not yet caught. The spoonbill chases the prey systematically and often by sight.

4) LOOK: The spoonbill looks up interrupting its foraging activities.

During the recording of the protocol, the cassette recorder was continuously on. In this manner the exact time of each activity is known. The successsive activities were linked to a time scale with a precision of one second. The first observation sets the protocol at t=0 seconds. Table 1.1. gives an example of a protocol. For processing data a portable computer (Tandy PC2) was used. The data were saved on magnetic tape. The following parameters were calculated.

1. The catch-, chase- and look frequency (activities/minute)
2. Sweeping, look and chase as a percentage of the total protocol time.
3. The standard deviation. To compute a S.D. the protocol is divided into 2 minute sub-protocols. According to the length of the protocol the S.D. was based on 5 to 12 subs.
4. The catch frequency corrected for the time the spoonbill looks around. Suppose the bird looks around for 40% of the time. Then the catch frequency is multiplied by the factor 1/(0.6) . This allows a reliable comparison of the protocols. An example of these computations can be found in table 1.2. a/b/c.

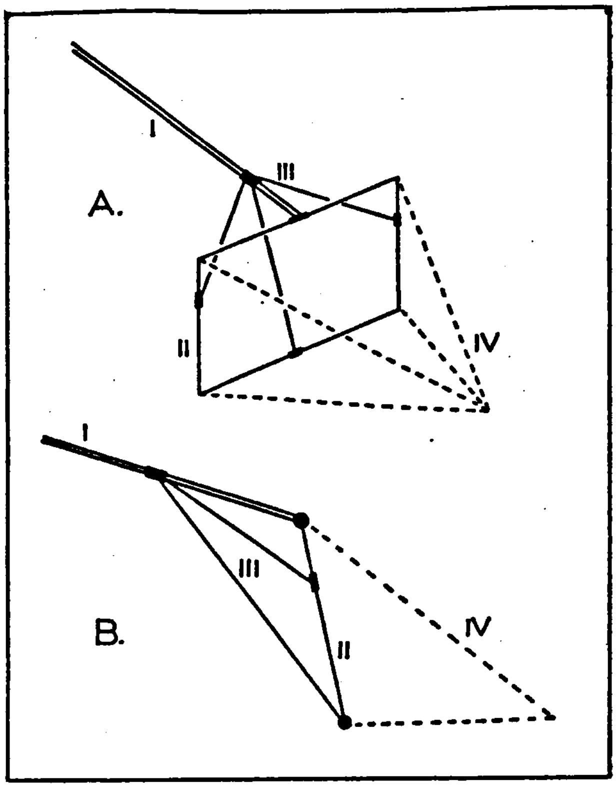


figure 1.1. The sample net as it was used to catch prey. (A). 3-Dimensional vieuw. (B). side vieuw. (I) Handling stick. (II) Window frame (80 x 40 cm). (III) Support rods. (IV) net.

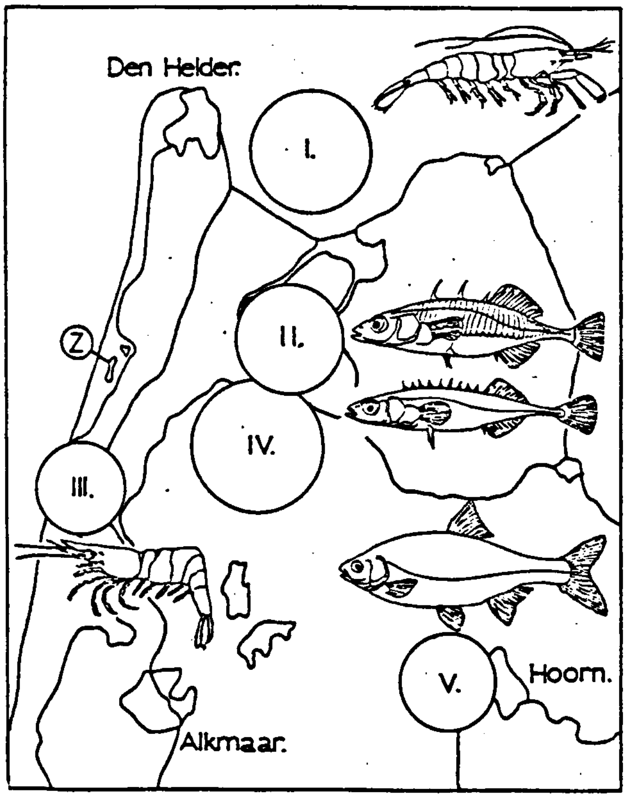


Figure 1.2. A review of five foraging areas. The areas are distinguised by the type of prey. I: Het Balgzand (C. crangon). II and IV: Area around Schagen (G. aculeatus and P. pungitius). III: Area behind the -Hondsbossche Zeewering- (P. varians). V: -Polder Westerkogge- (Scardinius erythrophthalmus), and (Rutilus rutilus). Z: Spoonbill colony in -Het Zwanenwater-.

1.2.2 Prey size and calorific value (W).

To determine average prey weight samples of prey were taken from the exact spots where the spoonbill foraged. The type of sample-net used, is shown in figure 1.1. To take a sample the net is put vertically into the water and then quickly moved towards the shore. The window of the net measured 80 x 40 cm. The stick is fixed to the window at an angle of 120^{o} and is two meters long. 3 extra bars prevent torsion of the window with respect to the stick. The size of the mesh is 4 mm.

All the potential prey was divided into 2.5 mm classes (class 1: 0-2.5mm). To determine the average weight of the prey the total amount of the prey of one kind was weighed and divided by the total number. Only a letter balance was available which made it impossible to weigh individual prey. The length-weight relations were used to verify and sometimes correct the measurements (Eq. 1.1-1.4).

$w = 8.22 * 10^{-6} * l^{3.01}$ (eq. 1.1.) l: length in mm.

$w = 10^{-4.568} * l^{3.219}$ (eq. 1.2.) w: weight in grams

$w = 2.3 * 10^{-3} * l^{2.806}$ (eq. 1.3.)

$w = 1.335 * 10^{-2} * l^{2.9}$ (eq. 1.4.)

In addition to the average prey weight calorific values of different types of prey were determined by taking samples of 10-20 individuals of one kind. The samples were weighed (fresh weight) and dried in a dessicator. After drying, the samples were weighed again (dry weight). The dried prey was homogenized in a mortar. For the actual measurement of the calorific value a "Phillipson Microbomb Calorimeter" was used. The following example shows the computation of the foodintake rate.

(C) Corrected prey frequency	: 4 prey items / minute
Prey	: 10 spined stickleback
♂♂/ ♀♀ ratio	: 6 :4
(W) Average prey weight(♂♂ + ♀♀)	: 0.64 grams
calorific value	: (0.6x460) + (0.4x510) = 480 (kJoule/100 gr fresh weight)
(F) Foodintake rate	: 4 x 0.64 = 2.56 (gram/min.) 2.56 x 4.8 = 12.29 (kJ/min.)

Pungitius pungitius

	kJoule/100 gram freshweight	samples	Dry/fresh weight
♂♂ ± 4 cm.	510 ± 19	4	0.24
♀♀ ± 4 cm.	460 ± 26	4	0.25
♀♀ + ♂♂ ± 2 cm.	490 ± 20	4	0.23

Table 1.3. Calorific value (kJoule/100 gram fresh weight) of the 10-spined stickleback(*Pungitius pungitius*). (♀♀ were pregnant.)

Gasterosteus aculeatus

	kJoule/100 gram freshweight	samples	Dry/fresh weight
♂♂ ± 4.5 cm.	440 ± 17	11	0.24
♀♀ ± 4.5 cm.	450 ± 13	5	0.23
♂♂ + ♀♀ ± 2 cm.	460 ± 9	2	0.24

Table 1.4. Calorific values (kJoule/100 gram freshweight) of the 3-spined stickleback(*Gasterosteus aculeatus*). (♀♀ were pregnant.)

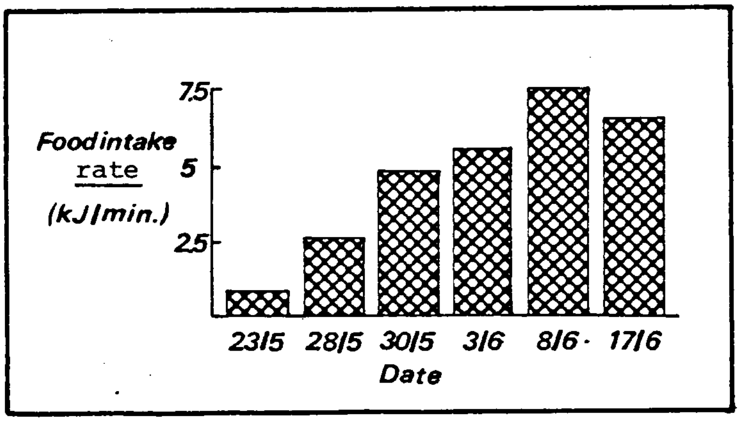


Figure 1.3. Increasing foodintake rate in -De Putten- (area III) caused by the growth of the *P. varians* population.

Paleomonetes varians.

Length (cm)	fresh weight (gram)	dry weight (gram)	dry/ fresh	measured	kJoule/ 100 gram freshweight	samples
2.0 -2.25	0.17	0.03	0.20	3	360	3
2.25-2.5	0.20	0.04	0.22	13	390	2
2.5 -2.75	0.25	0.05	0.21	8	370	1
2.75-3.0	0.40	0.09	0.22	15	410	1
3.0 -3.25	0.47	0.11	0.23	34	370	3
3.25-3.5	0.54	0.13	0.24	10	390	1

Table 1.5. The average fresh and dry weight (gram) per shrimp (*Paleomonetes varians*.) per size class. The calorific value per size class (kJoule/100 gram fresh weight).

Crangon crangon.

Length (cm)	fresh weight (gram)	dry weight (gram)	dry/ fresh	measured	kJoule/ 100 gram freshweight	samples
1.5 -1.75	0.06	-	-	4	-	-
1.75-2.0	0.09	0.02	0.22	19	370	2
2.0 -2.25	0.13	0.03	0.23	18	390	1
2.25-2.5	0.17	0.04	0.23	37	360	2
2.5 -2.75	0.22	0.05	0.24	23	360	2
2.75-3.0	0.28	0.06	0.22	22	370	2
3.0 -3.25	0.35	0.08	0.24	13	410	2
3.25-3.5	0.39	0.08	0.21	4	390	1

Table 1.6. The average fresh and dry weight (gram) per shrimp (*Crangon crangon*) per size class. The calorific value per size class (kJoule/100 gram fresh weight).

	kJoule/100 gram freshweight	samples	Dry/fresh weight
Rudd, roach	450 ± 6	6	0.24
P. varians	370 ± 11	11	0.22
C. crangon	370 ± 9	10	0.23

Table 1.7. Calorific values (kJoule/100 gram freshweight) of roach (*Scardinius erythrophthalmus*), rudd (*Rutilus rutilus*). Of *Paleomonetes varians* and *Crangon crangon*. the average is given of the values from table 1.5. and 1.6..

Rudd & Roach.

Date of sampling	average length(cm)	average weight(gram)
14/4	4.71 ± 0.47	1.15 ± 0.32
10/5	5.33 ± 0.76	1.71 ± 0.71
29/5	5.94 ± 0.48	2.27 ± 0.52
26/6	6.14 ± 0.61	2.53 ± 0.77

Tabel 1.8. Average length and weight of Rudd (*Rutilus rutilus*) and roach (*Scardinius erythrophthalmus*)

d. The fourth place is an area near Hoorn (area V: figure 1.2.) where small rudd (Scardinius erythropthalmus) and roach (Rutilus rutilus) are on the spoonbill's menu. This area is of special interest for the following reasons. (1) The large distance (30 km) to the colony. (2) The ditches are rich in small rudd and roach. (3) This prey is relatively large in comparison with the other prey species. This will turn out to be of great importance to the spoonbill. (4) The ditches are broad and shallow (<30 cm), which is a necessary condition for the spoonbill to forage.

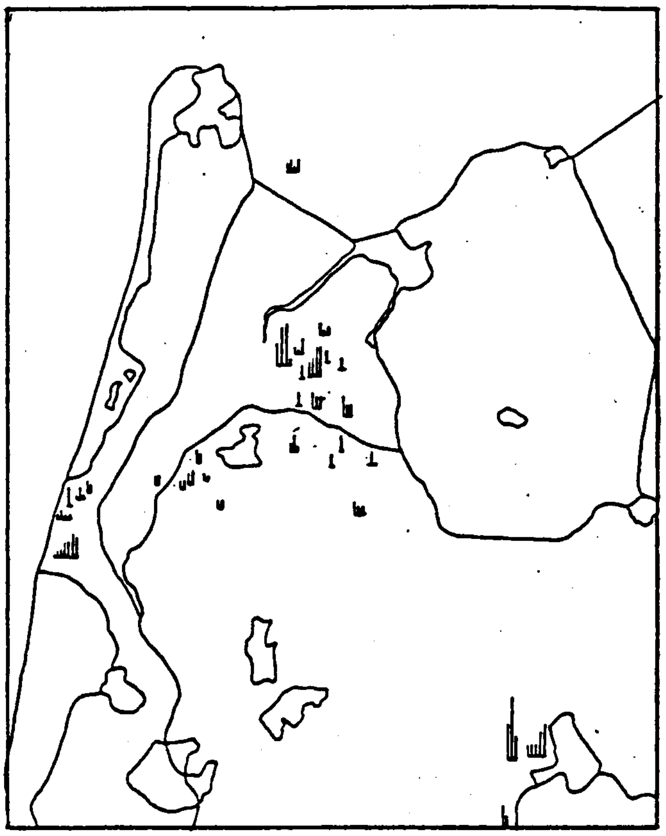
During the reseach in '84, measurements were taken from the mixed population of rudd and roach. Only the first year-class was measured, because of the, unjustified, opinion that two year old fish were to big for a spoonbill. Unfortunately, older fish could not be measured in 1985, as the entire population was wiped out by the severe winter of 1984/85. A few survivors and some influx from the Ysselmeer will allow the population to recover in a few years. The average length and weight are presented in table 1.8. The calorific value is shown in table 1.7.

1.3.2 Foodintake rate (F).

Figure 1.4. gives an impression of all the protocols that were made during the study period. When bars are interconnected with a horizontal line, protocols were taken at one spot (ditch), but at different moments. The length of the bars represents relative values of the foodintake rate. Protocols taken at one spot are arranged according to time from left to right. The results of area V. are from 1984.

From figure 1.4. we see that polder Wieringerwaard (II) has a rather high score. Therefore the area around Schagen was split in two (II and IV). The average values were computed and are presented in figure 1.5. The average is presented without the standard deviation (S.D.), but from figure 1.4. it's obvious that the S.D. is sometimes great. So the differences between the averages must be tested on significance. The p-values, at which the difference is significant, are presented in table 1.9.

In figure 1.6., protocols with a certain prey weight, were grouped. In practice this will mean, grouping according to prey type. Class 0.1-0.2 gram, for example, contains only juvenile sticklebacks. The average foodintake rate, and the corresponding average catch frequency, are presented in this figure.



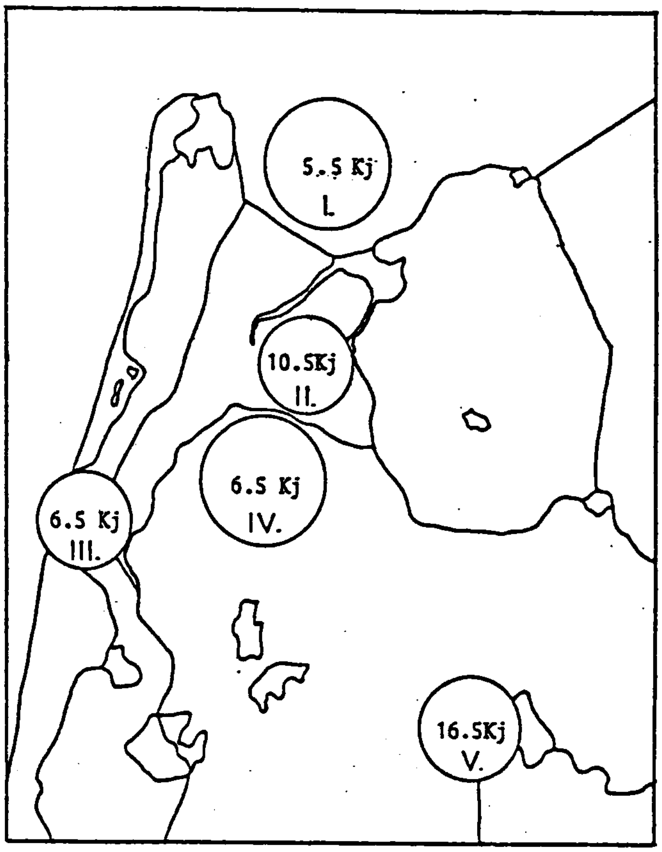


Figure 1.4. Every bar represents a protocol with the length of the bar as the relative foodintake rate Interconnected bars represent protocols at one spot at different moments, with the first protocol at the left.

Figure 1.5.. Computed averages of the foodintake rate per area.

	II	III	IV	V
I	p<0.1	N.S.	N.S	p<0.001
II		p<0.02	p<0.002	p<0.1
III			N.S	p<0.001
IV				p<0.001

Table 1.9. P-values at which the averages of figure 1.5. are significantly different from each other. The values are computed with the Mann-Witney U-test (one-tailed). At p>0.2 the value is not considered of any interest, so the abbr. N.S (not significant) is given.

1.4 DISCUSSION AND CONCLUSION

1.4.1 Calorific values.

There are two reasons why the S.D. for the calorific values are rather high. Some samples were very hard to homogenize, even using liquid nitrogen and a blender. Therefore not all the samples were the same. Secondly there was the heterogeneous composition (bone, muscle tissue, integument) that made the sample burn irregularly. It was to be expected that the pregnant females would have a higher calorific value than the males. P. pungitius shows the opposite. The 510 Kj. of the males is due to a high fat content. Together with the juvenile fish these samples were rather greasy. It is remarkable that the males of G. aculeatus does not show a higher value in comparison to the females.

Since the contents to surface ratio increases with the size of an individual a higher calorific value might be expected for a larger prawn. An increasing ratio would mean more muscle tissue (contents) and less, low calorific, integument (surface). Table 1.5. and 1.6. do not give any indication of the calorific value increasing with the size of the animal. Maybe a rather subtle difference is lost by the large standard deviation. But when the difference is that small, it is not of any importance for this study. The low calorific value of the integument has its effect on the average value of the individuals. 370 kJ is the lowest score, compared with the fishes.

1.4.2 Hoorn

Just like the area behind the Hondsbossche Zeewering, Hoorn becomes popular, rather suddenly. A clue can be found in the average weight of the fish. In this case, not the amount of prey but the weight increases drastically. It is not until the end of May, that the spoonbill becomes a regular guest. At that time however, the prey weight has doubled, compared with the first date of sampling.

1.4.3 Foodintake rate (F).

The observations on Het Balgzand are too few. In an early stage it was clear that the S.D. was large. Therefore it was very important to collect sufficient protocols, to show a significant difference in case there was one. On average two protocols could be made in one day. Het Balgzand is the most attractive but also the most difficult area to watch spoonbills. In order to make the best use of the scarce time, the Balgzand was neglected a little bit. Consequently, no significant

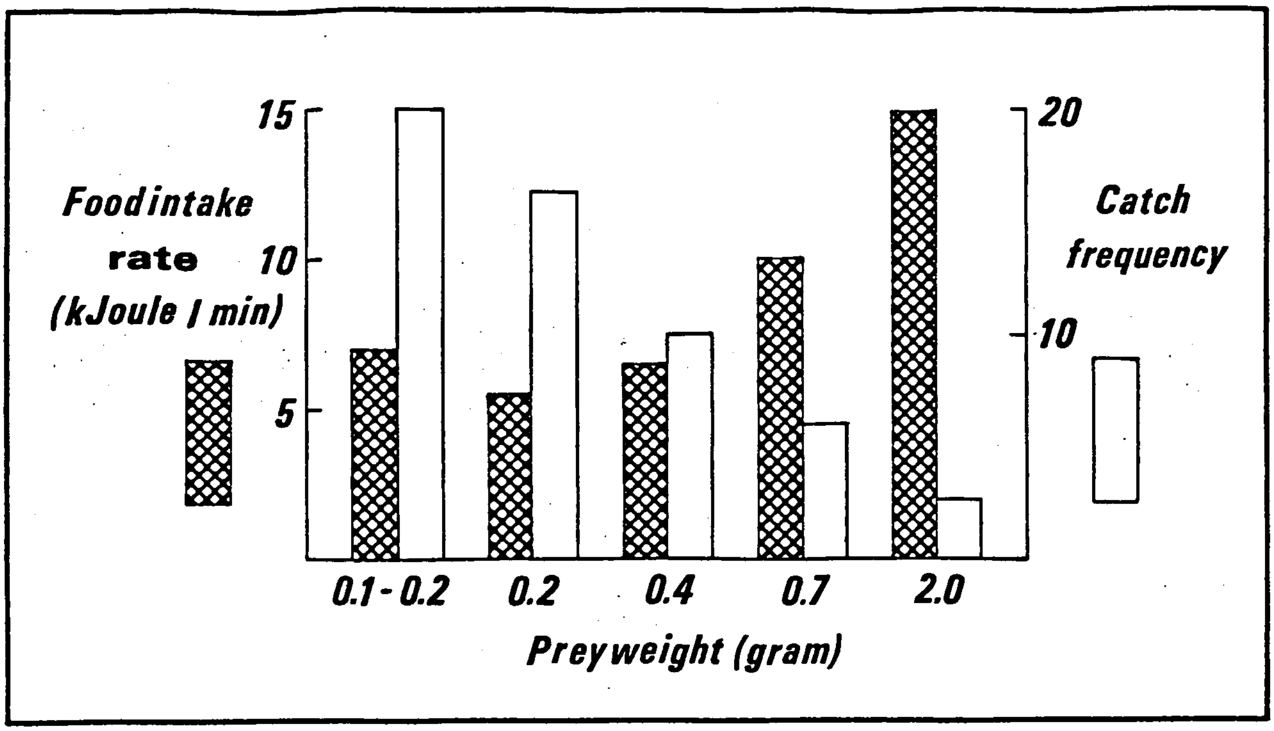


Figure 1.6. The white bars represent the average catch frequency (prey items per minute) of observations in which the spoonbill catches prey of a certain class of weight. The shaded bars represent the average foodintake rate (kJ/min.) of these observations.

FOODINTAKE RATE

	0.2	0.4	0.7	2.0
0.1-0.2	N.S	N.S	p<0.2	p<0.01
0.2		N.S	p<0.2	p<0.01
0.4			p<0.05	p<0.05
0.7				p<0.05

table 1.10.. Values for p at which the average values of the foodintake rate of figure 1.6. are significantly different. The values for p were computed with the Mann-Witney U-test (one tailed). At p > 0.2 these values are of no interest, so the abbreviation N.S. (not significant) is given.

CATCH-FREQUENCY.

	0.2	0.4	0.7	2.0
.1-.2	p<0.1	p<0.001	p<0.001	p<0.001
0.2		p<0.1	p<0.01	p<0.001
0.4			p<0.1	p<0.001
0.7				p<0.01

table 1.11. The same values as for table 1.10., here, however, for the catch frequency.

difference is shown between area I and II, although, without doubt, there is one.

The value of area V. is underestimated. It was not uncommon for the spoonbill to catch fish of 10 cm. If we realize that a 10 cm fish already weighs over 10 grams, it's obvious that 16.5 kJ is pretty much below the true value. Fortunately, the high foodintake rate is clear, in spite of the underestimation.

Figure 1.6. gives the most interesting information. As mentioned previously, foodintake rate is determined by catch frequency and prey-weight. The calorific value is of minor interest. From the white bars in figure 1.6 it is clear that the average catch frequency decreases when prey is getting bigger. The decrease in catch frequency will also decrease the foodintake rate. But on the other hand, an increasing prey-weight increases the foodintake rate. The question is; which of the two determines high foodintake rate most, under the natural circumstances? Is there a tendency, or is it just the right combination of catch-frequency and prey-weight? The shaded bars show that it is high preyweight, rather than high catch frequency which favors high foodintake rate.

With 20 prey items a minute the spoonbill will reach his maximum catch-rate. But even this high frequency cannot provide high foodintake rate with prey of 0.1-0.2 grams. There is a certain threshold for the size of the prey, determined by the maximum catch frequency of the spoonbill. Small waterinsects can therefore never be the main food for a spoonbill.

CHAPTER 2.

LARGE AND SMALL STICKLEBACKS.

2.1 INTRODUCTION

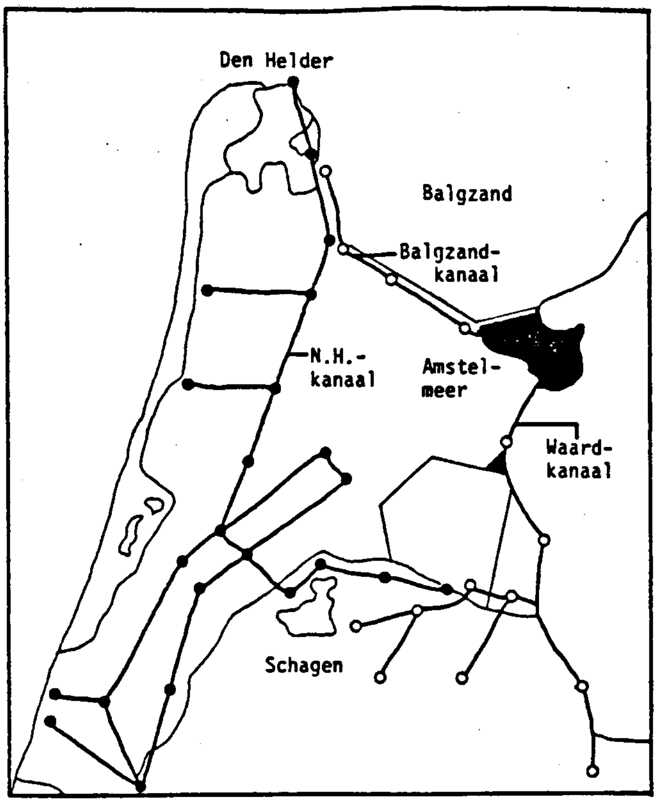
From marine throut it is known that there are different forms of the same species that can differ in size significantly. The smaller forms of this marine fish are encountered in fresh water. The stickleback G. aculeatus, shows the same phenomenon. Sticklebacks that are trapped in fresh water will remain significantly smaller than the ones that return to see in Autumn. As mentioned before, the size of the prey is of great importance for the foodintake rate of the spoonbill. Therefore the distribution of sticklebacks of different sizes was investigated in the foraging area.

Lifespan of G. aculeatus is only one year. In spring, G. aculeatus migrates from sea to fresh water to breed in shallow ditches. After a few months adult fish die. Juvenile fish return to sea in autumn (van Mullem en van der Vlugt 1964, Munzing 1962). Because of the short lifespan the size classes are pretty much normally distributed with a relative small standard deviation. Lifespan of P. pungitius is much longer. Males can live three years and females up to five (Baggerman 1957). Unlike G. aculeatus, P. pungitius shows no migration from salt to fresh water, but only a minor migration to deeper water in autumn. Therefore the frequency distribution of the size classes of P. pungitius populations have a large standard deviation.

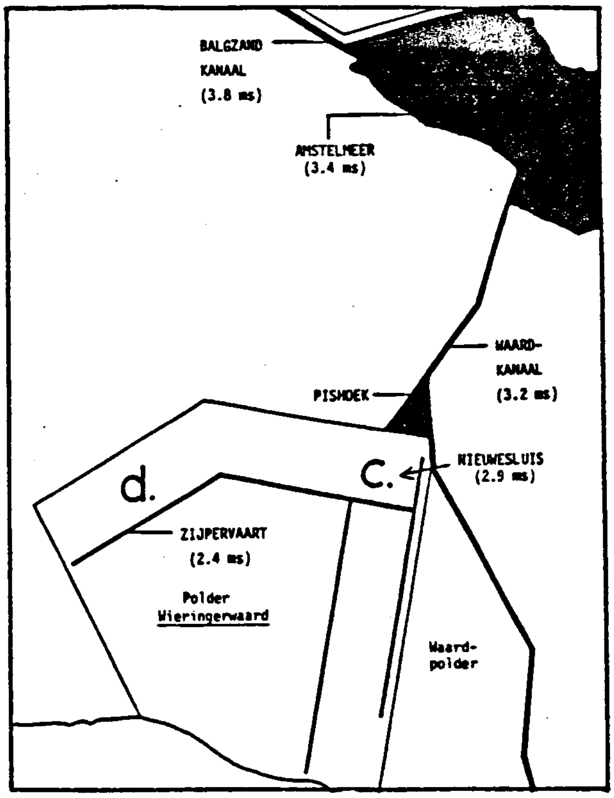
It was found out that most of the 3-spined sticklebacks in the polders did not come from sea but are so called -standpopulations-. The high foodintake rate in the Wieringerwaard can be explained by the population of big sticklebacks that migrates into this polder by the end of april.

2.2 MATERIALS AND METHODS

Samples were taken at approx. 150 places, two or three times during the research period. The sample net as described in chapter 1 was used. Sampling sites were selected according to the spoonbill census of 1984 and spoonbill observations in 1985. All fish were treated as described in chapter 1 with the exception that the fish were not weighed. For the average weight of the fish, the length-weight relationship (eq. 1.1. -



<u>Figure 2.1.</u> Two possible ways for <u>G. aculeatus</u> to reach the foraging area of the spoonbill. The first route starts at the harbour of Den Helder. Through Het NHK the fish has a free passage trough all canals marked with •-•. The second route starts at a sluice at Het Balgzand. (o-o).



<u>Figure 2.2.</u> A detail of the migration route. The letters C and D refer to the frequency distributions of figure 2.4. The figures in brackets represent the conductivity of the water.

	1	2	3	4	5	6	7	8	9	.	.	.	.	.	.	.	17
10										1							
11												1					
12		1	1								1	4	1				2
13		1									5	1	1				
14	1	1						5	1		1	1					
15		2				2	1	3	1		4						
16	1	2		1		1	1	2	1			1			1		
17		1	1	2		1							1		2		
18		1		2	1		1							1	4		
19				3		1				2				1	2		
20				2	1									1	2		
21				1			1							2	1		
22					1									3		1	
23														2			
24														1		1	

<u>Table 2.3.</u> Data matrix of 17 samples of <u>G. aculeatus</u> randomly chosen from samples of Wieringerwaard, Schagen and Petten. Divided in size classes.

	1	2	3	4	5	6	7	8	9	.	.	.	.	.	.		17
10	2	1			1					2			1		2		
11	2		1		1					3			1				2
12	3	1	1	1	1	1				3			3			1	2
13	1	1	1	1	2					3			1		1	2	4
14	1	2	2	1	3		1			2	1					1	4
15		1	1	2	2			1		2		1	1	1		1	1
16	1	1	1	2	3	1	1	1		1		1		2	1		4
17			2		2	1	2	1		1	1			1	2		4
18			3	1	1		1	1	1	1	1	1			3		4
19			1			1	1	1	1		1	1				2	2
20			1			1		1	1		1	1	1		2		1
21					1				1		1						
22			1		1				2		1				1		
23									1		1						
24									2					1			

<u>Table 2.4.</u> Data matrix of 17 random samples of <u>P. pungitius</u>. Divided in size classes (10 - 24).

1.2.) was used. All samples were statistically tested (van der Vaart, 1950). Every sample was obtained by ten strokes with the sample net with a five meter distance between each stroke. Data of a migrating population in the harbour of Den Helder was obtained from a collection of N.I.O.Z. in Den Helder (S. Nieuwenhuis). A sample of the population from Nieuwesluis is available in Zoologisch Museum Amsterdam (ZMA 119.413). In this study, juvenile fish were not included. A conductivity meter was used (WTW lf 90) to get an impression of the salinity of the water.

2.3 RESULTS

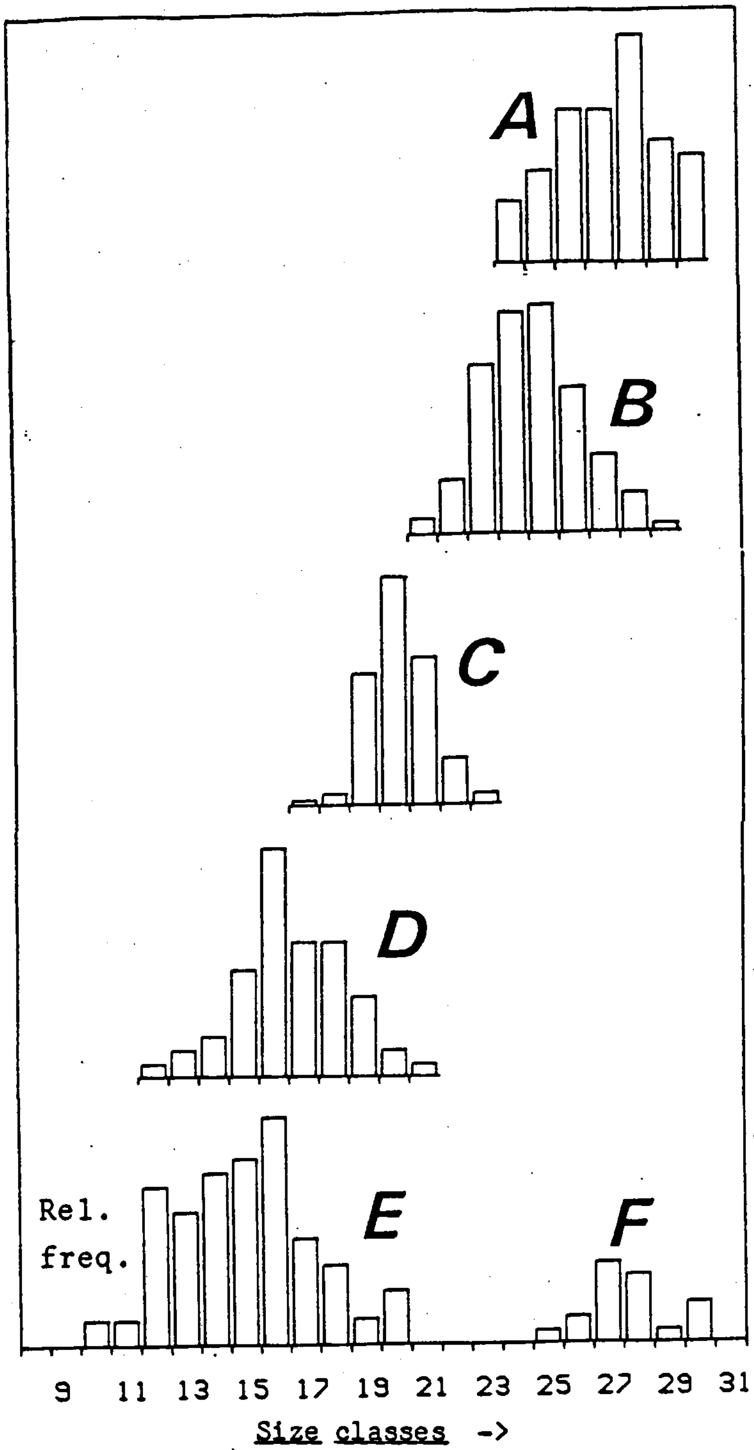
2.3.1 Migration routes.

G. aculeatus may reach the foraging area of the spoonbill by way of two possible routes from sea. The first route is represented by the line with the black dots in figure 2.1. This route starts in the harbour of Den Helder. In early spring, G. aculeatus passes the sluice De Helsdeur and enters Het Noordhollands kanaal (N.H.K.). Open connections with Het N.H.K. are shown in figure 2.1 (o-o-o) as far as the foraging area of the spoonbill is concerned.

The second entrance is the sluice at Balgzand. At low tide G. aculeatus can enter Het Balgzandkanaal (figure 2.1.: ●-●-●). By way of Het Amstelmeer they can get into Het Waardkanaal. A detail of the route is shown in figure 2.2. The values in brackets represent the conductivity of the water on the 23th of May. At Nieuwesluis, water is let into the polder Wieringerwaard, from Waardkanaal, in case of low water levels. The two routes are interconnected by means of a lift lock.

2.3.2 Populations.

Figure 2.3. shows frequency distributions of the size classes of six groups of G. aculeatus. Group A was caught in the harbour of Den Helder (march 1984). Group B is a sample from a migrating population in De Stevinsluizen near Den Oever. The migration took place from De Wadden to Het IJselmeer on 19-3-1979. Group C was sampled at Nieuwesluis where water is let into the polder Wieringerwaard. Water was let in for the first time, on the 28th of April. Huge amounts of sticklebacks were observed just behind the sluice on the 3th of May. Group D is a sample from a population that was on its way from De Zijpervaart (figure 2.2.) into the surrounding ditches. Group E is not



Average weight (gram).

A: 2.57 ± 0.5 (59)

B: 1.88 ± 0.37 (1020)

C: 1.00 ± 0.16 (102)

D: 0.57 ± 0.187 (60)

E: 0.50 ± 0.41 (128)

F: 2.48 ± 0.45 (12)

Figure 2.3.. Relative frequency distributions of several groups of *G. aculeatus*. 2.5 mm classes of size were used. A. Sample of migrating fish in the harbour of Den Helder. B. Sample of migrating fish near the Stevinsluizen (Afsluitdijk). C. Sample of migrating fish at Nieuwesluis. At Nieuwesluis, water is let into the Wieringerwaard from de Waardkanaal. D. Sample of a population from De Zijpervaart in polder Wieringerwaard. E. Group composed of all fish caught around Schagen and Petten. F. One sample, taken near Petten. All samples were taken in spring. Populations A - D are mutually significantly different ($p \ll 0.001$)

derived from one population but is the result of the total of all stickleback samples caught around Schagen (area III and IV in figure 1.2.), with exception of the polder Wieringerwaard. To get a rough impression of the composition of the samples, 17 randomly chosen samples are shown in a data matrix in table 2.3. The average weight of the fish from all groups are presented next to figure 2.3. Figure 2.4. is an overall picture of the places where the samples were taken. The meaning of the symbols used is as follows; (o) In the two or three times a sample taken, neither P. pungitius nor G. aculeatus was caught. (O) Only P. pungitius. (●) G. aculeatus and in most cases also P. pungitius. The letters D,C and F refer to the groups in figure 2.3. P. pungitius is much more numerous then G. aculeatus. The ratio G. aculeatus : P. pungitius in the polder. Wieringerwaard is Ø.21. This ratio in the area around Schagen is Ø.11.

Similar frequency distributions were made for P. pungitius. Figure 2.5.G represents the frequency distribution of all fish from the area around Schagen. Table 2.4. shows a data matrix of 17 randomly chosen samples of P. pungitius. Group H is caught in the Wieringerwaard. This group is composed of a few samples all showing frequency distribution similar to the one in figure 2.5.G. The average weight of the populations are given in the margin of the figures.

2.4 DISCUSSION AND CONCLUSIONS

2.4.1 Noordhollandskanaal.

The first migration route, starting at Den Helder, forms a circuit of fresh water into the foraging area of the spoonbill. It was expected that the migrating population from Den Helder (figure 2.3.A) would be found in the polder ditches. This expectation did not come true. Of the hundreds of samples that were taken, only one contained G. aculeatus of a size similar to the Den Helder population. This sample is represented by the frequency distribution of figure 2.3.F. This isolated observation near the village of Petten proves that G. aculeatus may migrate at least this far.

The frequency distribution of fig 2.3.E is composed of all G. aculeatus caught around Schagen and Petten. Although the distribution is rather broad the big size classes are lacking. Where do these populations come from and why are there no large sticklebacks? A explanation can be found in the barrier between the ditches and the canals. In spring, water is not let into the polders until water levels

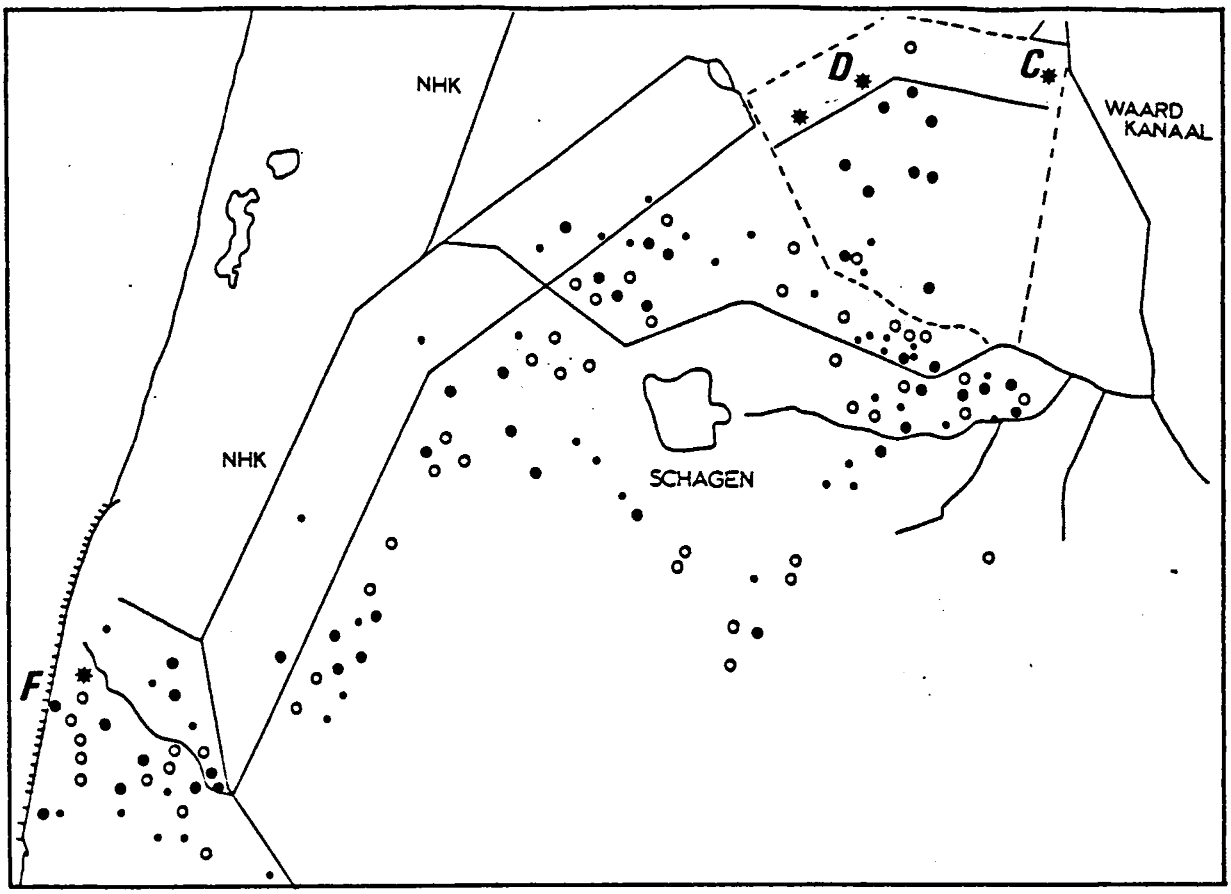
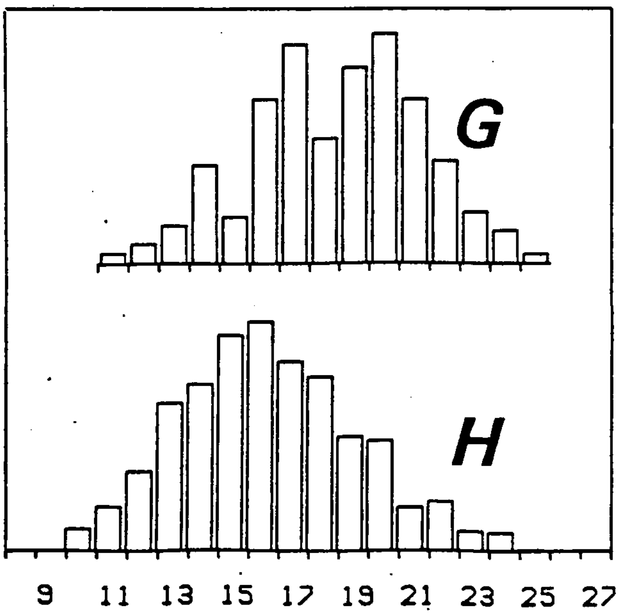


Figure 2.4. An overall picture of all samples that were taken. Except for the coastline, all lines represent canals. Symbols: (O) Only P. pungitius is caught. (●) G. aculeatus and in most cases P. pungitius. (o) No fish at all. At most places two or three samples were taken during the research period. The sample places with an asterisk (*) refer to the samples C, D and F in figure 2.3. Juvenile fish is not included.



Average weight (gram)

G: 0.80 ± 0.35 (322)

H: 0.57 ± 0.32 (1031)

size classes. ->

Figure 2.5. Relative frequency distribution of samples of P. pungitius. G: All fish caught in the polder Wieringerwaard. H: All fish caught in the area around Schagen and Petten.

are low. This can be in April or even much later, while the migration starts at the end of February and is at peak strenght a few weeks later. Before the water is let in most of the fish are settled in the canals and boezems, out of the spoonbill's reach. The few that can come into the polders are forced to remain in these waters by the labyrinth of ditches and the complicated draining systems. Such a migrating marine fisch, that stay behind in fresh water is called a -standpopulation-.

2.4.2 Balgzandkanaal-Amstelmeer-Waardkanaal.

Because of the many visits of foraging spoonbills to De Wieringerwaard and its high foodintake rate there, special attention is paid to this area. Nieuwesluis is the only place where water is let in. Here too, the weather determines the time of inlet, but nevertheless, migration takes place every year. When group C is compared with the one from Den Helder (A) or de Stevinsluizen (B), it is more likely that this population comes from the Amstelmeer than from the Northsea or Waddensea.

Group D (figure 2.3.) must have wintered in the Zijpervaart, since no water had been let in yet on the 15th of April. The population is significantly smaller than the migrating population at the waterinlet. The polder Wieringerwaard is a large polder with only one inlet and one place where water is pumped out. In addition there are two different waterlevels. The easy inlet makes the area function like a trap and may cause the relative large population of resident G. aculeatus in spring (21 % of all sticklebacks caught in this polder). Another reason for this may be the high salinity of De Wieringerwaard. The motivation to return to sea may be small under these circumstances. G. aculeatus can winter in the deep Zijpervaart where they can escape from low temperatures in winter.

The bird cencus of 1984 subscribs the importance of the population of big sticklebacks that enter the polder Wieringerwaard at the end of April. From figure 2.6. it is clear that no spoonbills were observed before water was let into the polder. After the waterinlet (at about the 20th of April) the spoonbill became numerous.

2.4.3 Populations.

Although it was not the objective of this study to give a causal explanation for the differences in size between populations a few remarks can be made. It is clear that the wintering habitat of G. aculeatus has a prominent influence on the size of the fish.

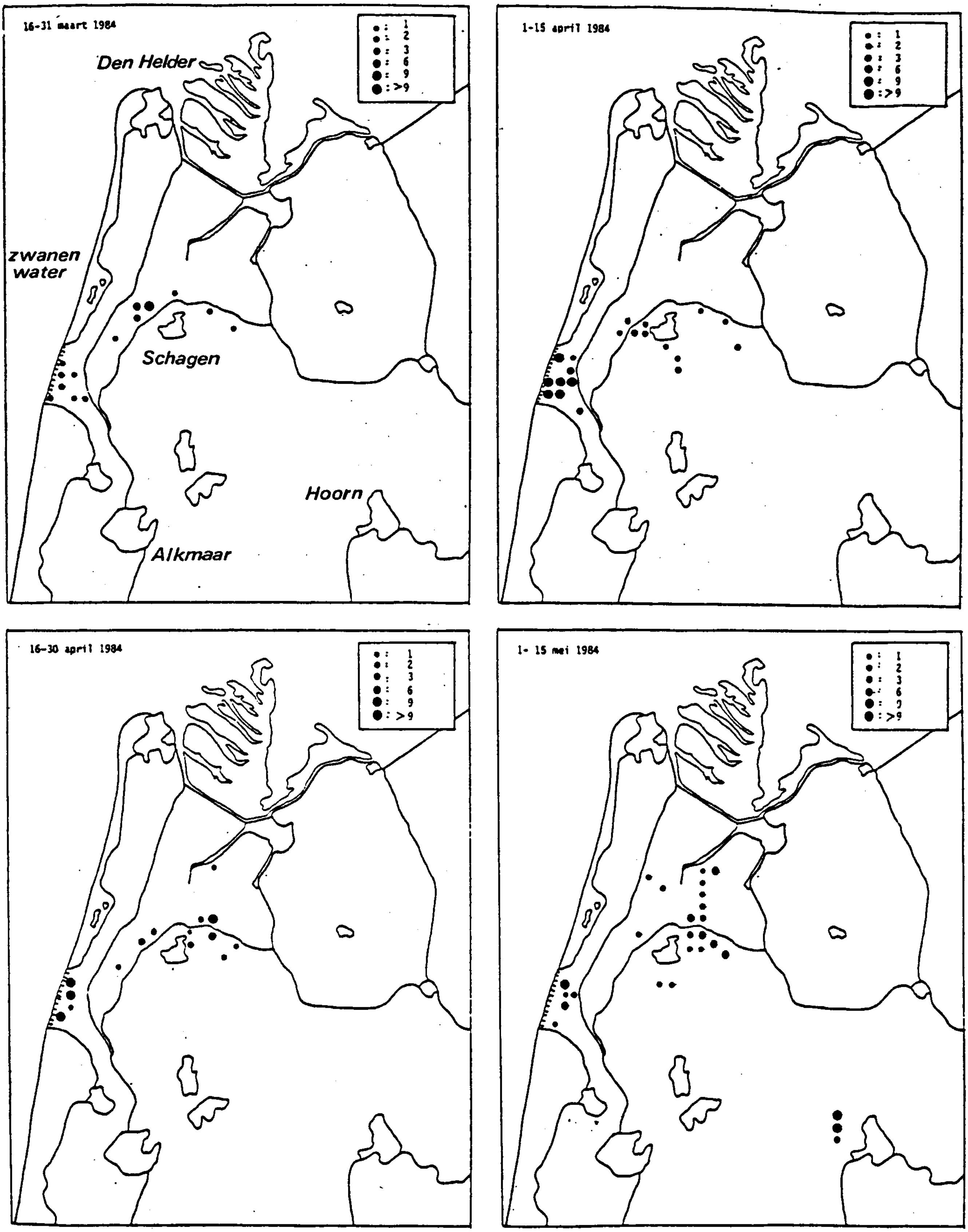


Figure 2.6. Spoonbill cencus of the first two months of the study in 1984. The bigger black dots are the more spoonbills were observed. The numbers in the right corner are relative amounts. (de Goeij, van Wetten, Kemper 1985)

Populations from sea, lake, wadden, canal and ditch all differ in size. There is a correlation between the size of the fish and the size of the wintering habitat. The larger the water the bigger the fish caught in it. An other tendency can be found in the salinity of the water. The gradient of the conductivity of figure 2.2. coincides with the increasing size of the fish.

Figure 2.3. and 2.5. show three remarkable aspects.

I. A multimodal frequency distribution is to be expected in figure 2.6.G and H because a population of P. pungitius consists of several year-classes. The population from De Wieringerwaard (G) is bimodal or maybe trimodal but Schagen (H) does not show anything of the sort.

II. The frequency distributions of P. pungitius (H) and G. aculeatus (E) are remarcably similar.

III. The frequency distribution of P. pungitius (G) fits the combined frequency distributions of C and D of G. aculeatus.

An explanation for the similarity between group G and H can be that both species live alongside under the same ecological circumstances. But the fact remains that the G. aculeatus population is only one year old and the age of the P. pungitius population ranges from one to five years. Compared with the distributions A-D the G. aculeatus population from Schagen is remarkably broadly distributed. As mentioned before, this can be caused by slight differences in the biotope, where the different samples came from. Also a longer lifespan then one year is possible, but the data of table 2.3. are insufficient to conclude this. G. aculeatus is forced to winter in fresh water in this area which certainly means a stress situation.

In addition to the multimodal frequency distribution of group G the whole distribution lies slightly right from H. There is much more similarity with the combined G. aculeatus distributions C and D. Again, both species live together under the same ecological circumstances. Since the right part of the distribution of group G fits group C so well, it must be concluded that also P. pungitius migrates from De Waardkanaal (Amstelmeer ?) into de Wieringerwaard. No measurements were carried out on P. pungitius at the waterinlet, because such a migration was not expected. At least half the population of De Wieringerwaard comes from De Waardkanaal. The left part of the distribution of group G probably comes from the resident population from De Zijpervaart, as the good fit with group D suggests.

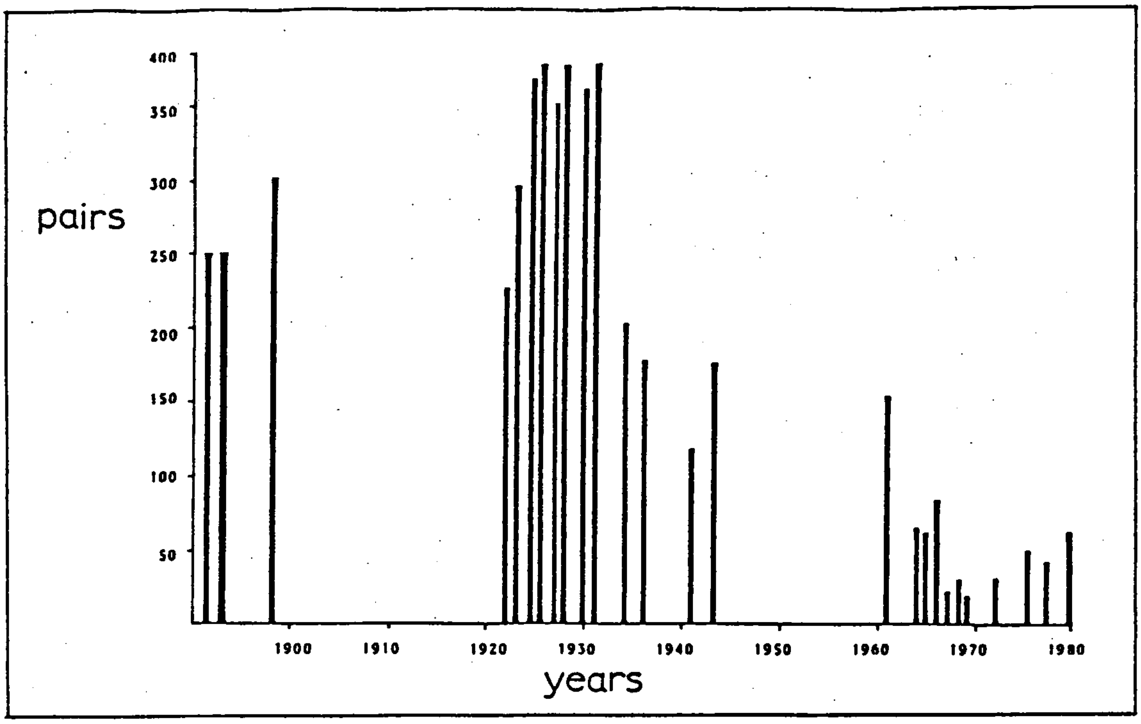


Figure 2.7. Pairs of spoonbills from 1890 untill 1980 in the Zwanenwater colony (Woets).

CONCLUSION.
Although G. aculeatus and P. pungitius are clearly separate species, they can not be distinguished by means of their frequency distribution of the size classes, as far as the investigated area is concerned

2.4.4. An historical situation.

Chapter 1 points out the importance of the prey size and chapter 2 shows that the large sized population from the sea is out of reach for the spoonbill. However, this situation may have been different in earlier years. At the beginning of this century the technique did not allow sophisticated draining in the polder. At some places there was no need for it. Considering that tens of millions of sticklebacks enter N.H.K. every year, G. aculeatus must have inhabited the polder ditches in great quantities. In addition to the great amount of large sized fish, the food was also in close reach for the spoonbills of the Zwanenwater, in comparison to Hoorn or Het Balgzand. Unfortunately, no data are available of the stickleback in that period. So the situation remains hypothetical. Nevertheless, there is a point of application. Figure 2.7. shows the development of the size of the spoonbill population from the beginning of this century. The minor decrease in the sixties may be due to the pollution of the environment (Woets). The first drastic decreas in the thirties and fourties however coincides with the improvements of the water level regulation. Especially the developing, bulb-growing industry required these improvements.

2.4.5. Suggestions.

I. It is likely that the value of De Wieringerwaard as a foraging area for the spoonbill can be improved, according to the results of this study. Migrating sticklebacks gather in front of the sluice at Nieuwesluis in early spring. When water is let in at these moments the stickleback density in De Wieringerwaard will increase significantly. In a few quarters of an hour great quantities of sticklebacks can enter the polder while not too much water is let in to disturb the watermark in the polder.

II. For future marshland bird sanctuaries it is commendable to consider a open connection with Noordhollands kanaal. At least for a few months in spring. In addition to the vital importance of large sticklebacks for the spoonbill, the offspring of juvenile fish can be a resource for many other birds.

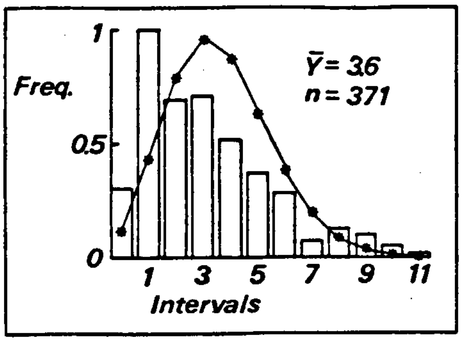


Figure. 3.1.

prey: G. aculeatus/P. pungitius
location: polderditch.
catchfreq.: 8.3
Chi square: $p < 0.005$

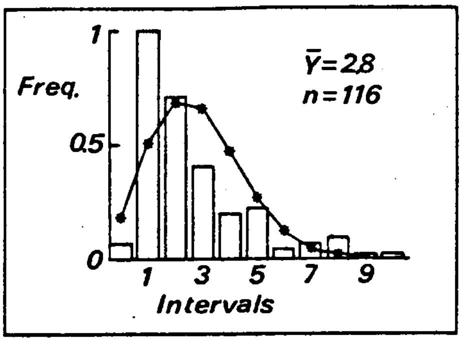


Figure. 3.2.

prey: (G. aculeatus/P. pungitius)
location: polderditch.
catchfreq.: 10.7
Chi square: $p < 0.005$

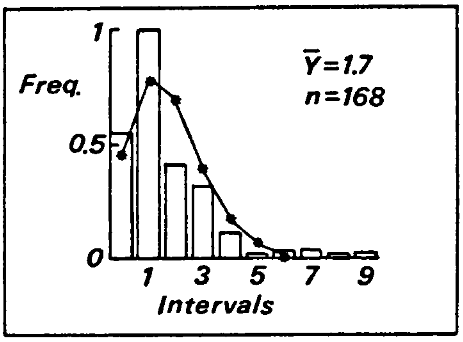


Figure. 3.3.

prey: juvenile sticklebacks.
G. aculeatus/P. pungitius
location: polderditch.
catchfreq.: 17.6
Chi square: $p < 0.01$

Figure. 3. Frequency distribution of timeintervals between two succesive catches (bar diagram). The drawn line represents the expected distribution in case of a poisson distribution (random catches). -Y- represents the average timeinterval and -n- the sample size (total number of catches). Interval -0- falls between 0 and 2 seconds, interval -1- between 2 and 4 seconds. The letter p of the Chi square test represents the probability that there is no significant difference between the observed and expected frequency.

CHAPTER 3.

A CLOSER LOOK AT THE CATCH FREQUENCY.

INTRODUCTION:

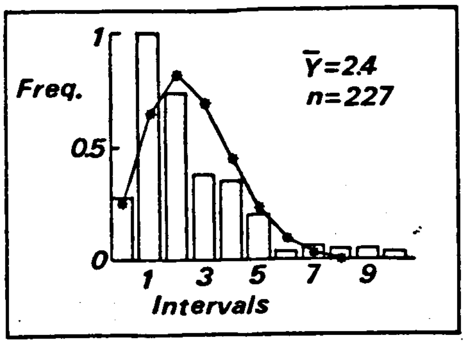
In the way the foraging behaviour of the spoonbill is recorded the exact time of every catch movement is known as table 1.1 shows. This makes it possible to get an impression of the distribution of the catches in time. It was the objective of this study to look for differences in fouraging strategies in the spoonbill when different prey with different prey density was caught. It seems that this approach can tell us somthing about the prey but very little about the spoonbill itself.

MATERIAAL AND METHODS.

To get an impression of the distribution of the catches a frequency distribution is made as is shown in figure 3.1. For this, timeintervals between every two successive catches is computed. Time intervals are summated in classes. Class Ø are timeintervals between Ø and 2 seconds, class 1 consists of intervals between 2 and 4 second etc. For the statistics of this problem, Biometry (Sokal and Rohlf 1981) is used.

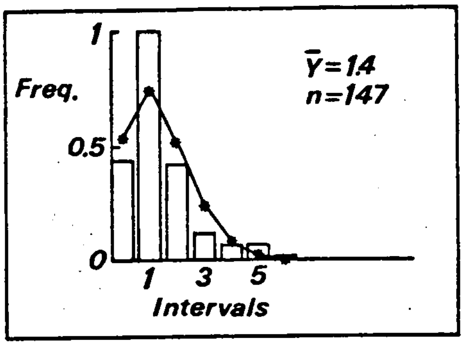
RESULTS.

The frequency distribution of figure 3.1 (bar diagram) looks similar to a poisson distribution. There are two conditions for such a distribution. (1). The mean interval must be small relative to the maximum possible number of intervals. (2.) A catch must be independent of prior occurances. It is to be expexted that the catches are indeed randomly distributed in time. In nine out of ten cases the spoonbill walks with a constant speed through the water. By means of the catches the distribution of prey in the water is reflected. With the average ($\bar{Y}$) of the observed distribution the expected distribution can be computed in case of a poisson distribution. The expectation is represented with a drawn line in fig. 3.1. Figure 3.1-3.3 are based on behaviour protocols where the prey was G. aculeatus and P. pungitius with different catch frequencies. Figure 3.4 and 3.5 are based on C. crangon and P. varians. At first sight it is obvious that there is a discrepancy between the expected and the observed distribution. To verify if the difference is significant the Chi-square test is applied. None of the investigated cases turned out to be poisson distributed. The probability (p) that the observed distribution is still poisson distributed are presented next to the figures.



<u>Figure. 3.4.</u>

prey: <u>C. crangon</u>.
location: Het Balgzand.
catchfreq.: 12.5
Chi square: $p < 0.005$



<u>Figure. 3.5.</u>

prey: <u>P. varians</u>.
location: Putten.
catchfreq.: 21.4
Chi square: $p < 0.005$

A closer look at the catch frequency.

Discussion and Conclusion

From the discrepencies between the observed and the expected distribution two conclusions can be drawn. In all investigated cases the frequency of the small intervals is larger than expected (drawn line). This can be explained when prey is not randomly distributed but appear in shoals. The high frequency of small intervals (Ø,1) represents the moments the spoonbill walks through a high density of prey. The idea is confirmed by the relative high frequency (higher than expected) of large intervals (1Ø,11..). This represents the moments the spoonbill walks in between two shoals of prey. The frequency of intermediate intervals are consequently lower than expected.

Sticklebacks as well as shrimps and prawns appear in shoals.

In all investigated cases the mode lies at interval 1 (2-4 sec). Maybe there is a more subtle difference in the area of Ø and 4 seconds but the accuracy of the measurements does not allow to be more precise. The conclusion from this data is that the density of prey within shoals is rather independent from the overall density in the water and this will do for all kinds of prey. Unfortunately this study can not tell us anymore about the foraging strategy of the spoonbill.

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