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Platalea leucorodia

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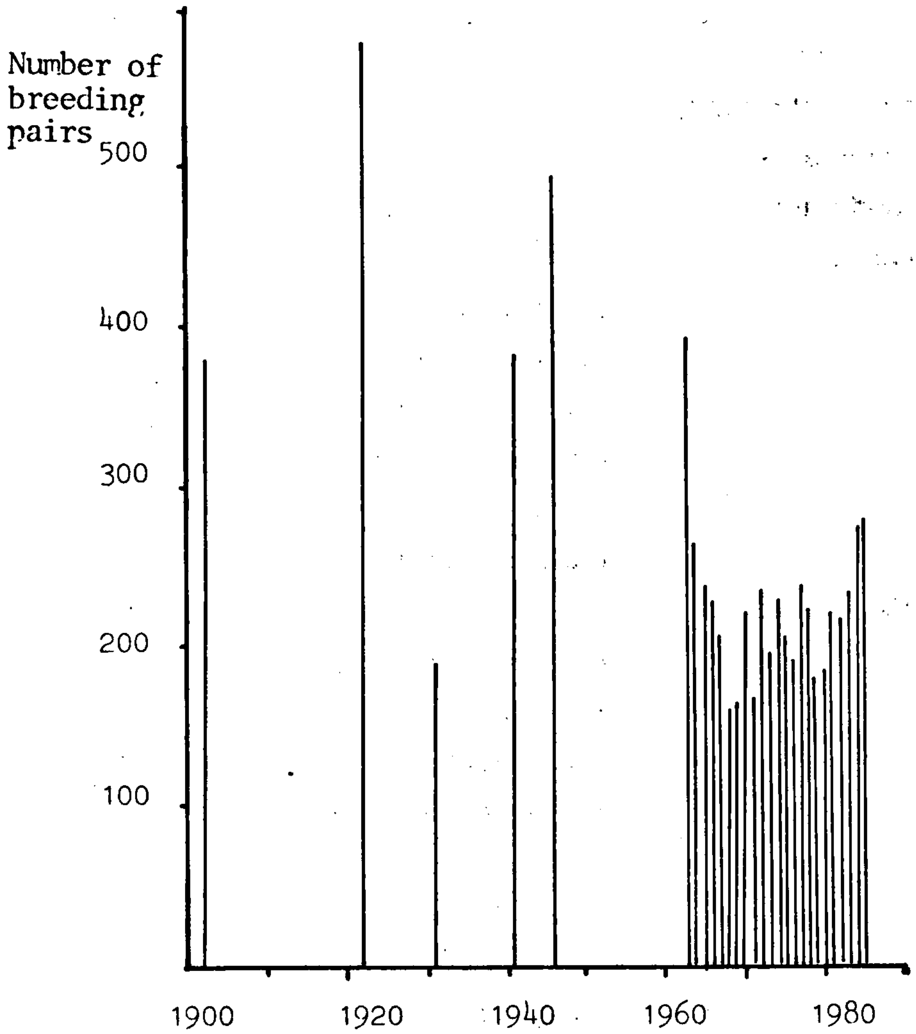

Figure 1 : Number of breeding pairs in the Netherlands from 1900 to 1985.

INTRODUCTION

In the past the spoonbill *Platalea leucorodia* used to breed in the Netherlands in far larger numbers than it does today. Recently the cause of the drastic fall in numbers was pollution of the environment with chlorinated hydrocarbons (Rooth and Jonkers,1972) during the years 1963 to 1970 (Fig.1) Since 1970 the population has been recovering and numbers are increasing. Especially on the Waddensea-islands the increase in numbers of breeding pairs is striking. At several places new colonies have been established.

At the moment the spoonbill are breeding in seven colonies all situated in the north-western part of the Netherlands (Fig. 2). Nevertheless, the total number is still much lower than at the turn of the century, or even shortly after the second world war. During the last thirty years the mainland of North-Holland, which forms the the most important foraging area during the breeding season, changed drastically. About 25% of the suitable foraging-areas with shallow waters and small ditches have vanished, owing to changes in agricultural management and urbanization. One of the changes is the artificial manipulation of the water-level. Due to this, many shallow ditches with flat beds and edges sloping gradually, have been replaced by straight deep ditches with steep slopes. In these ditches a strict schedule of a low winter-level (10 to 15 cm) and a steep increase to a high summer-level (20 to 40 cm.) is maintained. Other measures are the reduction of the number of sluices used for water-management and the special measures taken to prevent salt water from penetrating into the mainland. This (for instance) makes it impossible for the migrating three-spined stickleback *Gasterosteus aculeatus* to enter the fresh water in early spring and causes changes in the stickleback population (Wooton, 1976; Baggerman, 1957; Mullem and van der Vlugt ,1964). Fortunately the foraging-areas on the tidal flats of North-Holland and Texel remained intact and there are no indications at hand of big changes in the prey population (c.q. *Crangon crangon*).

In contrast with the opinion of several people, the Spoonbill is not a filter-feeder, but catches prey individually with its flat-tipped bill by means of the tacticle sense. According to Cramp et al. (1977) the food of the Spoonbill consists of small fishes (especially three-spined and ten-spined sticklebacks *Pungitius pungitius*, *Crustacea, Insecta, Amphibia* and even *Mollusca*. For the roseate Spoonbill *Platalea ajaja* stomach analyses showed that 14-82 % of its food consisted of small killyfish *Fundalus heteroclitus F.pallidus, F. similis, Mollienisia lattipinna* and *Gambusia spec. Cyprinidon variegatus, C. carpio, Gambusia affinus, Eurinostomus guta, Menidia atrimentis* and 4-45 % of shrimps (Allen, 1942). The Royal Spoonbill *Platalea regia* feeds almost exclusively on the shrimp-species *Macrobrachium intermedium* caught in seagrass beds in the tidal area (Howard et al., 1984). When foraging in fresh water, the Royal Spoonbill eats small fishes, crustacea and small water insects, like *Notanectidae* and *Corixidae* (Vestjens, 1974) and so does the Yellow billed spoonbill *Platalea flavipes*. In 1984 a census was carried out of the possible prey species of the Spoonbill on the mainland of North-Holland. It was concluded, that sticklebacks (both three-spined and ten-spined), small rudd *Scardinus erythrpthalmus*, roach *Rutilus rutilus*, and the prawn *Palaemonetes varians* were the most important prey species. Because of their relatively low biomass gammarids and fresh water insects are considered negligible prey items.

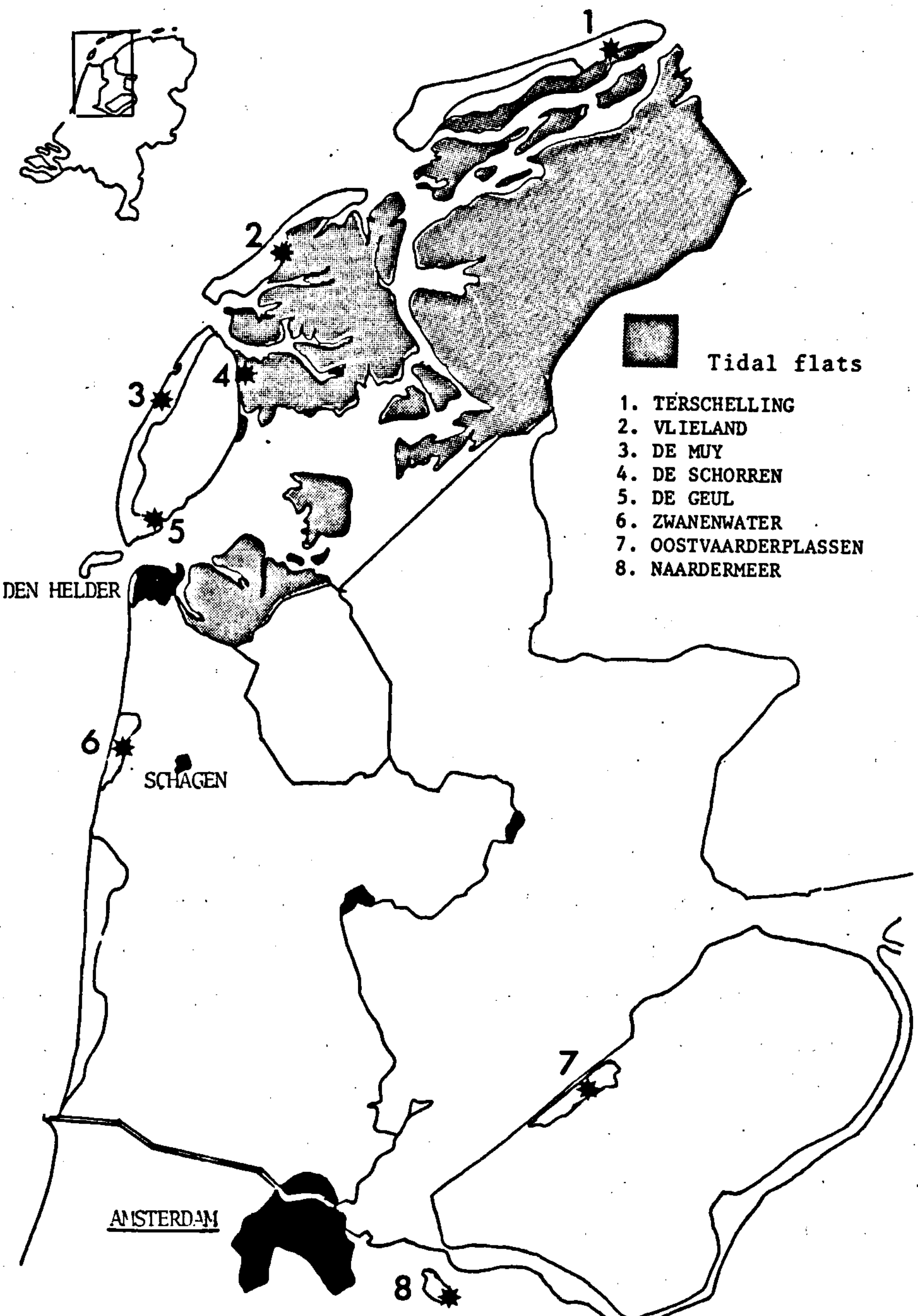

Figure 2 : Distribution of the spoonbill colonies in the Netherlands in 1985.

The aim of the study.

In the last decades the general deterioration of the foraging areas of the spoonbill on the mainland of North-Holland made the spoonbill shift its foraging activities to saltwater areas. This was first observed in 1984, when the spoonbill of the Zwanenwater colony were foraging on the tidal flats of the Balgzand from the second half of May onward. This new fenomenon was probably caused by the introduction of a different hydrological management in a substantial part of one of the freshwater foraging areas near Hoorn. Also the increase in population numbers of the colonies of the Waddensea-islands points to a growing importance of the salt water foraging areas. Observations made in 1984 on the island of Texel indicated that also on Texel spoonbill shift their foraging activity from fresh to salt water during the breeding season. Therefore Texel was selected as study area for an investigation into the food ecology of spoonbill foraging in both habitats. From investigations in 1984 it was concluded that three-spined and ten-spined sticklebacks, prawns, brown shrimps *Crangon crangon* and small rudd and roach form the main prey of the spoonbill. Therefore presence and availabillity of these species was investigated in both fresh and salt water areas to detect whether these factors influence the foraging success of spoonbills. As the foraging succes of spoonbills is also influenced by hydrological management measures it is neccessary to combine the information about the prey species and the hydrological management measures, in order to protect the foraging areas of the spoonbill properly.

The study area.

The research was carried out on the island of Texel for the spoonbill of the colonies De Muy (22 pairs) and de Schorren (22 pairs). Only the Northern and Eastern parts of the island (north of the line De Koog - Den Burg - Oosterend) were studied intensively, because of the expected importance as foraging areas. In the study area 4 different polders can be distinquished (Fig.3) :

- Polder Waalenburg: an old polder (1612) which consists mainly of meadows used for pasturage. Most ditches are straight and dug out deep (about 1.5 m) Throughout the year the waterlevel in the ditches varies from 15-50 cm. In a part of the polder (about 40 acres) the waterlevel is kept relatively high, because of bird preservation measures.
- Polder Eierland: A relatively young polder (1835), which consists of a mixture of meadows and arable land. The ditches are the same as in the polder WaalenBurgh apart from the fact, that they are longer. Throughout the year the waterlevel is a bit lower (10-30 cm) than the level of the other polders.
- Polder Het Noorden: A young polder (1865), which consists of a mixture of meadows and arable land. The ditches as well as the waterlevel are the same as in Polder Waalenburgh.
- Drijvers Vogelweide: A small reserve (40 ha.) situated in the southeast of polder het Noorden, which consists almost exclusively of uncultivated meadows. Beside the normal ditches which are also found in the other polders this area contains some wide ditches (10-30 meters), which are shallow and have edges that slope gradually. The waterlevel is less artificially manipulated and relatively constant throughout the year, especially in the bigger ditches.

In order to study the food ecology on the tidal flat, an area 3 km. to the east of the colony De Schorren (see study area), was selected. This area can be divided into 4 geophysically different units:

- Channel: A wide water of 10-40 m. with a sandy bottom and steep edges (> 10%). It always contains running water and varies in depth from 1-3 m. during the lowest ebb.
- Gully: A narrow water of 1-10 m. wide, through which the water of the sandy flats and the musslebeds flows towards the channel. It always containswater and varies in depth from 0-1 metre with an average depth of about 50 cm. The bottom conists of sand, shell deposit and some silt.
- Mussel beds: An area of slimy bottoms with banks, formed by an accumulation of mussles, between which pools and littles streams are formed. During low tide these pools remain filled with water, that can be up to 40 cm. deep.
- Sandy flats: A flat area with a sandy bottom, that normally does nothold water during

low tide. From half June onwards the excessive growth of weeds (*Ulva, Enteromorpha*) forms thick cables, that prevent water fromflowing to the channels and gullies. In this way numerous little pools (diameter 1-2 m.) are formed during low tide.

METHODS

Presence of birds.

The presence or absence of foraging spoonbills was scored from March till August in 1 km^2 squares (SOVON), by making two or three observation tours every two weeks covering an area of some 92 km^2. For the tidal flats (see study area) a tower, 5 m. tall with a blind on top was used. During low tide every 15 minutes the number of foraging spoonbills per unit was scored. In this way the relative importance of the units could be determined. Absolute, overall numbers were hard to count as weather condition varied enormously and could drastically change the range of sight.

Rate of prey capture.

If foraging spoonbills were detected at a distance of 20-300 m., protocols were made with the use of a telescope (20x, 40x, 60x) on a tripod and a taperecorder. Bercause it was difficult to make enough protocols on the mainland, here observations were carried on as long as possible (max. ± 20 min.) while on the tidal flat protocols of about 5 min. were made. At short range prey species could be distinquished, but the length of the prey was almost impossible to estimate. During the protocols the number of swallows, steps and other foraging spoonbills nearby was recorded, while regularly an estimate of the foraging depths was scored. The use of walky-talkies on the tidal flat made it possible to direct someone to the exact place, were a protocol had been made. In this way, the size of a step could be measured, by the use of foot prints, while also prey samples at the exact foraging spots were taken.

Salt water sampling.

From April till 15 July three of the four distinguished units on the tidal flats, channel, gully and mussle-beds have been sampled every 2 weeks. The sandy flats were added to the study area at a later stage in June, because they appeared to become important only at that time. Samples were made with a 40-70 cm. handpulled beam trawl (Kuiper, 1975), mesh size 5 mm. In every unit 2 hauls of 75 m. were made during the turning of the tide in a depth of 20 and 40 cm respectively. All samples were taken home to determine the possible prey species, their length distribution and relative density (relative, because as net efficiency is not known). To determine the exact prey densities on foraging spots, a pvc-tube with an diameter of 37 cm. and a height of 75 cm. was used. The tube is thrown foreward (about 2 m.) and quickly pushed into the ground. With the use of a 1 mm. sieve all organisms to a depth up to 1 cm. are caught. Samples with the tube were only taken in July.

Fresh water sampling.

In order to determine the food supply on the mainland of Texel, some 25 ditches and channals were sampled every 2 weeks from February to December 1985. The sample places were selected for obtaining variation in depth, width, and salinity. In this way migration of sticklebacks could be detected while at the same time information could be gathered about the food supply in the areas that are frequented by spoonbill. For small ditches (up to 2 m. wide) a net of 50 by 50 cm. was used versus a net of 50 by 100 cm. for wider ditches. The mesh size for both nets was 5 mm. The nets were mounted on a stick of 1,5 m. at an angle of about 150 degrees in order to improve efficiency, which is close to 90% for the small net and about 70% for the big net. The numbers of hauls needed to ascertain the density of sticklebacks in the ditches, was determined by calculating the point at which the standard-error of the mean number of prey caught per haul, did not change appreciably anymore. This meant that 8-10 hauls had to be made for each sample place. Of all samples the sex ratio and the number of sticklebacks per haul were registered, plus all other possible preys. A small part of the sticklebacks were taken home in order to be able to determine the length and weight distribution.

Foraging activity.

As was done in previous years (1983-1984) on the mainland of North-Holland the number of spoonbill leaving for and returning from the foraging areas were counted from a surveyable position near the colony. In this way information is obtained about the duration of foraging flights and the rhythm in foraging activity. Foraging activity was also scored during the numerous tours made for reasons of sampling and observation.

Cage experiments.

From April untill July a second-year spoonbill was kept in a tidal cage (Swennen,) at the Dutch Institute for Sea Research (NIOZ) on Texel. For a period of about 2 months the spoonbill was fed, only during low tide, at first with dead herring and later on with living shrimps and sticklebacks. In August the feeding experiments were carried out with living sticklebacks and shrimps, divided in 2,5 mm. length classes. The preys were offered in a 1.5 x 1.5 m. tank of about 20 cm. deep, placed in the tidal part of the cage. Both shrimp and sticklebacks were offered in varying combinations of length classes and in different densities. As to determine which length classes had been eaten, the spoonbill was interrupted each time when 10 preys had been swallowed. This procedure was repeated 3 times in succession every morning and afternoon, when the tide was low. With the use of a video the handling time of the various length classes of the different prey species was determined.

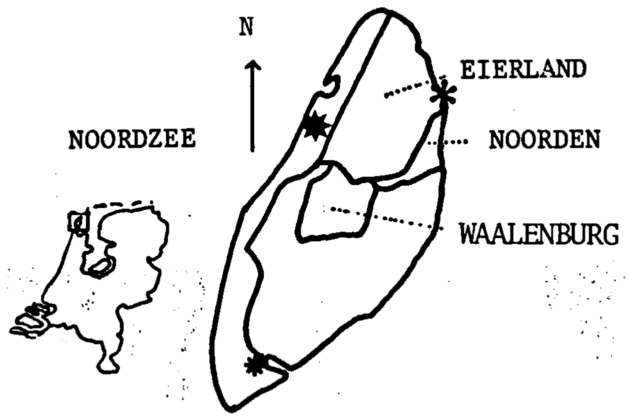

Figure 3 : Map of Texel, showing the main polders and distribution of colonies.

✸ De Muy

✻ De Schorren

✱ De Geul

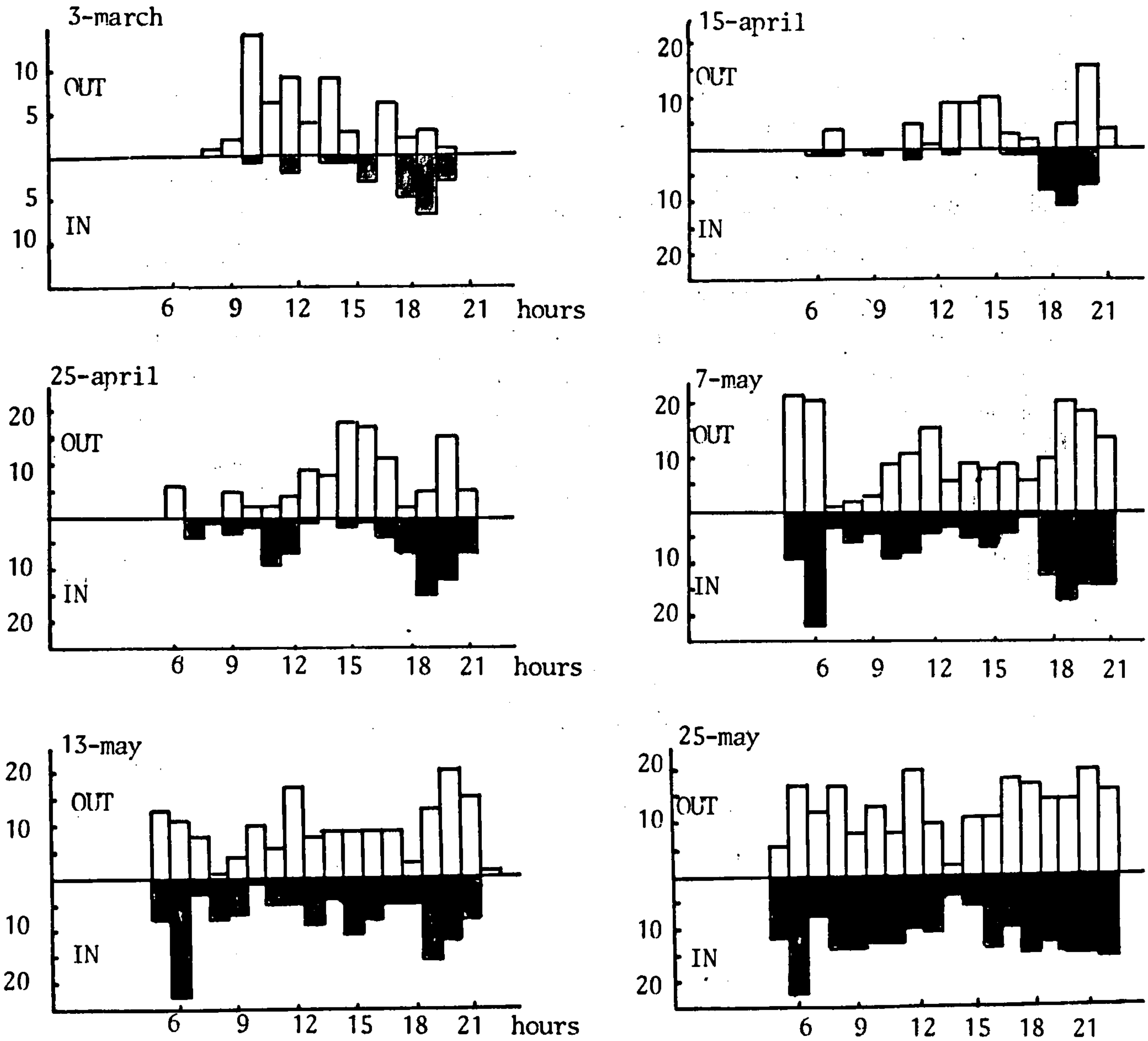

Figure 4 : Rhythm of daily foraging flights of the Zwanenwater colony in 1984, during the breeding season.
Out = Number of birds leaving the colony.
In = Number of birds entering the colony

RESULTS

Rhythm and daily activity

Counting of birds leaving or entering the Zwanenwater colony during the breeding season of 1984 gave a good impression of the number of foraging flights made per day and the hours in which the flights took place.

In April it seemed that each spoonbill only made one flight per day for gathering food. The total number of foraging flights increased during April and May (Tab 1). In May the total number of flights per day even exceeded the number of breeding adult spoonbill of the colony, which indicates that at that time the spoonbills started to make more then one flight per day.

In April and the beginning of May many of the spoonbills which left the colony during daylight did not return before dusk. This group spent the night outside the colony and returned before daylight. The group of birds which returned to the colony before dusk foraged only during the daylight period. The percentage of birds spending the night outside the colony decreased during the breeding season. So, from March till June the spoonbills shifted their foraging activity more towards the daylight period.

In the first half of April most birds left the colony before noon (Fig.4) and towards the evening some 38% of them returned to the colony. In the second half of April some 54% of the birds leaving the colony during daylight hours returned before dusk. It is remarkable that this 54% =33 birds is close to the number of active breeding pairs (38) at that moment. In the evening when the group of daylight foragers has returned a second group of spoonbills left the colony. It seemed that this group consisted for a great part of birds which had been relieved from the nest.

In the first half of May a group of spoonbills start leaving the colony in the early morning already. The two other groups (one at noon and one in the evening) could still be recognized. At the same time the number of foraging flights per day was increased and these facts combined with the previous one indicate that in May the rhythm of foraging flights was changing. At the end of May and the beginning of June spoonbills started leaving and entering the colony at every hour of the day and any clear pattern could no longer be recognized. The same pattern of rhythms was found by Fasola (1984) on Night herons *Nycticorax nycticorax* where before the egg-laying period all birds foraged during the night. During incubation of the eggs the activity of a pair was divided between nocturnal and diurnal foraging. While during the pre-fledging period foraging occured throughout the whole day.

Date	Pairs	Out	In
3-4	20	60	23
15-4	38	71	33
25-4	-	109	75
7-5	-	190	146
13-5	51	166	134
25-5	60	217	219
5-6	60	250	214
17-6	-	192	173

Table 1 : Numbers of birds leaving=Out, or entering=In, the Zwanenwater colony per day, compared with the number of breeding pairs at at that particular day (data from 1984).

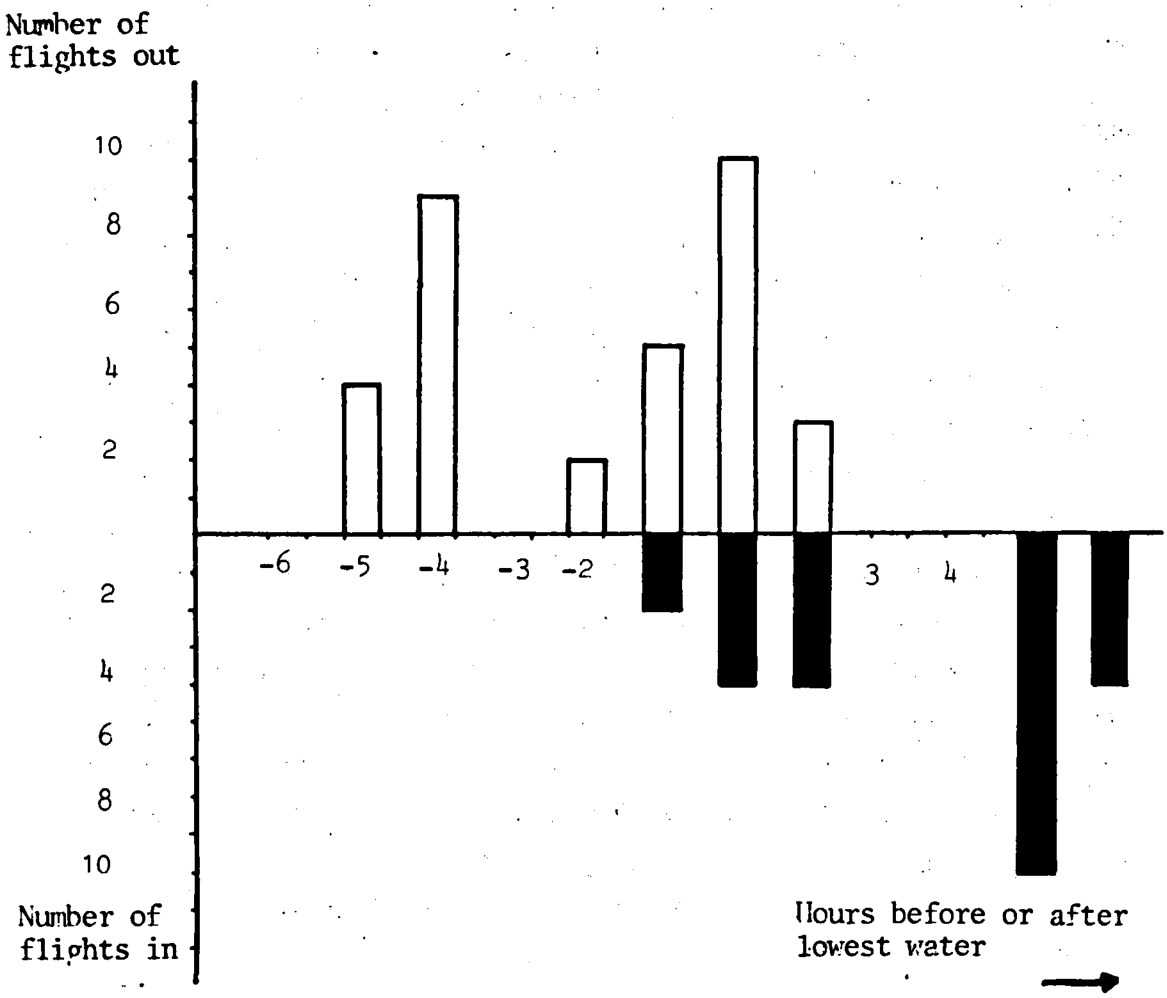

Figure 5 : Rhythm of daily foraging flights of the Muy colony in June 1985, in relation with the tide on the tidal flats of Texel.

Nest observations on ring marked individuals in April 1983 and 1984, made clear that during the morning till 10-11 o'clock both parents were in the colony. Most time was spent bathing, preening, nestbuilding, breeding, and mating. In most cases the female was sitting on the nest while the male was bringing in branches for nest construction. After a few hours this nest building activity of the male was followed by a copulation and nest relieve. Shortly after the female left the nest she took off for a foraging flight, leaving the male on the nest for the rest of the morning and afternoon. Before dusk the males were relieved from the nest by the returning females and took off in their turn for a foraging flight during the night.

In contrast to the Zwanenwater colony the Muy colony foraged entirely on the tidal flats of the Waddensea, in the second half of May. Some 5 to 4 hours before the lowest water a group left the colony (Fig 5). At the time the tide was turning this group came back to the colony and relieved their partners from the nests. Shortly after the first group had returned to the colony a second group left. This group returned some 3-4 hours later when the tide was coming in on the tidal flats.

Comments:During censuses and observation of spoonbills in the foraging areas in April and May it became clear that only in the afternoon and evening a good opportunity was obtained for spotting spoonbills. This is in agreement with the observations in the colony where only in the afternoon, evening and night spoonbills were out of the colony for foraging. Observations on the tidal flats made clear that during the lowest water spoonbills with heavy loaded bellies returned to the mainland of Texel. As the number of spoonbills on the tidal flats and in the colony remained almost stable and as it takes a spoonbill often some 5 to 10 minutes to belch out all the food, it is concluded that during one ebb period both parents make one foraging flight each. This means that each parent is foraging for about 6-9 hours per day on the tidal flats. While foraging in freshwater areas the length of a foraging flight during daylight hours could vary between 5-9 hours, and during the night between 7-8 hours.

The increasing number of flights per day towards the end of May and the beginning of June at the Zwanenwater colony may partly have been caused by the increasing number of nests and the growing food demands of the chicks. At the same time however some 18-28% of the spoonbills were foraging on the tidal flats of the Balgzand area. As in this case both parents made one flight each during the low tide (which occurs two times a day) it is clear that this also can have a substantial effect on the total number of flights.

	Mean Leng	in m		
	G.aculeatus		P.pungitius	
1-15 april	43.7	40.9	42.8	35.7
16-30 april	37.6	44.2	37.0	
1-15 may	36.1	42.8	35.5	42.7
	esti.	found	esti.	found

Table 2 : The mean length of G.aculeatus and P.pungitius found in the ditches, and the mean length sufficient for foraging spoonbills as calculated from rate of prey capture.

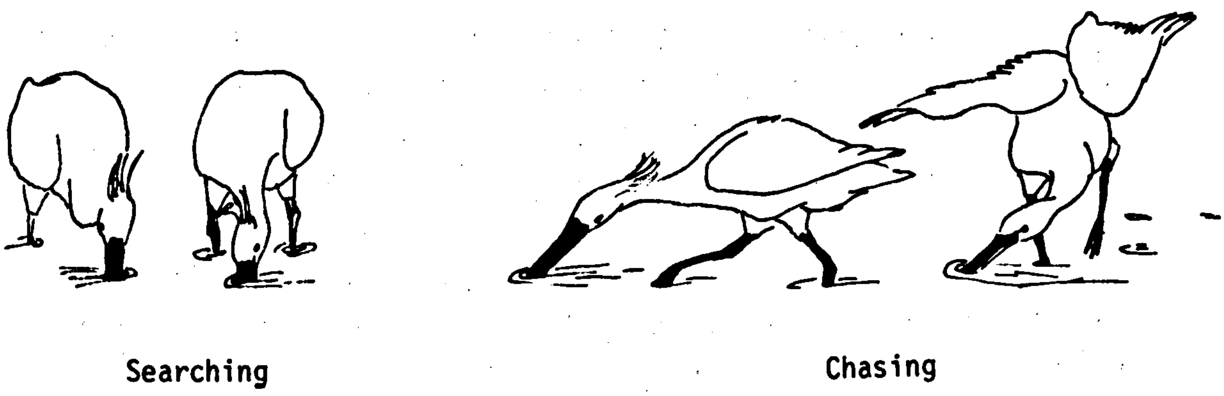

Figure 6 : Foraging behaviour of a spoonbill when trying to catch a fast prey by"chasing" after having detected it by"searching".

Foraging behaviour.

After entering a ditch or other type of shallow water, a spoonbill starts searching for prey by sweeping its bill from side to side. The tips of the bill which are kept 5 cm. apart slightly touch the bottom as afterwards prints of about 2-4 mm. deep are found in the mud. When a prey is detected by the sensible tips and edges of the bill the spoonbill quickly tries to grasp it. Then the prey is thrown into the throat by a toss of the head. When an armed prey like a three-spined stickleback is caught, the spoonbill first tries to crush the spines by snapping the bill.

It often happens, that after some sweeping movements the spoonbill suddenly starts running and turning vigourously through the water. During these chasing movements, the bill is held at one side of the body, with the lateral side in the direction in which the spoonbill is running (Fig 6). The speed at which this chasing takes place indicates that only fast preys like fishes are being hunted. In many cases other spoonbills were attracted by a spoonbill regularly chasing preys. The high escape-rate of fishes (about 63%) after the first attempt offers other spoonbill a chance to catch the prey in the second instance.

During observations of foraging spoonbill through the use of a telescope, we could often determine the species of prey being swallowed. About 27 % of the preys were caught after a chase by the spoonbill. In nearly 100% of the cases, in which we could determine these prey (caught after a chase) the prey turned out to be a fish. In 21-34% of the cases in which no chase preceeded the swallowing of a prey, the tossing of the head revealed that a fish (i.e. stickleback) had been caught. Figure 7 shows, that in the freshwater areas there is a strong relation between the total number of preys swallowed (without a chase) and the number of chases, followed by the capture of a fish ($R = 0,71$; $P > 0,02$; $N = 14$, two tailed). Figure 8 shows, that there is a remarkable difference between the number of chases per minute made in the freshwater areas and the number made on the tidal flat. This indicates that, in freshwater areas fast preys, like fishes, are being caught, versus slow preys on the tidal flats. In brackish waters where mainly prawns were eaten, spoonbill were never seen chasing preys. The same foraging behaviour on the tidal flat in which a high prey capture rate occurs (Fig. 9), combined with the absence of chases, indicates that almost all preys caught on the tidal flats were shrimps.

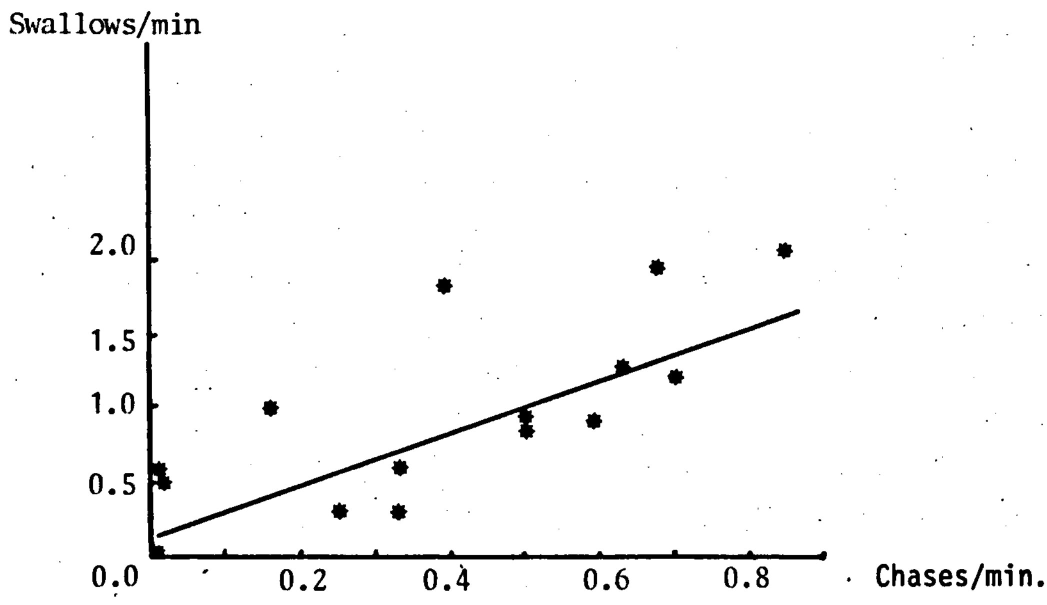

Figure 7 : Correlation between chase frequenty (followed by swallow) and rate of prey capture rate (with no chase), in fresh water areas. (Y=1.5 X + 0.14, N=15.p ⩾ 0.05 two tailed)

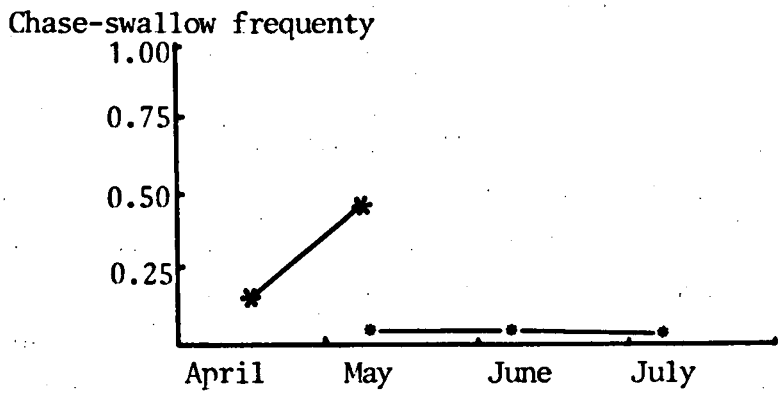

Figure 8 : Frequenty of chases followed by swallowing of a prey. In freshwater areas=✱ , and tidal flats=✸.

		Mean Length in m.m. of Shrimps	
1-15	may	33.0	30.6
16-31	may	35.0	35.9
1-15	june	36.5	18.1
16-30	june	40.5	18.5
		esti.	found

Table 3 : The mean length in mm. of C.crangon found on the tidal flats and the mean length sufficient for foraging spoonbills as calculated from rate of prey capture.

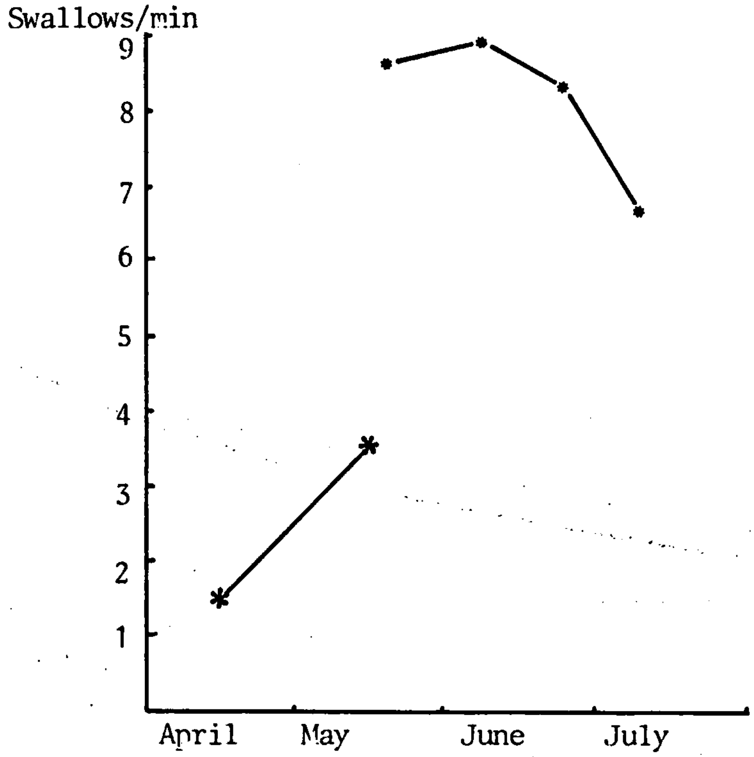

Figure 9 : Rate of prey capture (with and without chase)
In freshwater ares=✻ and tidal flats=✹

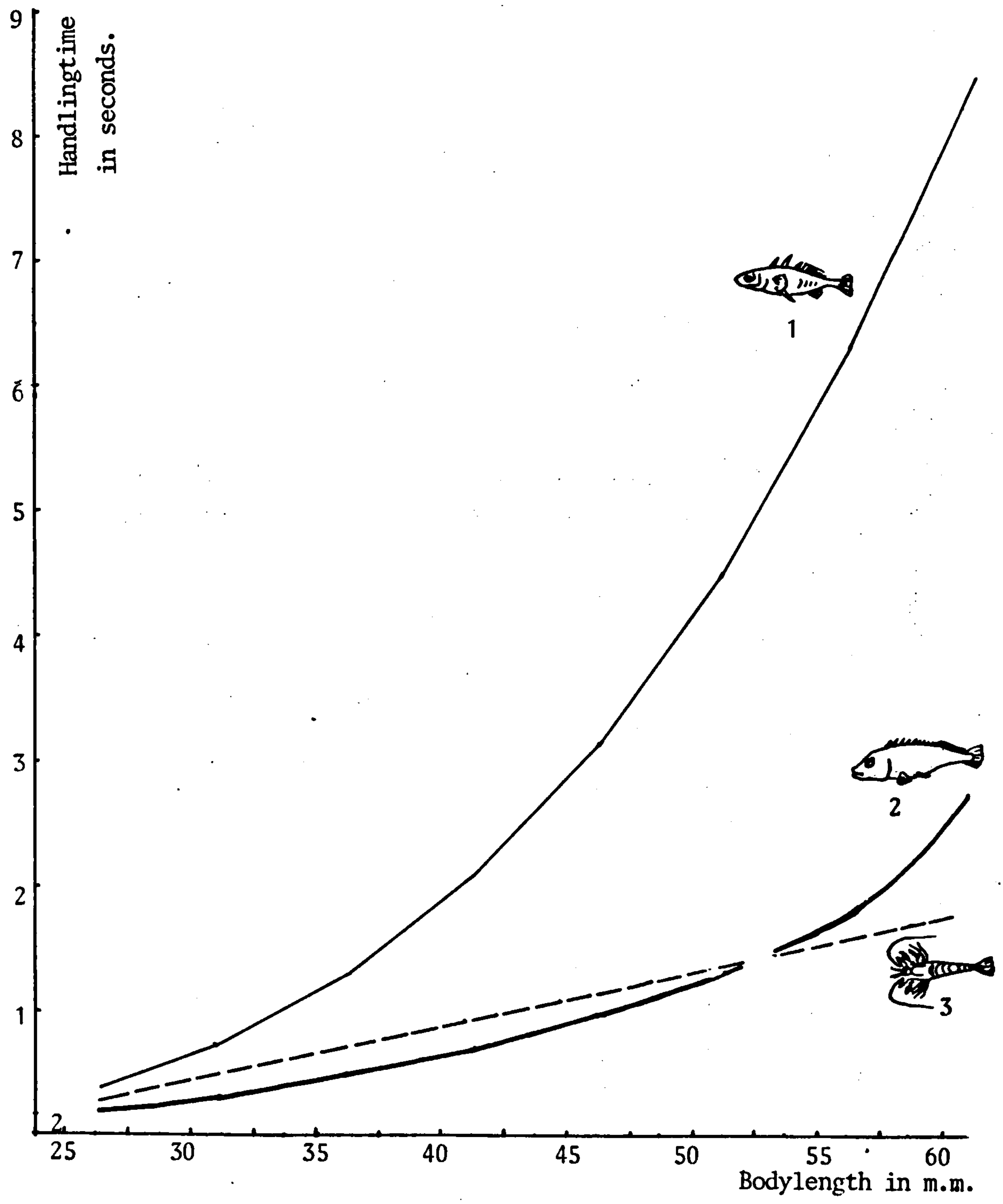

Figure 10: Handlingtime (Ht) of various prey species.
1 = G. aculeatus; Log Ht = 3.488 Log (lengthclass) - 3.882
2 = P. pungitius; Log Ht = 2.747 Log (lengthclass) -3.449
3 = C.crangon; Log Ht = 0.04 (Lengthclass)+0.1656

Cage experiments

The time a spoonbill spent handling various prey-species increased with the length of the prey (Fig. 10). For shrimps the handling time was a lineair function, while for sticklebacks this function was a logistic one:

$y = 0.04 \,.(\text{Lengthclass}) + 0.1656$, for shrimps
$\text{Log } y = 3.488 \,.\log(\text{ Lengthclass}) - 3.882$ for three-spined stickleback
$\text{Log } y = 2.747 \,.\text{Log}(\text{ Lengthclass}) - 3.449$ for ten-spined stickleback.

The relatively strong increase in handling time of the three-spined stickleback compared with the increase found for shrimps and ten-spined stickleback indicates that the defense system of the three-spined sticklebacks against predation is the most efficient.

As the caloric value of both stickleback species differs only slightly, the profitability of the ten-spined stickleback is much higher. When both stickleback species of the same size were offered, the spoonbill selected for the ten-spined stickleback,, which was the most profitable one (T=8,n=16 p.0.05), (Fig.11).

Because the handling time of large three-spined sticklebacks is much longer, the profitability of large three-spined sticklebacks should be inferior to that of small three-spined sticklebacks. This however is not what we found in our experiments, which clearly showed a selection of the largest three-spined sticklebacks (Fig. 12). The discrepancy between the results could be explained by the difference between the execution of the selection experiments and handlingtime experiments. During the selection experiments the sticklebacks offered spent some time in the tank before the spoonbill was permitted to start foraging. During the handlingtime experiments the sticklebacks were treated with our hands, in order to measure length, before offering them to the spoonbill. This treatment could have have made the sticklebacks more alert to predation and thus starting the putting up of spines for defence. This seems plausible as during the selection experiments and during the observations in the field, we never observed handling times as long as those found during the handling time experiments.

As the profitability of shrimps increases with length, one may expect a spoonbill to select for larger shrimps when the encounter rate exceeds a certain value of ¶ as predicted by Krebs and Davies (1984). Because the excact encounter rate is hard to determine, as it depends on the speed the spoonbill is foraging, we estimated the ¶ by using the density of the largest prey.

During the selection experiments each time two different lengthclasses of shrimps were offered. When the difference in body length between the two classes was big, e.g. 22.5 mm, the spoonbill already selected for the largest prey at a density of about

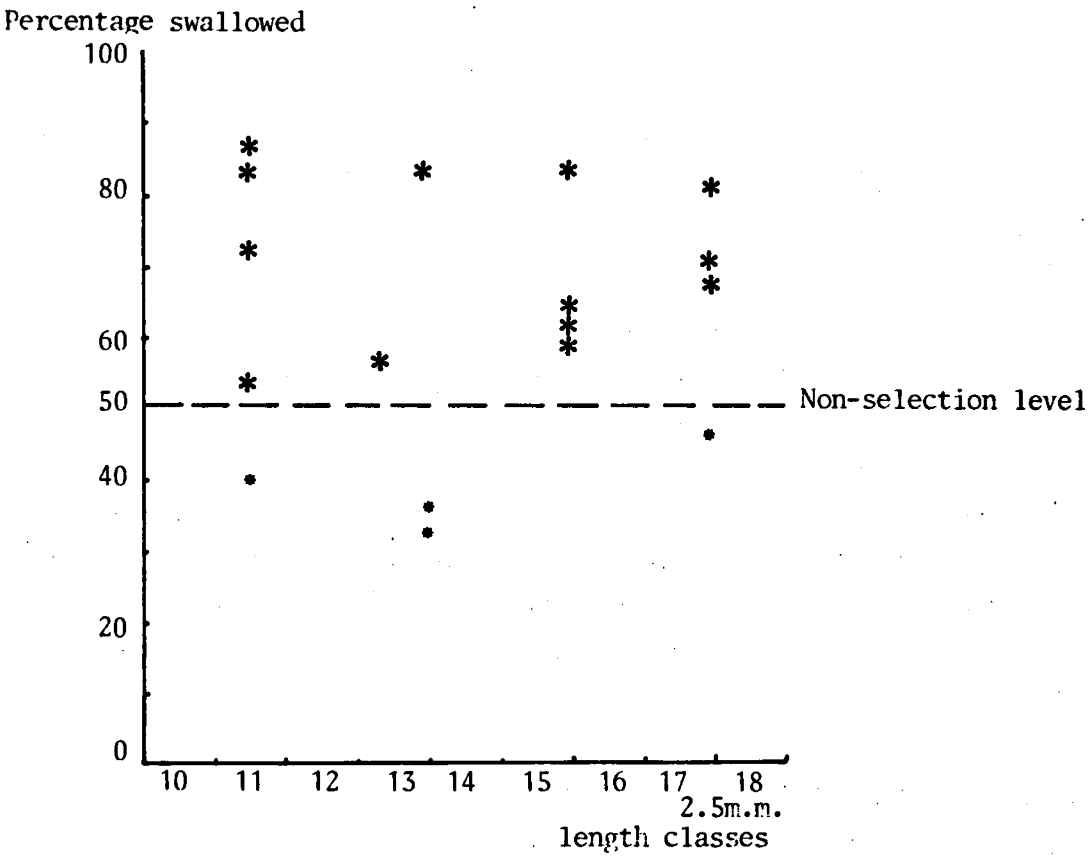

Figure 11: Percentage of P.pungitius swallowed out of total number number of swallows (with G.aculeatus and P.pungitius).

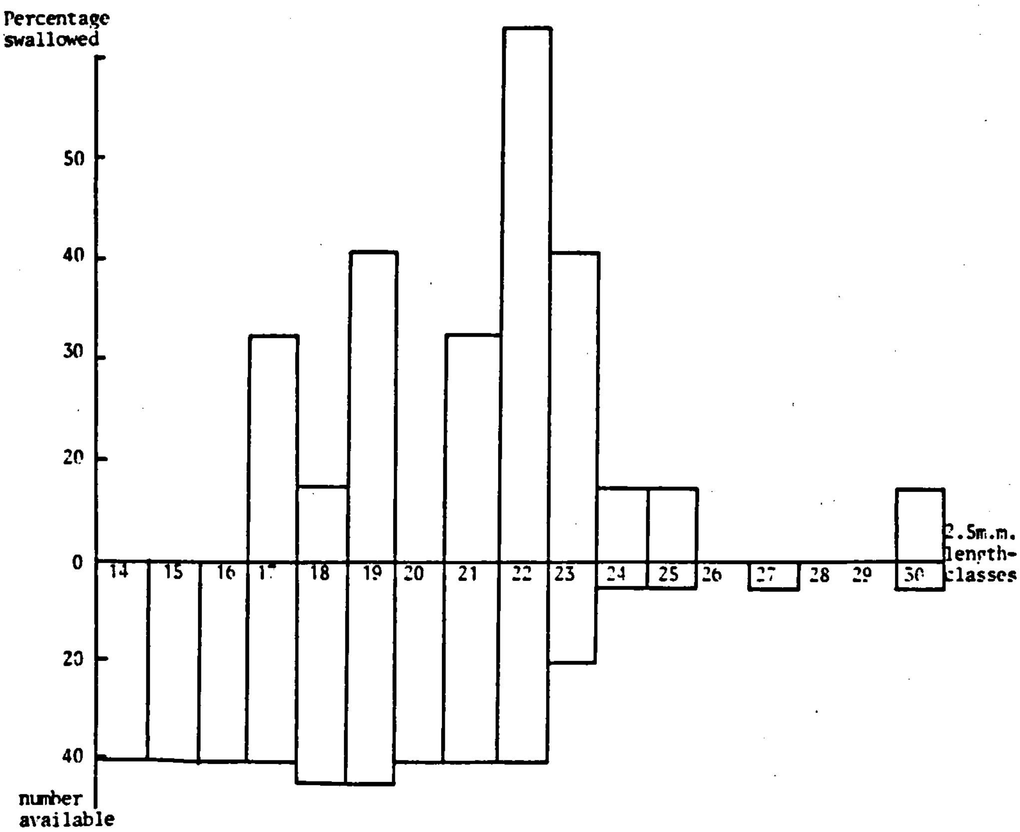

Figure 12: Length distribution of preys (G.aculeatus) offered to the spoonbill = below, and swallowed by the spoonbill = above.

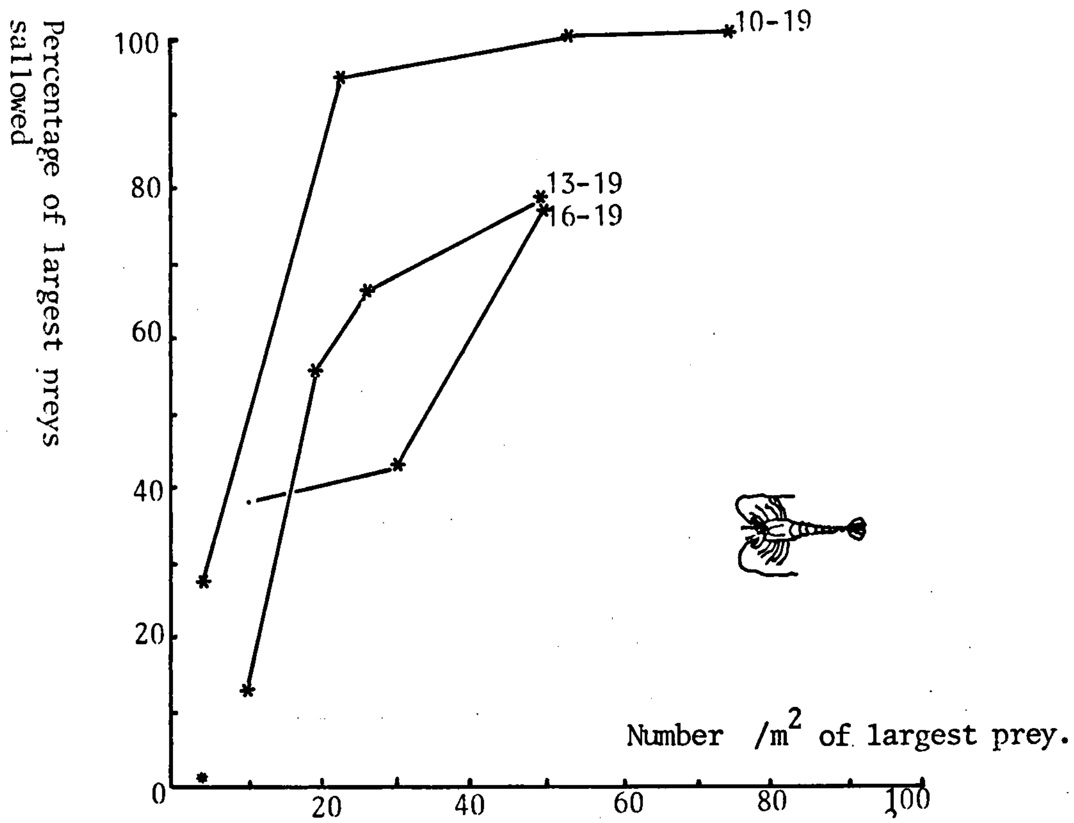

Figure 13: Percentage of total numbers of swallows in which largest prey (C.crangon) is taken. Density of smallest prey is kept constant at 100 individuals per m^2. Figures at the end of the lines indicate the lengthclass (2.5 mm.) of smallest and largest prey.

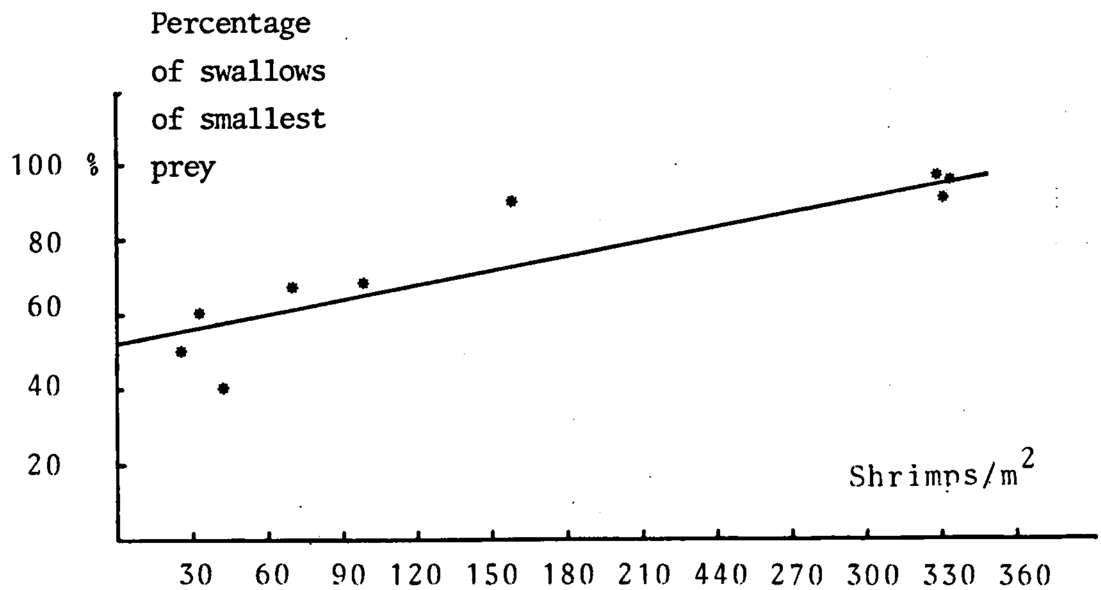

Figure 14: Correlation between the percentage of swallows in which smallest prey is taken and the density of the smallest prey. (in case the density of largest prey did not exceed the critical value of ¶).
(smallest prey = 36.2 mm, largest prey ± 46.2 mm.)
($Y= 0.139 X + 51.6$; $N= 9$, $p > 0.05$).

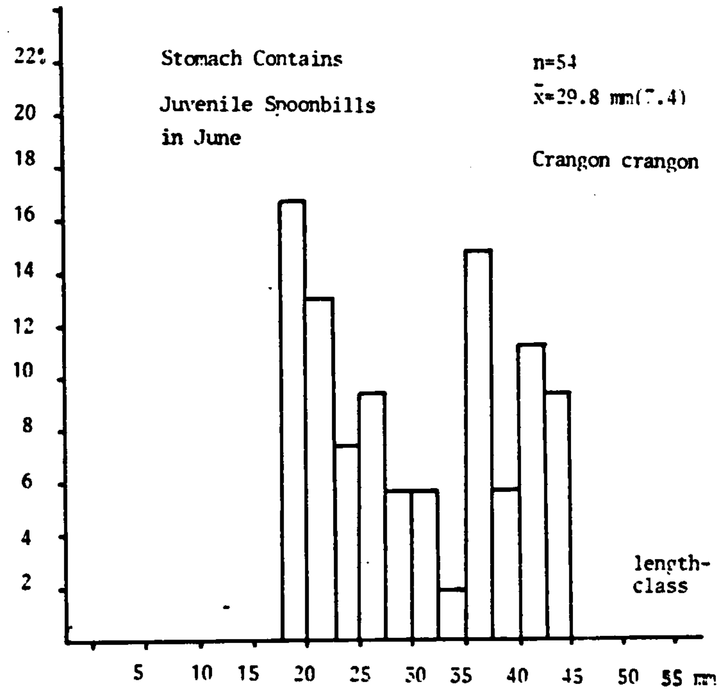

Figure 15: Length distribution of C.crangon found in regurgitations of juvenile spoonbills of the Muy colony in June.
(N= 54, x= 29.8 mm ± 7.4).

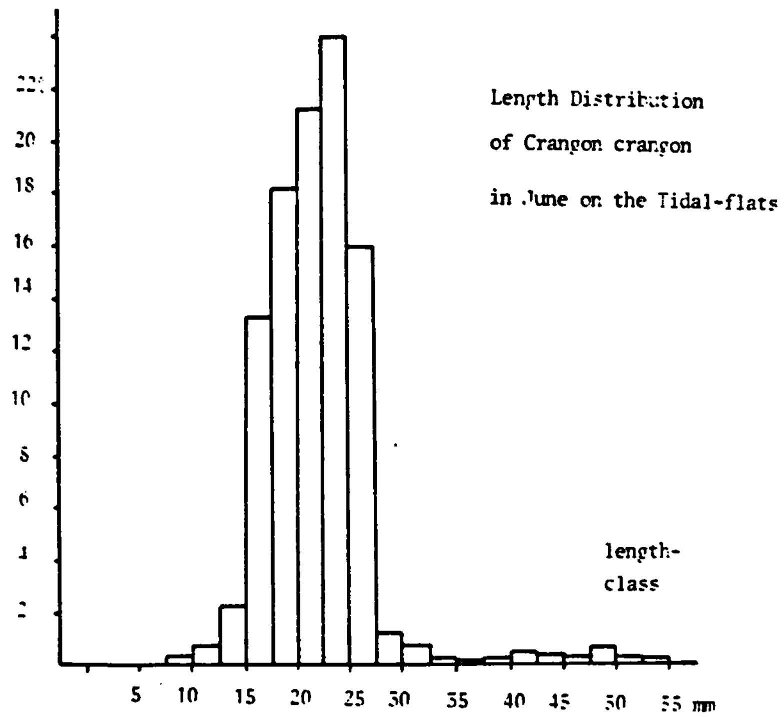

Figure 16: Length distribution of C.crangon on the tidal flats of Texel in June.

15 individuals per m^2.

When the difference in body length was reduced, e.g. to 7,5 mm, the spoonbill selected for the largest prey at a density of about 30 individuals per m^2. It is shown (Fig.13). that the selection occurs when the density of the largest prey exceeded 10-30 individuals per sq. metre. When the density of the largest prey didnot exceed the ¶, the number of the largest preys taken by the spoonbill, was negatively correlated with the density of the smallest prey (Fig.14), (R=0.748 n=6, R=0.84 n=9, R=0.88 n=9, R=0.73 n=10)

Selection of prey size.

The minimum energy demands of an adult spoonbill in April are estimated to be 1387 Kj/day (King, 1974). By using a food efficiency of 0.8 according to Doornbos (1984) and computing the mean number of prey taken per day in April (528 prey/day), the minimum mean energy content of the prey swallowed was calculated to be about 3,28 Kj. If the energy content of the prey in ditches, on average is smaller than 3.28 Kj the spoonbill will not be able the maintain themselves, unless they select bigger preys. Table 2. shows, that in early April the mean stickleback length is too small, so the spoonbill has to select larger sticklebacks, or other bigger species of prey. From 15 April to the 15 May, the mean length of sticklebacks caught in the ditches, exceeded the calculated length. This means that it is unlikely that spoonbill will ever take small prey-species like insects, gammarids or neomycids.

On the tidal flats, samples of prey were taken on the very spot where a spoonbill had been foraging a minute or less earlier. As it was concluded from the cage experiments, that selection for the largest prey occured when their density exceeded 10-30 individuals per m^2, we examined, which group of the highest length classes occured in a density of 20 per m^2 or more. By starting to compute the density of the largest size-class and subsequently adding the density of the second and third largest, we got a certain minimum length class, which formed the minimum length of the group with a density of 20 per square meter. In this way we computed that mainly shrimps of a length > 30 mm. are eaten in channels, gullies and mussle-beds. Only on the sandy flats smaller shrimps with a minimum length of 22.75 mm. are eaten also (Table 3). When we compared these rather hypothetical estimates with the length classes found in the regurgitations (Fig.15) of young spoonbill in June, it became clear that the calculated estimates gave a reliable value of the prey length eaten on the tidal flats. Some 48% of the shrimps eaten were larger than 30 mm., despite the fact that there existed an overwhelming mayority of small shrimps on the tidal flats in June (Fig.16). A great part of these small sized shrimps were neglected by the spoonbill while foraging and the mean length of shrimps eaten was 29.8 mm. During the observations of foraging spoonbill, step-frequency, swallow-frequency, and step-size

date	Plaice Length mm.	Plaice mgram/m^2	Gobius spec. Length mm.	Gobius spec. mgram/m^2
8 May	17.8(3.2)	19.0(3.0)	40.0(5.1)	7.4(1.0)
14 May	20.0(4.1)	3.6(0.0)	38.7(0.0)	1.5(0.2)
30 May	23.0(4.6)	8.7(1.7)		
5 June	27.2(6.7)	4.6(1.1)	51.2(0.0)	7.4(0.0)
20 June	29.2(2.8)	11.0(1.1)		
15 July	36.1(8.5)	7.7(3.5)	42.0(9.5)	

Table 4 : Mean length and biomass of plaice Pleuronectus platessa and goby Gobius spec. found in the foraging areas of the spoonbill on the tidal flats of Texel (between brackets the standard deviation).

Biomass of Shrimps in m.gram/m^2

date	Channel	Gully	Mussel	Sandy-flats
1-15 May	45.4	63.3	30.5	141.6
16-30 May	34.1	234.1	539.7	703.4
1-15 June	188.1	1238.7	1531.0	1278.5
16-31 June	866.0	2798.1	3018.2	1886.4
1-15 July	518.3	4360.9	4604.6	1953.5

Table 5 : Biomass of C.crangon in various areas on the tidal flats of Texel.

Mean Length of Shrimps in m.m.

	Channel	Gully	Mussel	Sandy
1-15 May	37.9	30.6	22.7	25.0
15-31 May	35.9	31.2	20.2	21.5
1-15 June	33.1	21.7	18.1	19.1
16-30 June	25.5	24.0	22.3	18.7
1-15 July	28.5	27.4	25.3	18.5

Table 6 : Mean length of C.crangon in various areas on the tidal flats of Texel.

were recorded. The spoonbill usually sweep their bill some 25 cm to both sides, thus covering about 50 cm while walking forward. By multiplying the number of swallows made per metre walking with a factor 2 we computed by approximation the number of swallows made per square meter between 3.07 and 1.64 per m^2. At densities of about 20 -700 shrimps per m^2, it is clear, that the spoonbill did not catch most of the shrimps and probably only swallowed the largest ones. Estimating the energy demands of a breeding spoonbill in June, (which vary between 1785-1985 Kj/day) and dividing this by the number of swallows made per day, a prediction about the mean size of shrimp taken is obtained. It is computed, that the size of the shrimps should vary between 33 mm. and 35.2 mm., which is slightly larger than the mean size of the shrimps, found in the regurgitation and the minimum size of shrimps calculated above.

Salt water samples.

As shown, the food of the spoonbill on the tidal flats consisted mainly of slow prey species, like shrimps.

During the first half of May, when the biomass of shrimps was quite low, both plaice *Pleuronectus platessa* and gobies *Gobius minutus* and *G. microps* could compete with shrimps as possible prey-species (Table 4). From 15 May onwards the biomass of shrimps per m^2 (Table 5) was far larger than the biomass of plaice and gobies. Therefore it was concluded that plaice and gobies could only form a minor part of the diet of the spoonbill and that shrimps formed the main prey.

The explosive increase in number and biomass of small shrimps (up to 30 mm.) on sandy flats and mussel beds is caused by the settlement of new brood waves of juvenile shrimps. This also explains the decrease in the mean length of the shrimps in all habitats (Table 6).

The low density of shrimps and the absence of small juvenile shrimps in the channels indicate that the mayority of juvenile shrimps (<30 mm) are only found in the more shallow parts of the tidal area. As shown by Kuiper and Dapper (1981), brood waves enter the tidal flats in the first half of May and settle on the sandy flats. After this settlement the increasing water temperature and food supply cause a fast development of the young shrimps (Fig 17). When increasing in length the shrimps gradually move from the sandy flats towards the little streams, gullies, and channels at the edge of the sandy flats. At a length of 30 mm. they finally migrate from these parts towards the deeper parts of the Waddensea or North Sea. Shrimps of late brood waves that do not reach the length of 30 mm. before the end of October return to the tidal flats early next spring to complete their growth. After reaching a length of about 30 mm. they again start moving out of the tidal area towards deeper parts of the Waddensea and North Sea in order to spawn. The

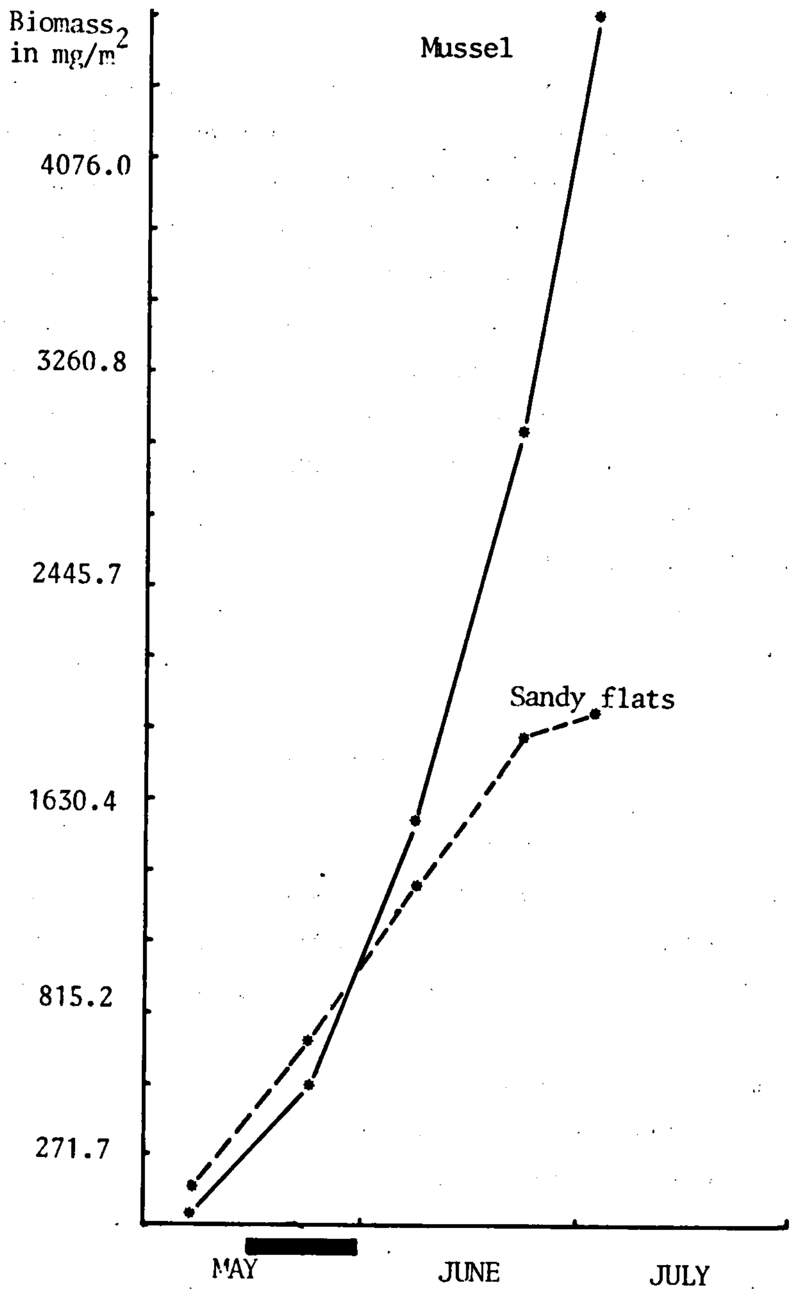

Figure 17 : Biomass of C.crangon on sandy flats and mussel of the tidal flats of Texel. Black bar indicate first appearance of new brood in samples.

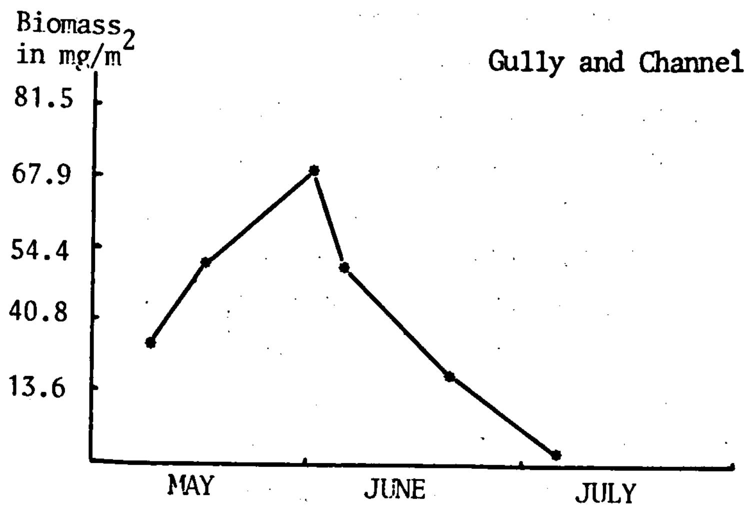

Figure 18 : Biomass of C.crangon (⩾30 mm) in channel and gully, on the tidal flats of Texel.

shrimps of about 30 mm found in our samples in May and June in channel and gully probably belong to this group of second year juvenile shrimps which came back to the tidal area to complete their growth.

In chapter "Selection of Prey size" it is shown that spoonbill mainly select shrimps of ≥ 30 mm . Therefore the density of these shrimps was determined in the course of the breeding season.

In May the biomass of shrimps of 30 mm or more in the channels and gullies increased whereas in June it rapidly decreased to almost zero in July (Fig 18) .

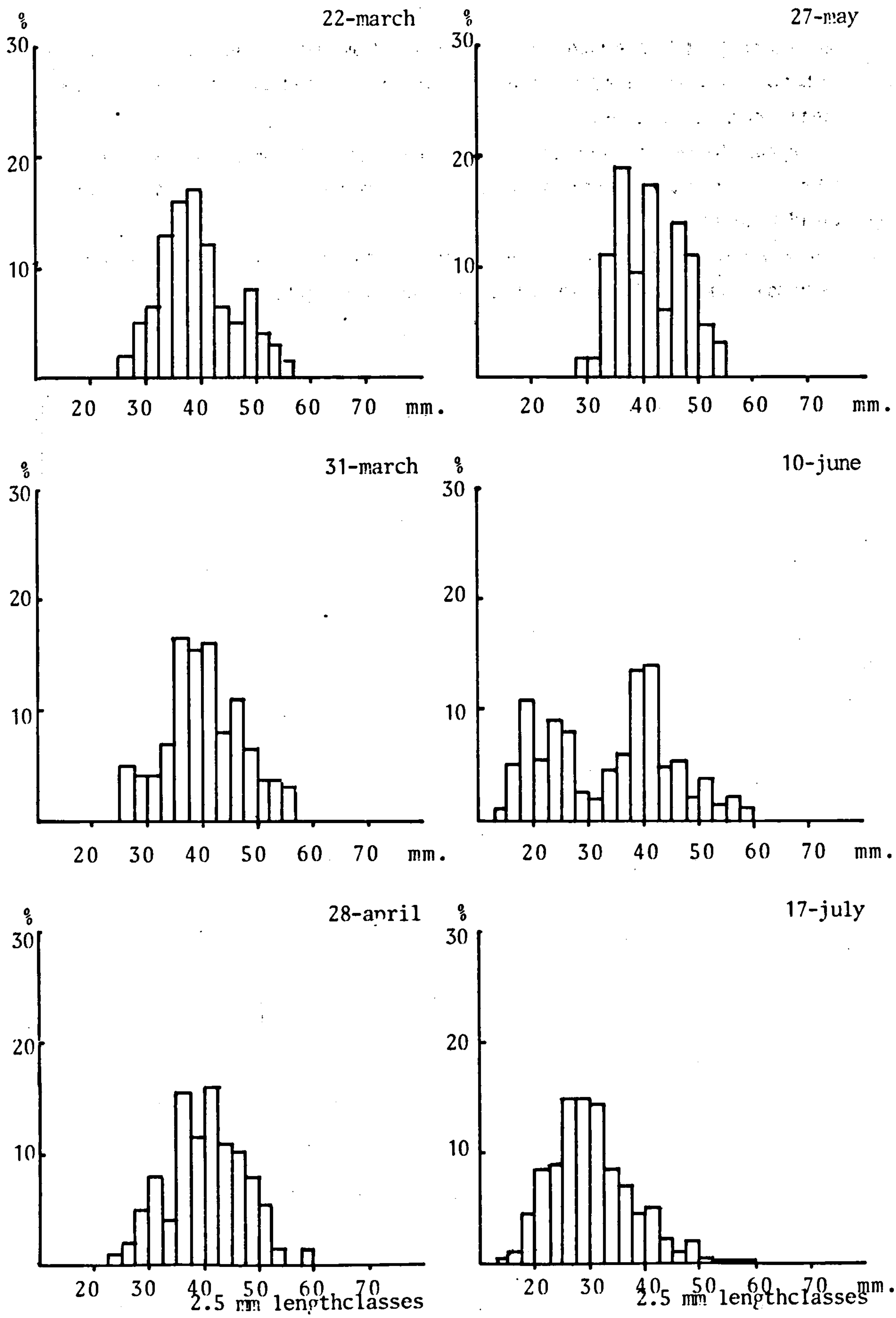

Figure 19 :Length distribution of P.pungitius from March to December, in the ditches of Texel.

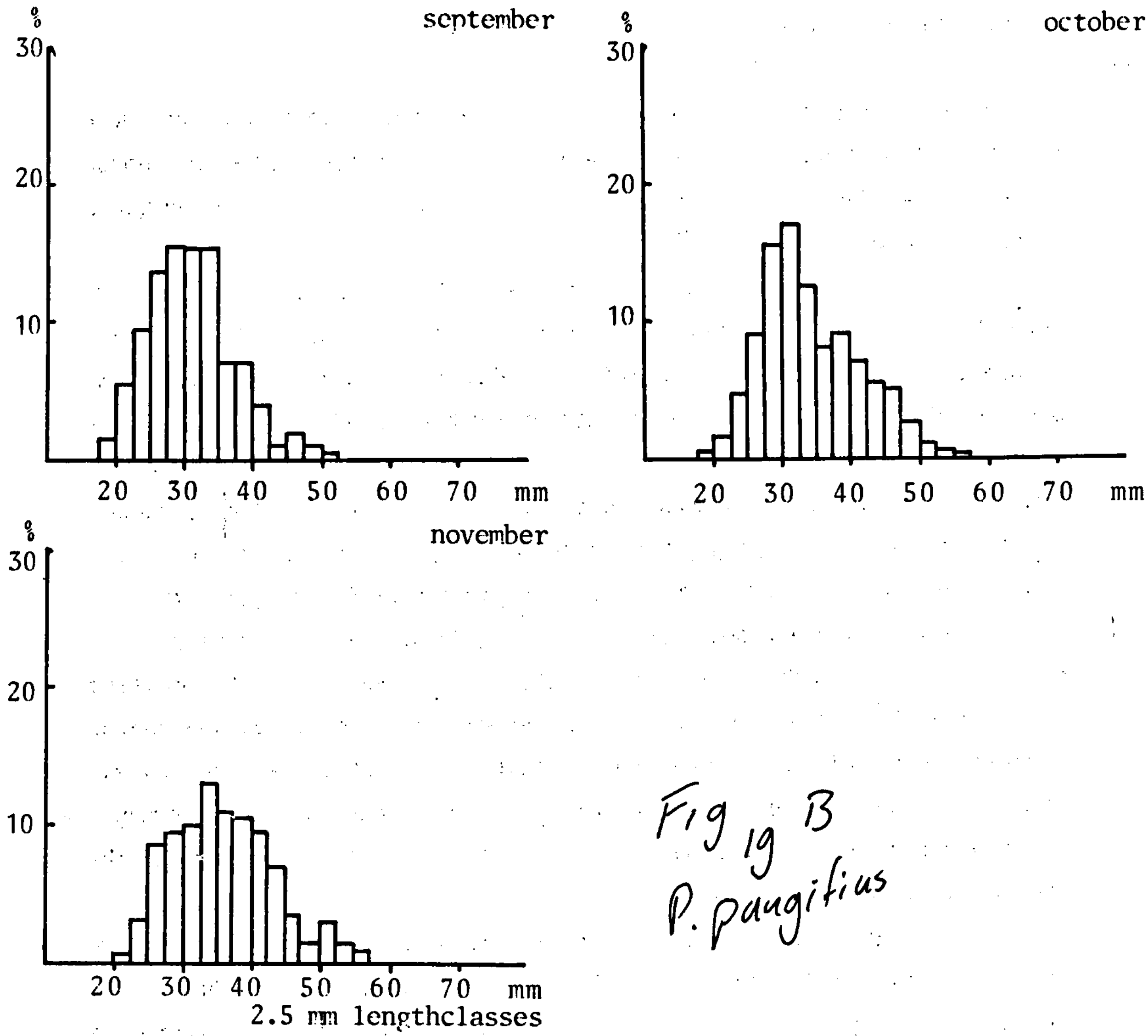

Fig 19 B
P. pungitius

	Waal		Eier		Noord		Drijvers	
16-31 March	0.13	0.04	0.15	0.25	0.77	0.94	-	0.91
1-15 April	1.07	0.39	0.14	0.42	1.42	1.05	-	4.32
16-30 April	0.91	0.40	0.17	0.20	1.82	0.37	-	5.42
1-15 May	0.91	0.52	0.11	0.16	1.35	0.20	-	5.40
16-31 May	1.00	0.72	0.09	0.18	1.11	0.33	--	3.59
	10-Sp	3-Sp	10-Sp	3-Sp	10-Sp	3-Sp	10-Sp	3-Sp

Gram/m^2, 10-Sp=P. pungitius, 3-Sp= G. aculeatus.

Table 7 :Biomass of G.aculeatus and P.pungitius in the various polders of Texel in the course of spring and summer.

Fresh water samples.

As shown, an important part of the prey caught in the freshwater areas consisted of fish. In almost all the sampled ditches on the island of Texel the ten-spined stickleback occurred. Only in the very wide ditches of the reserve "Drijvers Vogelweid" no ten-spined sticklebacks were caught .

In March most ten-spined sticklebacks (especially females) were found in shoals in the deeper parts of the ditches. The species is non-migratory (Jones, 1950; Wooton, 1976) and the only increase in density is found in Polder Het Noorden during the second part of March and the first half of April. This is probably due to a shift from the deeper parts to the shallow parts of the ditches. In these shallow parts they establish their territories in order to spawn. From 15 April onwards the densities hardly changed, so that the increase found in mean body length (Fig.19) is probably due to growth, rather than to new migration waves. At the beginning of June the young sticklebacks appeared in our samples while the number of adults decreased (van Wetten and Wintermans in prep.). The decrease is caused by the death of sticklebacks that have been engaged in spawning (Jones, 1950). Nevertheless, fully grown ten-spined sticklebacks of sizes varying from 37 to 45 mm. were still found in the ditches throughout the winter. The great similarity between the length distribution of sticklebacks caught in March and in October, indicates that the population on Texel is a closed, standing population, in which some sticklebacks reach an age of two or even three years.

Three-spined sticklebacks were found in smaller numbers then ten-spined sticklebacks in the polders Waalenburg, Eierland and Het Noorden. As the three-spined sticklebacks average much longer than the ten-spined sticklebacks their biomass per m^2 nearly equalled the biomass of the ten-spined stickleback (Table 7). In early spring the increase in biomass of three-spined sticklebacks occurred at the same time and in the same rate as the increase found for ten-spined sticklebacks. In March and early April large shoals were found in the deeper parts of the ditches (van Wetten and Wintermans, in prep.). Later, when territories were being established, they showed random distribution. In the beginning of June the first young appeared in our samples (Fig 20). As the adult sticklebacks gradually disappeared after spawning, only first-year sticklebacks were found in samples in November. As no adult sticklebacks were recorded in the deeper waters on Texel, it was concluded that they all died after spawning. The similarities between the samples of the ten-spined and the three-spined stickleback population made us conclude that the three-spined stickleback population is non-migratory as well. During winter and early spring three-spined sticklebacks must grow considerably. This is illustrated by the difference in mean length of the sticklebacks caught in March and November. Very high densities of three-spined sticklebacks were recorded at Drijvers Vogelweid (Tab 7). This

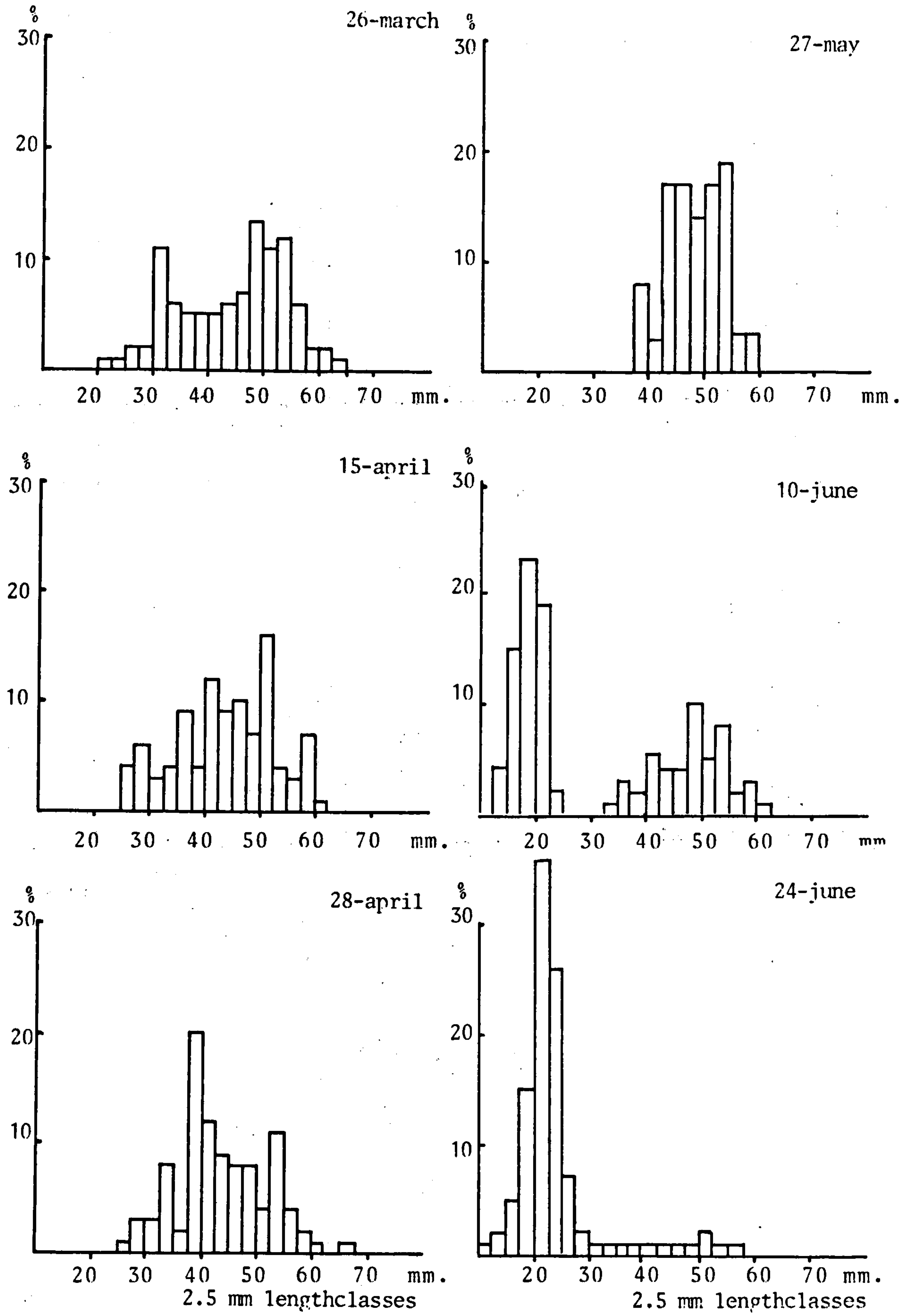

Figure 20 :Length distribution of G.aculeatus from March to December, in the ditches of Texel.

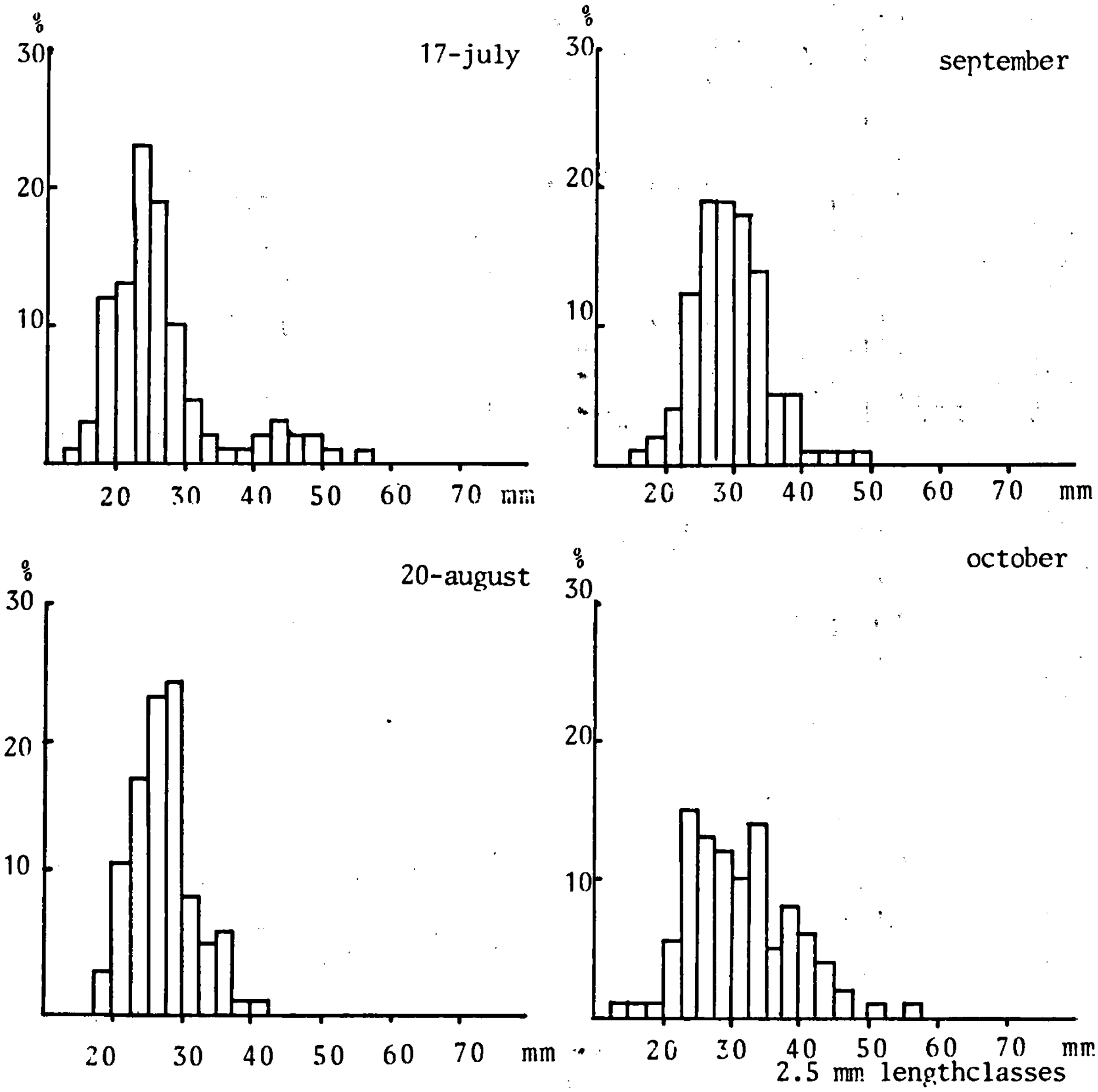

Fig 20 B
S. oculeatus

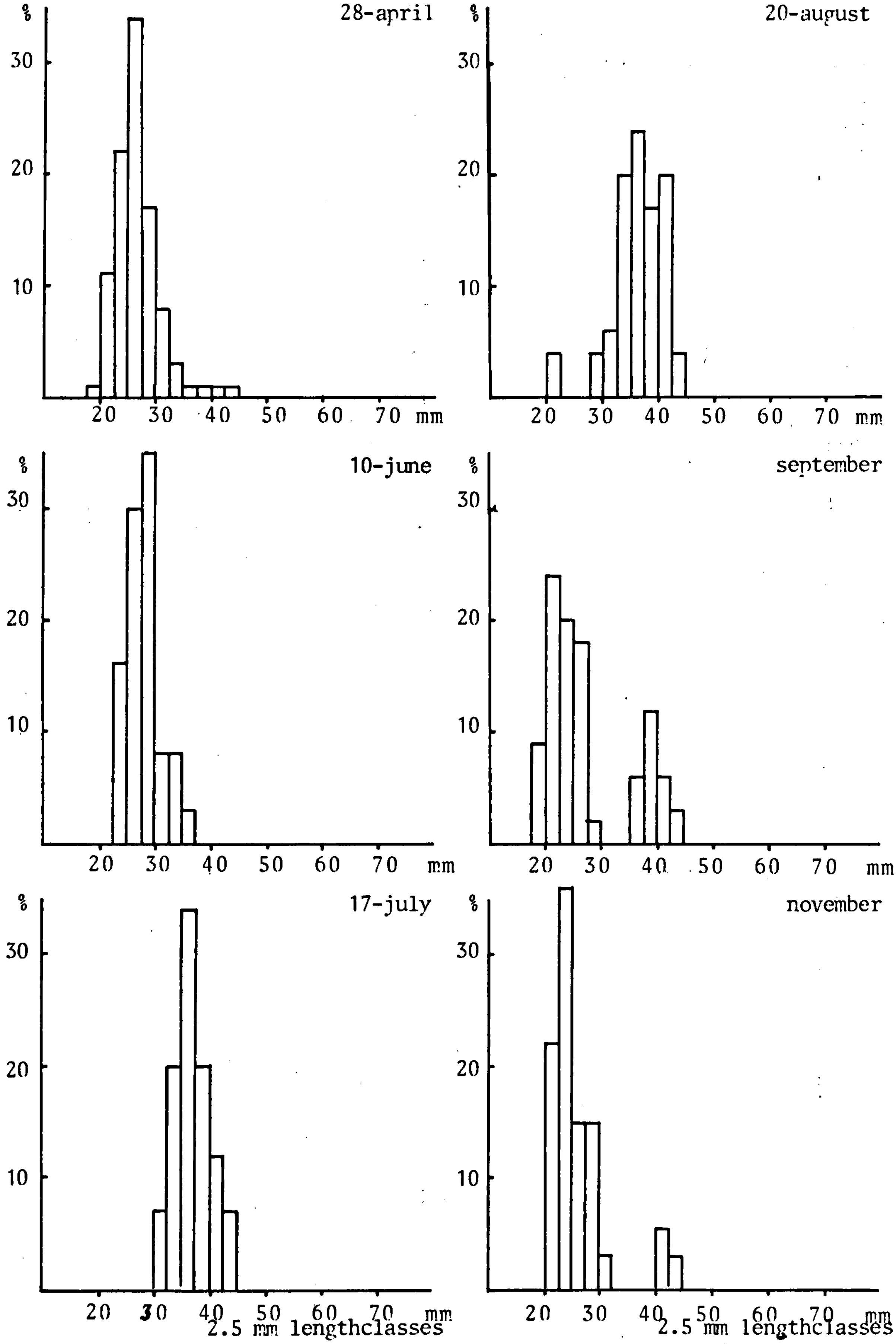

Figure 21 : Length distribution of G.aculeatus from March to December in"Drijvers Vogelweid".

small brackish water area contained a population of very small sticklebacks, which were significantly smaller than those from the other sampling areas on Texel (Kolmogorov, Smirnov X=290 p<0,001 for April; X=90 p<0,001 for November). The small sizes and the late spawning, at the end of August (Fig 21), indicate that these sticklebacks were not fully grown yet.

According to Baggerman (1957), Mullen, van der Vlugt (1964), and Wooton (1976), three-spined sticklebacks migrate from fresh waters to the North Sea in autumn. As shown by Mullen, van der Vlugt (1964), in the island of Tholen, three-spined sticklebacks, which cannot migrate to the sea and spend the winter in fresh or brackish waters, are remarkably smaller than the migrating sticklebacks that return the next spring. On the main land of North-Holland where migration is believed to occur, the mean length of three-spined sticklebacks is much larger than on Texel. As no direct evidence was obtained about invasions of numerous large sticklebacks in the ditches of Texel, it was concluded that migration did not occurred.

In recent years the water management of Texel has changed drastically. The old sluices through which the surplus of water was sluiced towards the sea during ebb and through which three-spined sticklebacks could move into the fresh waters, have been demolished. These sluices were replaced by siphon-pumps, which form an impregnable barrier for sticklebacks entering or maybe even leaving the fresh waters (pers. comm. mr. Vonk). Even when shoals or individuals from the sea reach the canals (as observed once) they cannot migrate much further as pour-overs of 30 to 60 cm. high are placed in the canals. Because the fresh water of Texel flows from the ditches via the canals to the sea, these pour-overs hamper migration towards the fresh waters of the smaller ditches.

In one distinct ditch prawns were caught in such densities that they formed a possible prey for spoonbill. These prawns represented a biomass of 2970 to 5100 mg. per m^2 in the period in which they formed an important prey for the spoonbill. Besides sticklebacks and prawns no other potential prey species were found in sufficient quantities to form a possible prey. A preliminary research in 1984 already showed, that other preys like Coleoptera, Corixidae, Notonectidae only represented a biomass of 55,6 to 135,9 mg. per m^2, a negligiable quantity compared with both stickleback species.

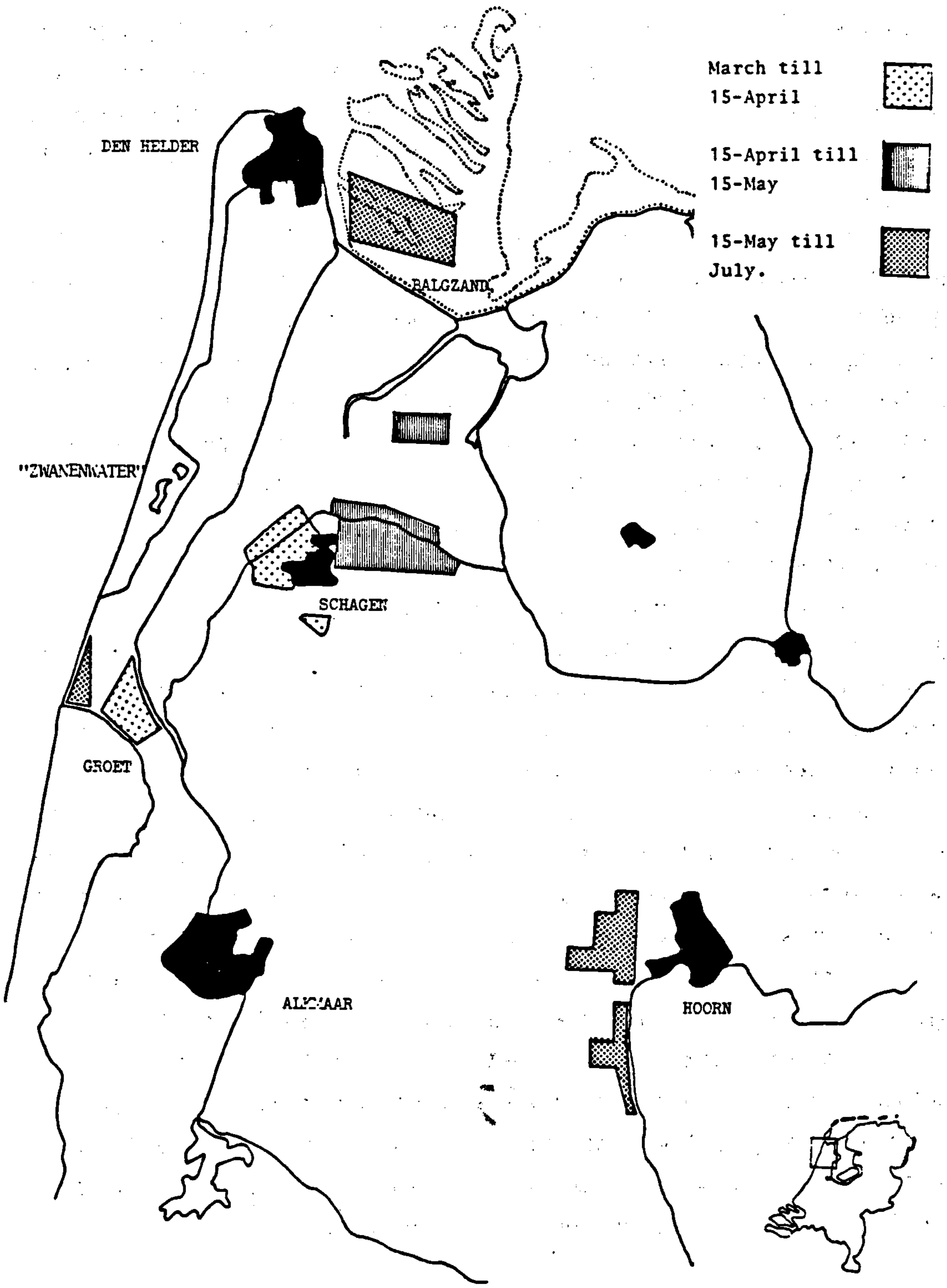

Figure 22 : Main foraging areas of the Zwanenwater colony during the breeding season of 1984.

Foraging areas of the Spoonbill.

The results of the census of foraging spoonbill from the Zwanenwater colony in 1984 revealed, that untill 15 May the spoonbill were found in the areas around Schagen (Fig. 22). In these areas sticklebacks were eaten almost exclusively, as other prey was not found in sufficient quantities to form a suitable source of food. After 15 May the decrease in biomass of large sticklebacks compelled the spoonbill to look out for other foraging areas like the polder near Hoorn, where young rudd and roach were caught, the tidal flats of the Balgzand, where the most probable prey is the brown shrimp, and the Ley-polder, where the prawn occurs in very large numbers.

In 1985 the results of the census carried out on Texel for the colonies of de Muy and de Schorren showed a similar pattern (Fig. 23). Untill the first of May the spoonbill foraged exclusively in freshwater areas, where sticklebacks and prawn formed the most important prey species. From the first of May onwards the number of spoonbill foraging on the tidal flats gradually increased. After 15 May the spoonbill were almost exclusively foraging on the tidal flats. As shown in chapter "Freshwater Samples" this shift is not caused by a decrease of biomass of suitable prey in the freshwater areas as was the case in the shift in the foraging areas of the Zwanenwater colony.

On the island of Texel itself we first found a shift in foraging areas in the second half of April from polder WaalenBurgh to polder Eierland. In the first half of April the foraging success in polder WaalenBurgh was high (Table 9). Despite the fact that the biomass of suitable prey did not decrease in the second half of April (Table 8) the spoonbill shifted to polder Eierland where the foraging success was much lower. In the second half of April however the waterlevel in polder Waalenburgh was raised from 10-20 cm. to 30-50 cm., which made foraging almost impossible for the spoonbill. In polder Eierland the waterlevel was kept lower and seldom exceeded 30 cm. This raise of waterlevel in the ditches of polder Waalenburgh probably compelled the spoonbill to leave this profitable foraging area.

At the end of April and in the beginning of May also polder Eierland became unsuitable for foraging. The excessive growth of reeds *Phragmites australis* in the ditches made foraging almost impossible and forced the spoonbill to shift to another foraging area once again. During this period only two other places in the freshwater areas remained suitable for foraging and were frequented. These places were the little reserve Drijvers Vogelweid and one distinct ditch, near Drijvers, both in polder "Het Noorden". From the beginning of May onward the availabillity of food on the tidal flats (c.q. brown shrimp) increased and in the second half of May the foraging circumstances were better then in the freshwater areas. In this period the spoonbill gradually shifted their foraging activities to the tidal flats.

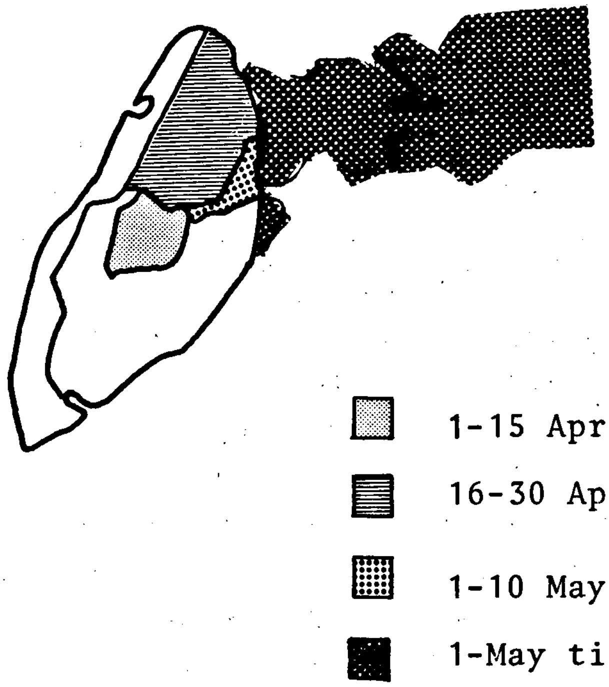

Figure 23 : Main foraging areas of the Muy and Schorren colonies on Texel during the breeding season of 1985.

Biomass of Sticklebacks in g/m^2

	Waal	Eier	Noorden	Drijvers
15-31 March	0.172	0.401	1.715	0.910
1-15 April	1.375	0.561	2.472	4.324
16-30 April	1.303	0.378	2.198	5.427
1-15 May	1.430	0.275	1.563	5.395
16-31 May	1.725	0.277	1.442	3.588

Table 8 : Biomass of suitable prey (G.aculeatus and P.pungitius) in the ditches of Texel.

During the summer the spoonbill showed a remarkable distribution-pattern on the tidal flats (Fig. 24). In May they were mainly found in the channels and gullies, whereas in June and July they were mainly foraging on the mussel beds and the sandy flats. This shift may have been caused by the explosive growth of algae and weeds on the sandy flats in June. These huge quantities of vegetable material prevented water from flowing to the channels and gullies during low tide, thus creating numerous pools. These pools of about 15 cm. deep formed suitable foraging places for spoonbill. The main reason for this shift probably is the presence of second-year shrimp (of 30 mm. or more) in the channels and gullies during May and the first half of June, and the increase of shrimps of catchable size on the sandy flats and the mussel beds in June and July. Therefore it is concluded that the presence of spoonbill in the various units on the tidal flats is closely related to the presence of large shrimps of 30 mm. and more.

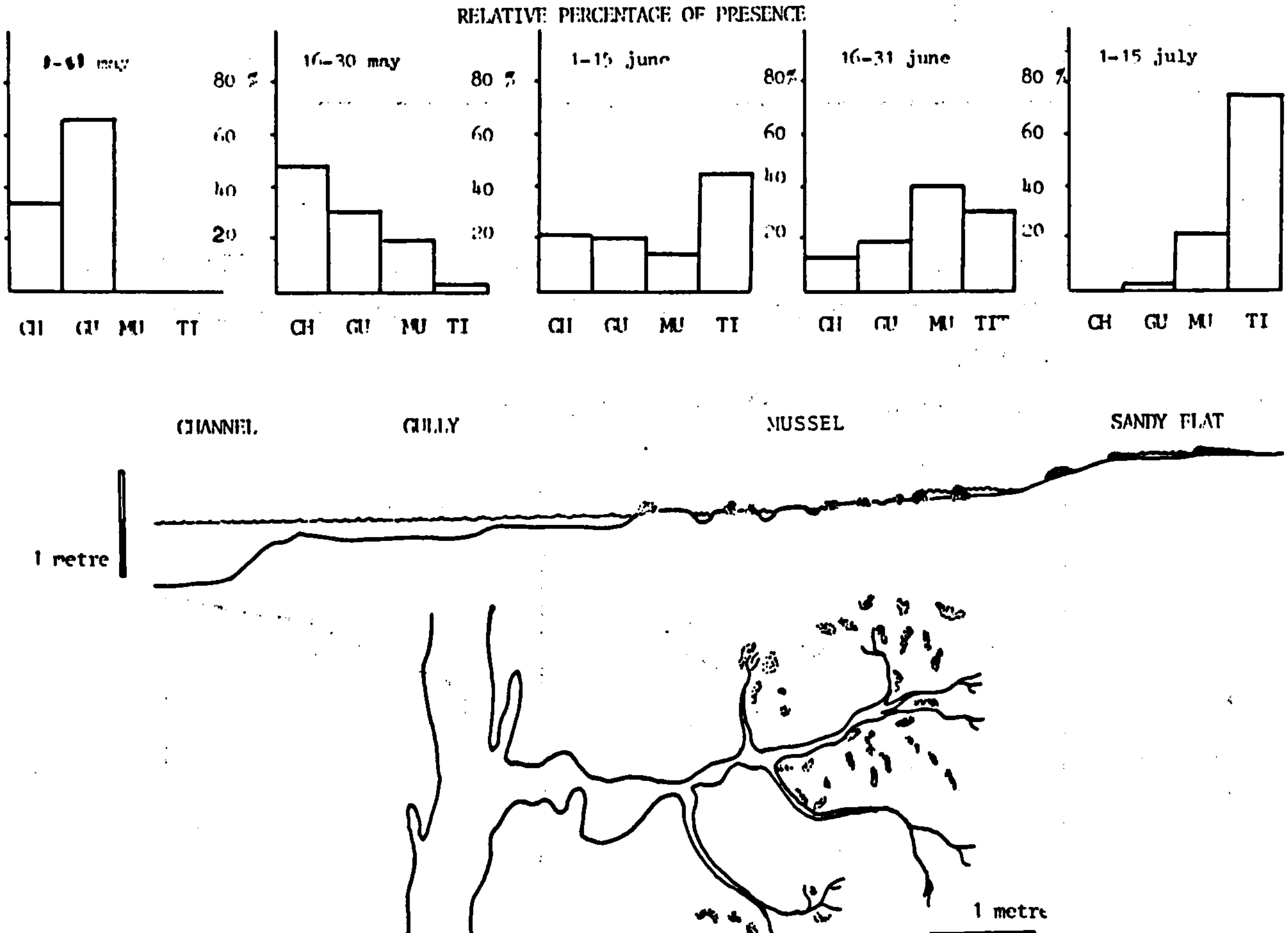

Figure 24 : Relative prescence of spoonbills,during the breeding season of 1985 in various areas on the tidal flats of Texel, including a schematic cross-section of the study area. CH=Channel, GU=Gully, MU=Mussel, TI=Sandy flat.

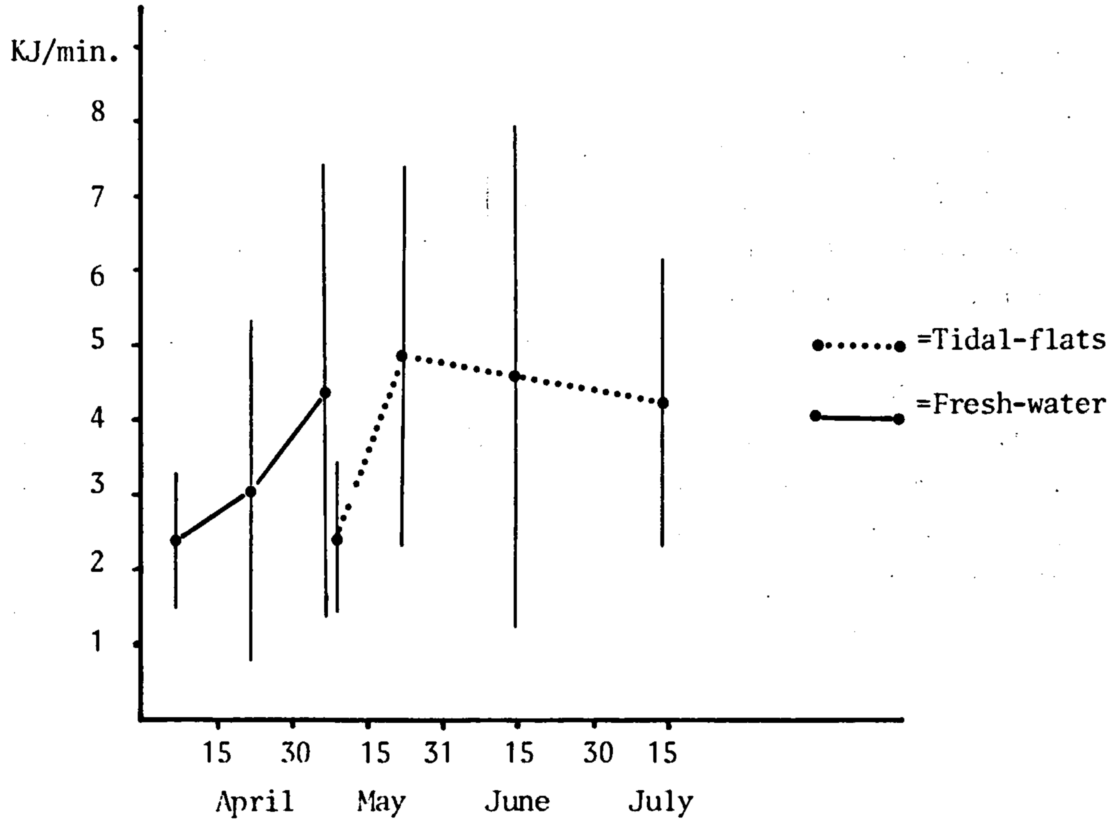

Figure 25 : Foraging success (Net energy intake) of the spoonbills of the Muy and Schorren colonies during the breeding season of 1985.
(Vertical bars indicate standard deviation).

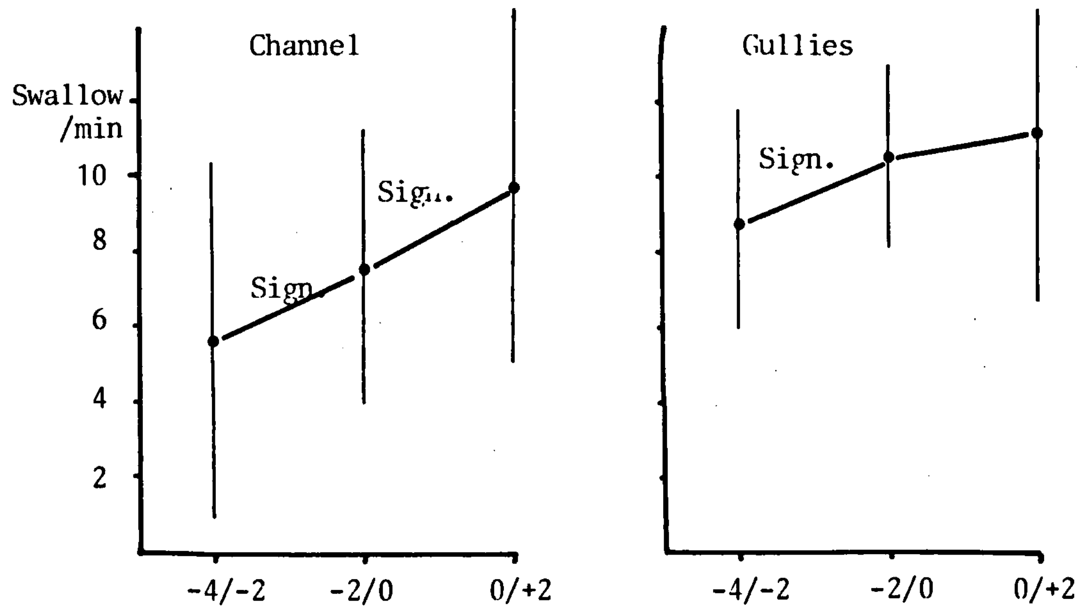

Figure 26 : Rate of prey capture in Channel and Gully during the course of the low tide, expressed as hours before or after the lowest water.

Foraging success.

At the start of the breeding season in April, spoonbills from the "Muy" foraged in fresh water areas. Here the foraging success was quite low (Fig 25) and increased only towards the beginning of May. In April spoonbills mainly fed on the two stickleback species while in the first half of May the prawn *Palaemonetes varians* became an important prey species.

Before May spoonbills were not seen on the tidal flats. From the second half of May onward they foraged almost exclusively on the tidal flats. During the second half of May the food intake on these tidal flats equalled the food intake in the freshwater areas. When the spoonbills shifted their foraging activity toward the tidal flats the shrimps became the most important food item of the spoonbill.

While foraging in the fresh-water areas in April, the spoonbills shifted their foraging activity from Waalenburgh to polder Eierland. It was remarkable to see that the foraging success became significantly lower after this shift, (MWU-test, n=6, n=8 ,U=8, $p<0.05$), (Table 9). At the beginning of May, the spoonbills concentrated their activity in the polders Het Noorden and Drijvers, where prawns and three-spined sticklebacks were eaten. During this period their food intake increased and became significantly higher then during the previous periods in April, when the spoonbills were foraging in Waalenburgh and Eierland, (MWU-test,n=13,n=11,U=35,$p<0.05$).

The foraging success of the spoonbills increased steadily through April and May (Fig 25),(MWU-test, n=13, n=11, U=35, $p<0.05$), due to an increasing foraging success in the fresh water areas from April towards May and on the other hand an increase of the foraging success on the tidal flats during May (MWU-test, n=6, n=40, z=2.2, $p\leq 0.05$, 1-15 May compared with 16-31 May). From early June towards July the foraging success on the tidal flats decreased slightly but not significantly and it seemed that at the end of May and the beginning of June the foraging circumstances on the tidal flats were optimal.

In May and June the foraging success in channels and gullies (Fig 26) on the tidal flats increased significantly during the course of the ebb, (MWU-test, z=1.34, $p<0.03$ one tailed, -4/-2 compared with -2/0 hours before the lowest tide) and (MWU-test, z=1.52 $p<0.06$ one tailed, -2/0 compared with 0/+2 after the lowest tide). In July the foraging success in gullies and in small streams between the mussel beds increased significantly during the course of the tide, (MWU-test, z=1.84, $p<0.03$ one tailed, -2/0 compared with 0/+2 hours before and after the lowest tide) respectively (MWU-test, u=2 ,$p<0.01$ one tailed).

In contrast with the channels, gullies and little streams the foraging success on sandyflats and mussel beds showed no increase (Fig.27) but even decreased significantly in the course of the ebb, (MWU-test, z=3.54, $p<0.02$ two tailed, -4/-2 compared with -2/0 hours before the lowest tide).

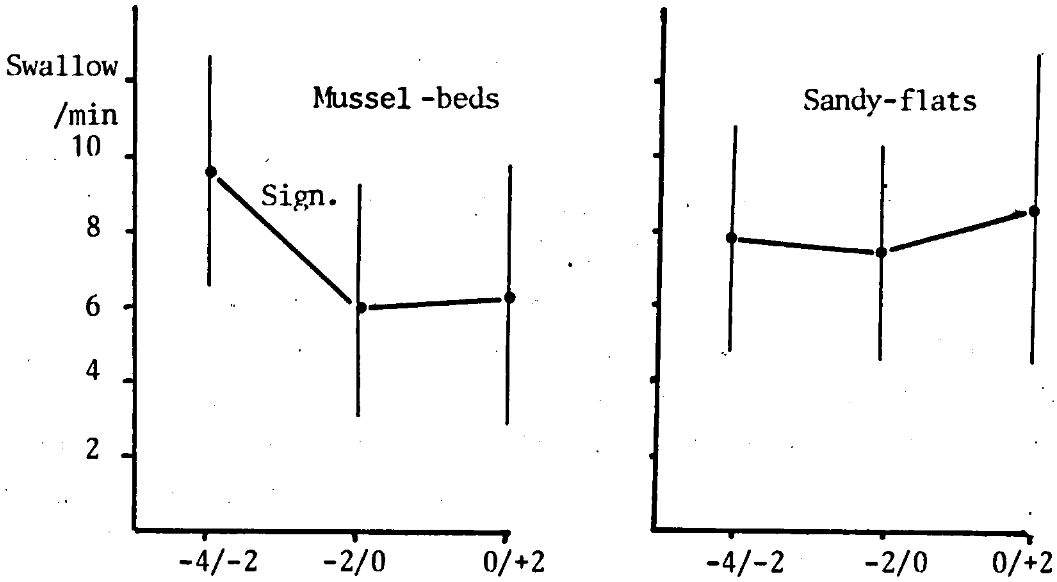

Figure 27 : Rate of prey capture in Mussel and Sandyflats during the course of the low tide, expressed as hours before or after the lowest water.

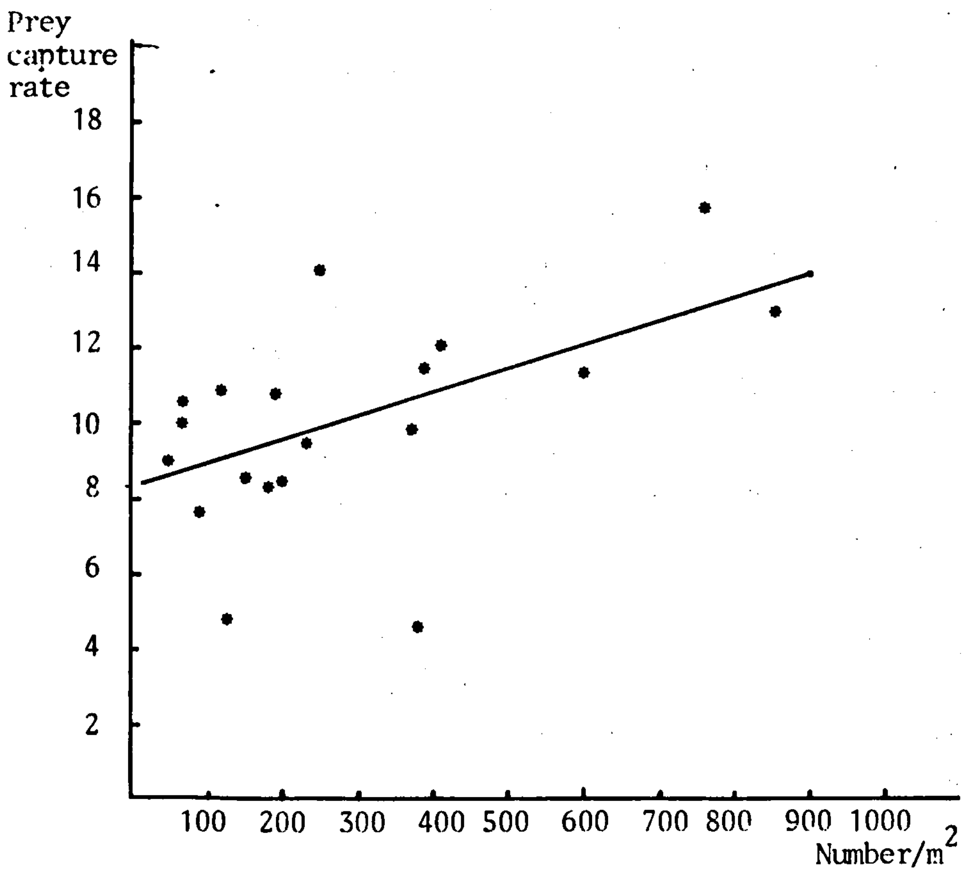

Figure 28 : Correlation between rate of prey capture and prey density of C.crangon on the tidal flats.
(Y = 6.34. 10 exp. -3X + 8.32: R + 0.46, N = 21, $p \geqslant 0.05$ two tailed).

Comments: The foraging success of the spoonbills on the tidal flats is related to the density of shrimps ($N=9$, $R=0.89$, $p \leq 0.05$, $Y = 0.139x = 51.6$), (Fig.28). As shown by Janssen and Kuipers (1980), some 1.5 % of the shrimps which are present close to the edges of channels and gullies, are moving into the channels and gullies, during the ebb period. This movement causes a threefold increase of numbers per m^2. The higher foraging success of the spoonbill in the course of the ebb period in small streams, gullies and channels is caused by the accumulation of shrimps living near the edges of these streams. On the sandy flats and mussel beds hardly any migration of shrimps exists, because all shrimps bury themselves some millimetres in the mudd and sand. So, the density of shrimps on the mussel beds and sandy flats does not change during the tidal cycle.

Spoonbills foraging on the sandy flats and mussel beds always walked through the shallow streams and pools where shallow water remained. On flats with no relief where no water remained during the ebb period spoonbills were never seen foraging. Although the density of shrimps is quite high (up to 18-20) individuals per square metre, (Kuipers and Dapper 1981)), the spoonbills cannot grasp the shrimps out of the mud and sand. This is in contrast with places where some 10-30 centimetre water remaines. At these places shrimps can be detected with the eye, swimming around freely.

In fresh water areas the foraging success of spoonbills is influenced by the prey density. This is shown by a rare occasion, when a flooded meadow of some 10 ha in WaalenBurg that was drained contained a very high density of ten-spined sticklebacks which were trapped in the remaining pools. The spoonbills were foraging very successfully in these circumstances which only lasted two days. The low foraging success of the spoonbills in Eierland in the second half of April was caused by the very low density of sticklebacks in this polder.

When we compare the foraging success of the spoonbills from the Zwanenwater colony in 1984 with that of the spoonbills from Texel in 1985, we see that in the polders on the mainland of North-Holland the foraging success is significantly higher than on the island of Texel, 8.1 ±3.6 KJ/min respectively 3.4 ±2.5 KJ/min. (MWU-test, $n=19$, $n=29$, $z=3.81$, $p<0.04$ two tailed). The swallow frequency of the spoonbills foraging on both the mainland of North-Holland and on the mainland of Texel did not differ significantely. Consequentely the difference in foraging success must be caused by the lower energy content of the prey swallowed on Texel. The fact that the sticklebacks in the ditches of Texel are on average smaller supports this idea.

FORAGINGSUCCES IN KJ/MIN.FORAGINGTIME

	NESK	KAAG	WIEW	HOOR	TID	WAAL	EIER	NOOR	DRIJ
1-15 April	6.4					2.8	2.3		
16-30 April	12.7						2.1	5.6	
1-15 May		8.1	5.3		2.4			4.5	4.5
16-31 May			3.8	16.5	4.8				2.2
1-30 June			14.1	16.5	4.6				
PREY	STI	STI	STI	WHB	SHR	STI	STI	PRA	STI

STI=STICKLEBACK
WHB=WHITEBAIT
SHR=SHRIMP
PRA=PRAWN

NESK=NESKAAG POLDER
KAAG=KAAG POLDER
WIEW=WIERINGERWAARD
HOOR=UOORN
TID =TIDAL FLAT
WAAL=POLDER WAALENBURGH
EIER=EIERLANDS POLDER
NOOR=POLDER HET NOORDEN
DRIJ=DRIJVERS VOGELWEID

Table 9 : Foraging success (net energy intake) of spoonbills
- left = the mainland of North-Holland
- centre = the tidal flats of Texel
- right = the mainland of Texel

DISCUSSION

Food

According to Olney (in Cramp et al., 1977) the food of the spoonbill *P.leucorodia* consists of aquatic insects and their larvae, molluscs, frogs, tadpoles, worms, leeches, reptiles, and fishes. In the Netherlands the food consists mainly of three-spined and ten-spined sticklebacks, shrimps, prawns, aquatic insects, and their larvae (Poorter, 1979). The stomach of a spoonbill found on Texel in the summer of 1934 contained 100% shrimps (Tinbergen, 1934). Stomach contents of spoonbills found in the Waddensea area and on the English coast in September mainly consisted of three-spined sticklebacks and young flounders. Allen (1942) analysed the stomach contents of the Roseate spoonbill *Pl. ajaja* and ascertained that some 62 % volume consisted of fishes,some 20% of crustaceans and some 14 % of insects.

According to Vestjens (1974) the stomachs of the Yellow-billed spoonbill *P. flavipes* contained 42-65 % of insects by volume, 21-39 % of crustaceans and only some 14-19 % of fish, while the stomachs of the Royal spoonbill *P. regia* contained some 42 % of fish, 30 % of insects and 25 % of crustaceans.

Sampling in the foraging areas of the dutch spoonbills from the Zwanenwater Muy and Schorren colonies showed that small fishes like ten- and three-spined sticklebacks, rudd and roach, together with prawns were the main prey species for spoonbills. The low energetic content of the various Coleoptera,Notonectida and Corixidae species and the low density in which these species occure make them unsuitable as potential prey species for the spoonbill.

Other Spoonbill Species.

Most spoonbills species of the world forage in both fresh- and salt water habitats. Only *Platalea minor* in China and Korea is known exclusively from fresh water marshes (Etchecopar and Hue,1978). *Platalea alba* which breeds in many places in Africa south of the Sahara, is found in coastal waters as well as in rivers, lakes, and marshes (Moreau, 1966 ; Brown and Urban 1982). *Platalea flavipes* is mainly found in fresh water lakes, but is occasionally seen in coastal waters. This in contrast with *Platalea regia* which breeds near the coastal waters of New Zealand, Australia and Indonesia (Billing ,1977) and *Platalea ajaja* in America whichs breeds near lagoons and salt water marshes along the coast of the Carribbian Sea and the Pacific. Sometimes the latter spoonbill is found in the upper reaches of big rivers or near fresh water pools (Allen, 1942).

In India, Kazakhstan, Austria, Greece, Yugoslavia, Turkey, and China the spoonbill *PLatalea leucorodia* breeds only in freshwater areas. In Sri Lanka, Iran, Sovjet Union, Spain, and the Netherlands the spoonbill breeds near coastal waters and estuaries. In Spain and Sri Lanka where spoonbills are both breeding and foraging in salt water and fresh water areas, the spoonbills shift their foraging activity from the salt water areas towards shallow fresh water areas when they are flooded and high fish densities occur (Own observ.). The impression exists that the foraging of spoonbills in fresh water areas depends on the high fish densities in flooded areas or semi permanent pools.

The wintering grounds of the spoonbills from the Balkan and the Sovjet Union are the freshhwater marshes of the Soedan (pers. comm. G.Nikolaus,1985). This in contrast with the wintering areas of the spoonbills from the West European population which use the coastal waters of Mauritania and Senegal (Poorter,1982).

The agricultural activity of man in Holland has created huge surfaces of artificial shallow waters. The many ditches with high fish densities formed a favarouble foraging area for the spoonbill. As other potential preys like shrimps, gobies and plaice are not available in early spring, the early precence of sticklebacks in the fresh water areas enabled the spoonbill to start breeding already in March or April. The profitable foraging circumstances in the farmland of North-Holland and South-Holland probably have been the main reason for the thousands of breeding pairs of spoonbills present in the Netherlands in the past.

Biomass and carrying capacity.

In a previous chapter it has been shown that in the fresh water areas in April, the rate of pry capture varies between 1.5 and 2.0 per minute. Assuming that spoonbills spend some 6-8 hours a day foraging it is computed that one spoonbill swallows about 540 to 960 prey items daily. In case of the Muy colony where some 50 adult spoonbills are present, the total daily consumption of the colony lays somewhere between 27.000 to 48.000 prey items a day, or 810.000 to 1.440.000 prey items a month.

According to the calculations of King (1978) the daily consumption of a spoonbill must be close to 410 gram of fish per day. This means a monthly consumption of the total colony of about 1.232.200 sticklebacks. This value lays within the range of the previous computation.

On Texel the length of shallow ditches was measured to be about 858 km in which approximately 2.000.000 sticklebacks were living. This means that if our density computions of sticklebacks are right, some 41 to 72 % of the total stickleback population has been consumed by the spoonbills in one month. As in April and May no decline in densities of adult sticklebacks was observed in our samples a gradual influx of sticklebacks from deeper parts of the fresh water must have occurred.

During the breeding season not all ditches are suited as a foraging ground for the spoonbill. Consequently the number of available prey during t must have be lower then computed. Further research much point out when and where the spoonbills face a shortage of available fresh-water prey.

Food availability and breeding season.

The start of the breeding season of spoonbills seems synchronized with the food availability in their foraging areas. According to Scott (1984) and Kahl (1969) initiation and success of nesting Wood storks *Mycteria americana* is related to the seasonal fluctuations of the water level in the foraging areas. The period of maximum food requirements during the pre-fledgling period coincides with minimal water level in the marshes (Scott, 1984) (Kahl, 1969). The declining water level increases availability of food (fish) The Grey heron *Ardea cineria* synchronises its breeding period with maximum fish densities in rivers and lakes during the pre-fledgling period aswell (Owen, 1959).

The Dutch spoonbills of the Naardermeer and Zwanenwater colonies start breeding in April (pers.comm. W. Klomp; own observ; and Poorter , 1979). The spoonbills of the Muy on Texel start breeding in the first week of April. Till the second half of May the spoonbills of these three colonies are mainly foraging on sticklebacks. The early start of the breeding period of these colonies coincides with the growing availability of sticklebacks in the ditches between the end of March and the beginning of April.

In the colonies on the islands of the Waddensea, except for the Muy, the spoonbills start breeding at the end of April or during the first weeks of May. This slightly retarded start is probably initiated by the growing food availability on the tidal flats. When, after approximately 24 days (Cramp et al,1977), the first young appear in the second half of May and the beginning of June, food supply on the tidal flats has increased strongly (Kuiper and Dapper,1981).

Information transfer and colony size.

Compared with the Waddensea colonies the mainland colonies the Zwanenwater and the Naardermeer are far larger. Only the colony the Muy on Texel which contained 110 and 150 breeding pairs in 1938 and 1953 respectively (Brouwer,1964) forms an exception. As is shown in this paper the spoonbills of the Muy like those of the colony the Zwanenwater and Naardermeer, are mainly foraging on sticklebacks.

The size of the colony can play an important role in the information transfer (Ward and Zahavi,1973,). Krebs (1973) made clear that the information transfer in a colony of Great-blue herons *Ardea herodias* was necessary for the exploitation of high fish densities which occured irregularly in time and space.

On the mainland of North-Holland it is often seen that spoonbills forage in flocks while hunting fishes. When leaving the colony as a group the spoonbills sometimes show a distinct flight-display which might play an important role in the information transfer (van Wetten, 1985). Leaving the colony in groups can produce a higher foraging success for each of the members of the group as patchily distributed preys are more easily found and caught when the birds are foraging in flocks (Evans ,1982). Spoonbills foraging actively and gaining a high foraging succes often attract other spoonbills flying over. The very conspicuous white plumage probably plays an important role in this gregarious behaviour (Kushlan, 1977).

As shown by Kemper (1986) sticklebacks, rudd and roach occur in aggregations rather than being randomly distributed. This in contrast with the distribution of shrimps on the tidal-flats during low tide. The densities of shrimps in the gullies and mussel beds can be very different but are always very high. In the gullies and mussel beds themselves densities do not vary much. As at every ebb period the highest densities of shrimps are always found in these gullies and mussel beds the spoonbills do not have to search for the best foraging spots. In this case information transfer is not be very useful. At the end of the summer spoonbills sometimes were seen hunting plaice or smelts *Osmerus eperlanus* in groups of 10-20 birds. The group clumped together when some of the spoonbills were foraging succesfully, but spaced out after a few minutes probably when the shoal of fishes has disappeared. (This pattern was also observed in sandwich tern *Sterna sandvicensis* (Veen, 1980). This foraging behaviour was only observed at the end of the breeding season when the spoonbills hardly visited the colony anymore.Therefore there are no reasons to believe that while the birds are foraging on the tidal flats, the colony plays an important role in the information transfer. Assuming that the mainland colonies are more numerous because of the advantage and need of information transfer in freshwater areas, the relatively small size of the Waddensea colonies could be explained by the absence of this advantage and need.

Foraging range and settlement of new colonies.

Long foraging flights made by spoonbills are often observed (Poorter ,1979 ; van Wetten ,1984).Also other piscivorous colonial bird are known to make long foraging flights. (Brouwer ,1936) recorded flights of 25 km made by *Ardea cinerea* in order to reach the foraging areas. Of the wood stork it is known that very long flights of more than 70 km are being made (Kahl ,1969).

According to Tucker (1974) the energy costs of a spoonbill flying at a speed of 60 km/hr (Manneveld,1983) is about 11.5 Kj / km. When we combine this calculation with the average food-intake(390 Kj/hr) and the time spent on foraging (8hr), the maximum flight distance of a spoonbill can be computed. A spoonbill with chicks needs about 5.1 hr to gain its DME (Drent,1980). Assuming that the maximum foraging period is about 8 hours, this means that 2.9 hours can be spent on flying to the foraging area and compensating the costs of flight. Taken into account the duration and costs of flight the maximum foraging distance turned out to be 31.5 km.

When we assume that a spoonbill is foraging 9 hours a day its maximum foraging range is about 42.5 km. It was concluded from their daily activity pattern that spoonbills forage for approximately 8 to 9 hours aday. This means that no exceptional long forage flights can be made

The maximum distances at which spoonbills from the various colonies are actually found foraging do not exceed 40 km. In 1984 it was observed that the spoonbills from the Zwanenwater, Naardermeer and Oostvaardersplassen foraged near Hoorn which lays respectively 38.4, 30.0 and 33.0 km away from the colonies. Spoonbills from the Oostvaarderplassen are foraging on Kamper-eiland also some 30 km away from the colony. Therefore it is very unlikely that spoonbills of Terschelling forage in the Lauwerszee as is believed by some people. The distance between the colony and this area is about 50 km. Also spoonbills of the Naardermeer colony will probably not go to the Balgzand area wich lays at a distance of some 72 km.

When the spoonbills of the colony the Muy colony face a shortage of foraging possibilities in the fresh water areas in the future, they will have to fly 33 km in order to reach the nearest fresh water foraging area on the mainland of North-Holland. This is close to their maximum flying distance. We believe that the fresh water areas on the mainland cannot compensate for the loss of fresh water foraging areas on Texel. When in the near future, the area near Hoorn is no longer suitable for spoonbills of the Zwanenwater colony, the spoonbills will have to fly some 37 km to reach the nearest suitable fresh-water foraging area in the Zaanstreek.

It is obvious that when spoonbills want to compensate the loss of their present freshwater foraging areas they have to fly close to their maximum range in order to find good foraging areas. On the other hand it is clear that the Balgzand area which lays only at some 15 km distance of the Zwanenwater colony can form a suitable alternative for the lost areas near Hoorn.

Research carried out by the NIOZ (Kuipers and Dapper, 1981) on shrimps and plaice populations in the Waddensea showed that the western part of the Waddensea contains the highest shrimp and plaice densities. Especially the tidal flats of the Balgzand and the Vlakte van Kerken east of Texel are very rich. At the moment some 70 % of the spoonbills breeding on the Waddensea island use these two areas for foraging. As is shown on Vlieland and Texel new colonies can quite easily be formed in locations near these tidal flats that are suited as a breeding place. For instance the Robbenoordsbos near Wieringen and de Makkumerwaard near Harlingen might form such a suitable breeding location for the spoonbills in the near future.

Bottleneck and deterioration of foraging areas.

As pointed out in previous chapters, the fresh water foraging areas on the mainland of North-Holland are quite profitable. It was shown in 1984 that until the second half of May the spoonbills from the Zwanenwater colony foraged in the polders near Schagen. In the second half of May the biomass of adult sticklebacks in the small ditches decreased drastically which caused the spoonbills to shift to the polders near Hoorn. During the last years however, the foraging area near Hoorn has been deteriorating due to changing agricultural activities. As no other foraging areas are at hand within the range of the Zwanenwater colony the spoonbills are compelled to go to the Balgzand. Until 1983 no spoonbills were seen on the tidal flats of the Balgzand before the end of July (pers. comm. mr.Otter), while during the last years a growing number of spoonbills have been observed on the Balgzand already in May. During various ebb periods in 1984 we observed some 25 birds. In 1985 this number increased to about 50 birds which came for a substantial part from the Zwanenwater colony, where at that momemt some 70 pairs were breeding. It is obvious that the growing number of spoonbills on the Balgzand synchronises with the deterioration of the polders near Hoorn.

The spoonbills of the Muy colony do not face a decline in fish densities in the course of May and June. Vegetation growth and rise of water level in ditches however, forces them to shift to the tidal flats. Foraging succes in the fresh water areas of Texel is very low compared to the mainland of North-Holland. Therefore spoonbills of Texel probably shift their foraging activity to the salt water areas. This may explains the declining number of spoonbills breeding at the Muy colony during the last 4 years (Tab 10) and the growing number breeding at the Schorren.

When in the near future the foraging areas near Schagen will disappear due to modernisation of the farmland, the spoonbills of the Zwanenwater, again, will lose one of their main foraging areas. This area is important during the second half of April and the first half of May, because in this period the tidal flats of the Balgzand do not offer adequate foraging circumstances. If in the near future no measures are taken to protect these polders, the Zwanenwater colony will seriously be threatened. In case of further deterioration of the fresh water foraging areas, one may expect the spoonbills to start breeding later in the season in order to synchronize their breeding activity with the food availability on the tidal-flats. Another possibility is that they leave the colony and start breeding in an area much closer to the tidal flats.

Year	TERSCH.	de MUY	de GEUL	SCHORREN	VLIELAND	Percentage of Dutch population
1963	8	75	11			24
1964	7	75	13			36
1965	9	40	13			28
1966	10	35	7			23
1967	9	25	10			22
1968	10	16	7			21
1969	8	19	8			23
1970	10	20	10			19
1971	12	22	12			28
1972	15	30	12			26
1973	8	27	11			19
1974	14	28	11			25
1975	14	25	7			25
1976	15	29	6			27
1977	10	30	5			20
1978	15	28	7			25
1979	19	34	12			36
1980	19	36	8			34
1981	22	39	8			31
1982	29	41	7	3		36
1983	27	36	6	4	3	33
1984	35	35	8	16	10	38
1985	30	22	8	22	20	37

Table 10 : Number of breeding pairs in the various colonies on the Waddensea islands.

Growth of the Waddensea population.

Fig. 29 shows the increase of the spoonbill populations of the Waddensea islands and of the two largest mainland colonies. The Waddensea population forms an important and growing part of the Dutch population. It is remarkable that the number of breeding pairs of 1984 and 1985 exceeds the number of pairs breeding on the islands before the pollution with chlorinated hydrocarbons from 1960 to 1970 caused a fall in numbers. This in contrast with the numbers of breeding pairs in the Zwanenwater and Naardermeer colonies, which at present contain some 100 pairs less than in 1963.

The changes on Texel where the spoonbills from the Muy colony shift their foraging activity more and more towards the tidal flats and the increasing number of spoonbills of the Zwanenwater colony at the Balgzand indicate the growing importance of the tidal flats of the Waddensea as a foraging area for the Dutch spoonbill population.

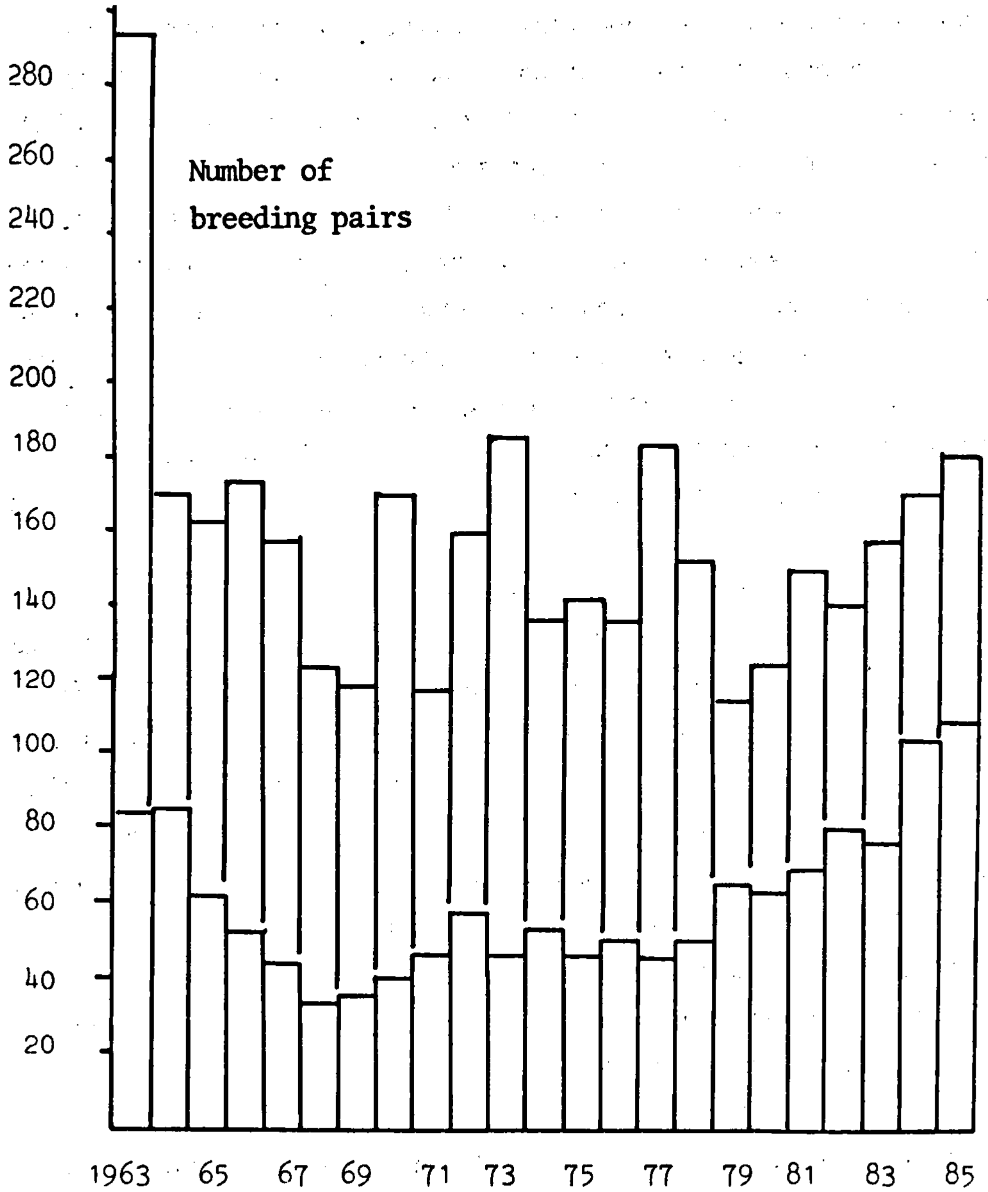

Figure 29 : Number of breeding pairs in the last 25 years in Zwanenwater and Naardermeer colonies = above,, and in Waddensea-island colonies = below.

Protection and management measures

When in the second half of April the water level in the polders is raised, the spoonbills face the loss of many suitable foraging sites. During this period the tidal flats form no suitable alternative because of the absence of shrimps and other prey species. Polders used by spoonbills in the first half of April would also form suitable foraging areas for spoonbills in the second half of April and the beginning of May, i f the water level would be raised a few weeks later.

Old traditional polders with ditches in which a low water level of about 20 cm is maintained throughout the summer are important foraging areas for the spoonbill. In the last decades many of these traditional polders have been modernised. This means that small and shallow ditches are either filled up or transformed into deep ditches with very steep slopes. Due to these changes foraging circumstances have been deteriorating.

Polders having been modernised and thus become unsuitable as a foraging area are shown in Fig 30. Unfortunately, for many of the remaining traditional polders, which still are important foraging areas, plans for modernisation are being prepared. Protection of these areas is very important, especially for the Zwanenwater colony. Apart from the changes in waterlevel and the reduction in number of ditches another aspect of the modernisation of polders is the limiting effect on the possibilities for migration of the sticklebacks. Because old sluices are being replaced by heavy powered pumps insurmountable barriers are created for migrating three-spined sticklebacks at places where fresh water used to be sluiced into the sea. Further inland, barrages or small dams between the large bosom waters and the shallow ditches form a further limitation to migration into the shallow ditches.

The spoonbill is not the only species suffering. In Friesland, a huge smelt population migrates from the IJsselmeer to the Friesian lakes each spring. These small young smelts form an important prey species for many predators like perch *Perca fluviatiles* and pikes *Esox lucius* (Vijverberg, pers comm). Future plans for hydrological reconstruction must incorporate special accomodation to create new migration possibilities for the sticklebacks and other migrant fish species. In case of the Oostvaardersplassen, the inlet of these larval smelt in early spring into the shallow lakes might create huge food resources for the spoonbills breeding in this area. At the moment, shortage of food in close vicinity of the colony during the breeding season forces the spoonbills to make long foraging flights (pers. comm. Poorter, van Eerden). This is probably the reason for the low numbers of breeding spoonbills in this area.

During our study it became clear that the prawn *Palaemonetes varians* also is an important prey species. Brackish conditions in which this prawn is living are becoming scarce, on the mainland of North-Holland and on Texel.In this respect, the inlet of salt water in certain polders and ditches and the creation of shallow brackish waters might be an important protection measure as well.

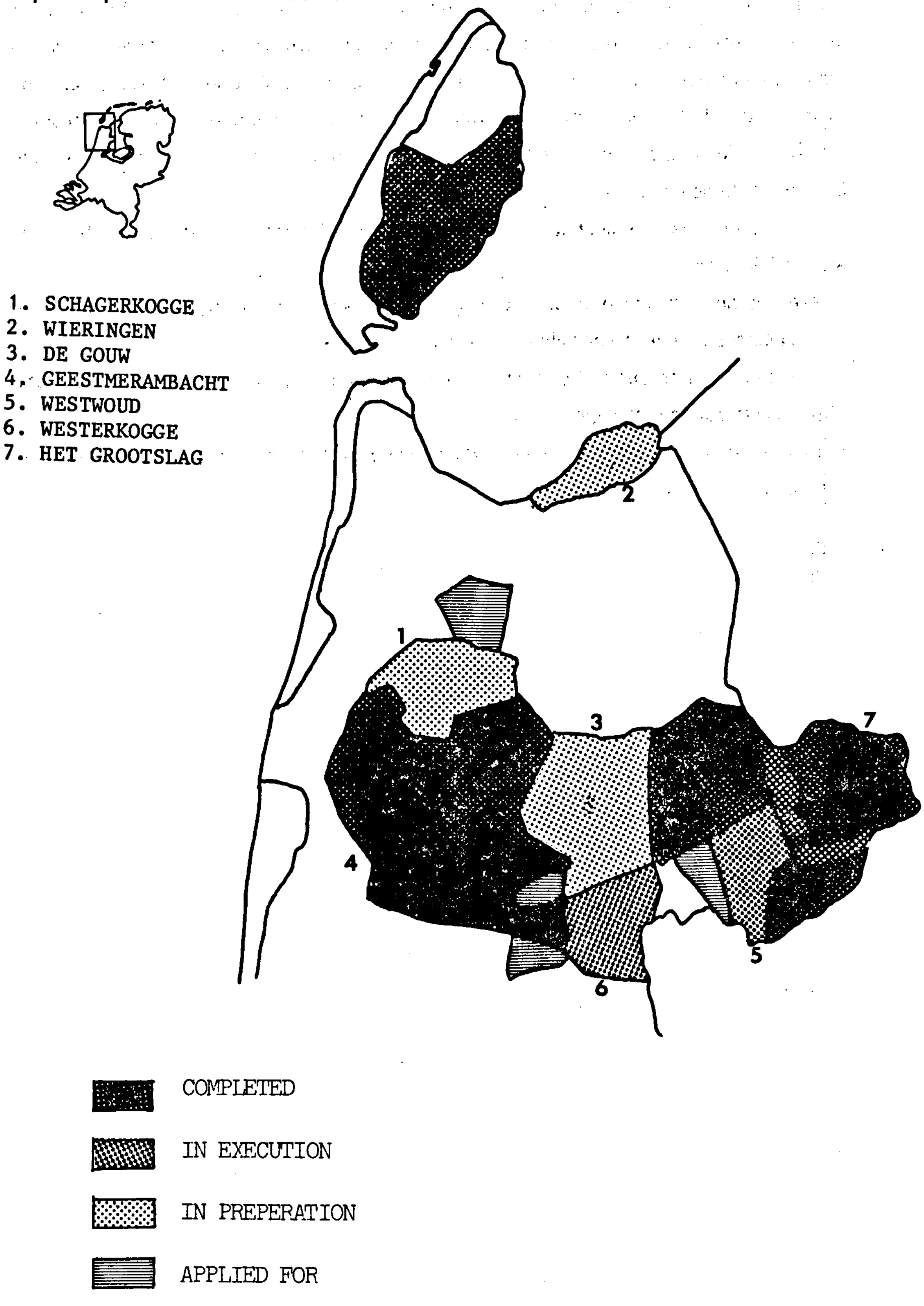

Figure 30 : Re -allotment activities in present and past on the mainland of North-Holland and Texel.

Conclusions.

For both the Zwanenwater colony and the Muy colony, the deterioration of fresh water foraging areas causes the spoonbill to shift its foraging activity towards the tidal flats. In the future an increase of the proportion of pairs breeding on the Waddensea islands is to be expected due to this development. Further declines in the numbers of breeding pairs in the Muy colony and Zwanenwater colony can be prevented by protecting the main fresh-water foraging areas.

Measures to protect and improve the foraging circumstances in fresh-water areas are the following:

- re-establishment and protection of migration possibilities for migrating three-spined sticklebacks or other small migrating fishes
- protection and creation of suitable foraging circumstances, like shallow ditches and pools with edges that slope gradually.
- postponement of raising the water level in ditches in early spring until the availability of food on the tidal flats is adequate.

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