THE BIRDS OF THE SML RICE FIELDS IN SURINAME: SPECIES COMPOSITION, NUMBERS AND TOXICHEMICAL THREATS

Peter W. Hicklin
Arie L. Spaans

TECHNICAL REPORT SERIES NO. 174
Atlantic Region
Canadian Wildlife Service

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This series may be cited as:

Hicklin, P.W. and Arie L. Spaans. 1993.
The birds of the SML rice fields in Suriname:
species composition, numbers and toxichemical threats.
Technical Report Series No. 174.
Canadian Wildlife Service, Ottawa.

Issued under the Authority of the
Minister of the Environment
Canadian Wildlife Service

Minister of Supply and services Canada 1993
Catalogue No. CW69 - 5/174E
ISBN 0662 - 20696 - 7

Copies may be obtained from:

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FOREWORD

It was the shorebirds of Suriname which made the two authors of this report colleagues (albeit long distance colleagues), co-workers and friends. On 11 August, 1981, in Sackville, New Brunswick, near the shores of the Bay of Fundy, a lady brought bands to Peter Hicklin which had been removed from the leg of a Semipalmated Sandpiper killed by a domestic cat. One band was a standard U.S. Fish and Wildlife band and the other was an orange colour band. The sandpiper had been banded by Arie Spaans near Paramaribo, Suriname, in spring 1976. And thus began the collaboration between two researchers which led to the field work on North American shorebirds and other aquatic birds in the rice fields of Wageningen in Suriname described in this report.

Our research in the intervening years has identified the critical importance of the Suriname coastline to migrant shorebirds in the Western Hemisphere. These areas are of great importance to both man and shorebirds - in this case, rice cultivation and Yellowlegs *Tringa melanoleuca* and *T. flavipes*. How humans use and abuse these critical habitats can have a considerable influence on the birds which require them to survive the overwintering months. This report provides important information on how these areas are used by man and birds.

The strong desire to protect these lands and the migrant shorebirds which depend on them, is best exemplified by the collaboration we received from the governments of Suriname, Canada and The Netherlands. That three very different and distant countries can be brought together by a sandpiper and a cat, and collaborate so successfully to better understand and protect the environment, is a most remarkable example of successful international collaboration.

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9 August, 1992

ABSTRACT

Between 9 and 19 November, 1989, we censused aquatic birds in 62 rice fields owned by the company SML (9,800 ha; 50% in cultivation) near Wageningen in the coastal belt of Suriname, South America. We censused 1,024 ha of cultivated rice fields. A total of 9.6 km of irrigation and drainage canals, were surveyed separately. We recorded 39 species for an estimated population of 15,000-16,000 birds or 3.1-3.3 birds/ha of cultivated rice field. North American shorebirds and local ardeids proved to be the most abundant species-groups foraging in the rice fields (60.5% and 33.2%, respectively). Along the canals, jacanas (39.3%) and ardeids (37.3%) were the most common birds. Compared with the species and numbers which were recorded in 1971, the Black-bellied Whistling-Duck (*Dendrocygna autumnalis*), nine species of birds of prey, the Purple Gallinule (*Porphyrula martinica*), the Gull-billed Tern (*Sterna nilotica*), and probably the Snowy Egret (*Egretta thula*), decreased most dramatically. The data we collected suggest that rice fields in northern South America are an important habitat type for overwintering Lesser (*Tringa flavipes*) and Greater Yellowlegs (*Tringa melanoleuca*), Least Sandpipers (*Calidris minutilla*) and for local ardeids as well. Bird densities were highest in flooded fields which were in the process of being harrowed, plowed or levelled (34.3 birds/ha). In the other six habitats types we recognized, bird densities were much lower (0 birds/ha in fields with ripe rice to 11.1 birds/ha for recently-flooded fields).

We collected 17 specimens of 7 species which were feeding in flooded fields in the process of being harrowed, plowed or levelled, or which had just recently undergone the process. Mammals and fish were found in the digestive tracts of the Great Egret (*Casmerodius albus*) only, amphibians were taken by the Snowy Egret, Cattle Egret (*Bubulcus ibis*) and the Greater Yellowlegs. Spiders were found in the Snowy Egret, Cattle Egret, Wattled Jacana (*Jacana jacana*) and the two species of yellowlegs. All specimens of those six species and the single Solitary Sandpiper (*Tringa solitaria*) had also taken insects.

Four herbicides, two molluscicides, and five insecticides were used during cultivation in the rice fields we surveyed in 1989. Spraying began one week before sowing the rice and continued to the end of the growing season. Black-bellied Plovers (*Pluvialis squatarola*), Least Sandpipers and White-rumped Sandpipers (*Calidris fuscicollis*) foraged, to a large extent, in fields which had recently been sprayed. *AZODRIN*, and possibly *BESTRAN* and *AMBUSH*, are a potential threat to Great Egrets and the three species of shorebirds which feed mainly in the recently-seeded rice fields.

RÉSUMÉ

Du 9 au 19 Novembre, 1989, nous avons recensé les oiseaux aquatiques se nourrissant dans 62 champs de riz aménagés par la companie SML (9,800 hectares et 50% cultivé) près du village de Wageningen au Suriname en Amérique du Sud. Nous avons aussi prospecté 9.6 km de canals d'irrigation. Nous avons identifié 39 espèces d'oiseaux pour une population totale d'environ 15,000-16,000 oiseaux, soit une densité de 3.1-3.3 oiseaux/hectare dans les champs de riz cultivés. Les espèces d'oiseaux de rivage Nord Américains et de hérons Sud Américains furent les deux groupes d'oiseaux les plus abondants (60.5% et 33.2%, respectivement). Le long des canals d'irrigation, les Jacanas (39.3%) et les données collectées en 1971, les effectifs du Dendrocygne à ventre noir (*Dendrocygna autumnalis*), de neuf espèces de rapaces, de la Talève violacée (*Porphyrula martinica*), de la Sterne hansel (*Sterna nilotica*) et probablement de l'Aigrette neigeuse (*Egretta thula*) ont sérieusement diminués. Nos données indiquent que les champs de riz au Suriname sont très importants pour les migrateurs néarctiques -Grand (*Tringa melanoleuca*) et Petit Chevaliers (*Tringa flavipes*) et Bécasseau minuscule (*Calidris minutilla*)- et les populations de hérons Sud-Américains. Les plus grandes densités d'oiseaux furent observés dans les champs de riz innondés en train d'être labouré (34.3 oiseaux/hectare). Dans six autres habitats, les densités d'oiseaux furent beaucoup moins élevées (de 0 dans les champs avec du riz mûr jusqu'à 11.1 oiseaux/hectare dans les champs récemment innondés).

Nous avons collecté 17 échantillons de 7 espèces différentes d'oiseaux qui se nourrissaient dans les champs innondés ou ceux en train d'êtres labourés. Dans ces échantillons, nour avons retrouvé des poissons et des mammifères dans le système digestif de la Grande Aigrette (*Casmerodius albus*) seulement. L'Aigrette neigeuse, le Héron guarde-boeuf (*Bubulcus ibis*) et le Grand Chevalier s'étaient nourrient sur des amphibiens lorsque l'Aigrette neigeuse, le Héron guarde-boeuf, le Jacana noir (*Jacana jacana*) et les deux Chevaliers avaient attrappés plusieurs araignés. Les échantillons de ces six espèces et celui du Chevalier solitaire (*Tringa solitaria*) avaient tous pris des insectes.

Durant la cultivation du riz dans les champs que nous avons recencés, la compagnie SML s'était servi de quatre sortes d'herbicides, de deux molluscicides et de cinq sortes d'insecticides. L'emploi de ces produits chimiques, répendu par avion, débutait une semaine avant que le riz soit planté jusqu'a la récolte. Le Pluvier argenté (*Pluvialis squatarola*), le Bécasseau minuscule et le Bécasseau à croupion blanc (*Calidris fuscicollis*) se nourissaient principalement dans les champs qui furent récemment traités avec ces produits. Spécialement le produit *AZODRIN* et possiblement *BESTRAN* et *AMBUSH*, sont des menaces potentielles pour la Grande Aigrette et les trois espèces d'oiseaux de rivage qui se nourrissaient principalement dans les champs nouvellement semés.

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-The birds of the SML rice fields in Suriname-

(Not shown)

NOTE: The appendix with the data on all birds observed in each rice field and on the specimens collected is extensive and available as a separate volume by request to PWH.

INTRODUCTION

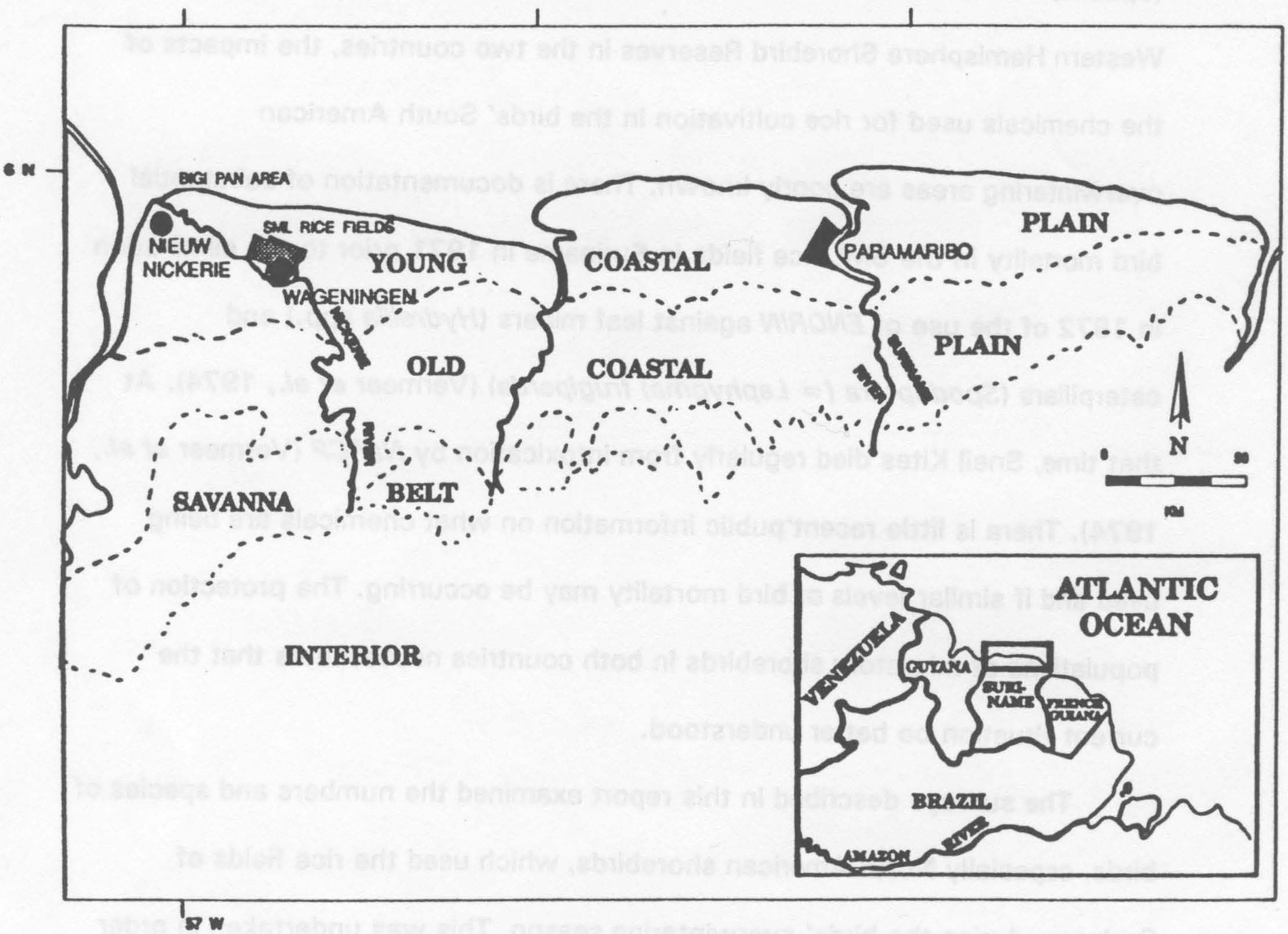
Suriname is located on the northeastern coast of South America between French Guiana and Guyana (Figure 1). The country has a total area of 165,000 km^2 with a population of approximately 400,000. Ninety-five percent of the population is concentrated in the city of Paramaribo and small settlements in the coastal plain.

In 1949, the Dutch government established SML, the Foundation of Mechanical Agriculture, to undertake large-scale rice production north of the village of Wageningen in the northwestern portion of the country (Figure 1). In 1989/1990, when our field research was under way, this agricultural enterprise had 9,800 hectares of land for rice production. Due to the poor economic conditions in the country at that time however, only half of that area was actually under cultivation with the other half left fallow (SML, pers. comm.). Adjacent to the SML operations, a 1,500 ha area with 60 privately-owned rice farms had recently been established and the area under rice cultivation in northwestern Suriname continues to expand.

Pesticides are in common usage for rice cultivation in Suriname and some highly hazardous chemicals have been known to kill fish, frogs, Snail Kites (*Rostrhamus sociabilis*), egrets, herons and Wattled Jacanas (*Jacana jacana*) in, or near, the SML rice fields (Vermeer *et al.*, 1974). The aerial application of such chemicals can also contaminate wetlands and irrigation and drainage canals adjacent to the rice fields. Wetlands are also indirectly contaminated by the drainage of used irrigation water into these wetlands. For instance, water from the Bigi Pan Multiple-Use Management Area near Nieuw Nickerie has been

Figure 1.

Map of northern Suriname showing the location of the SML rice fields in Wageningen.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SML RICE FIELDS
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WAGENINGEN
YOUNG
COASTAL
PARAMARIBO
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SAVANNA
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VENEZUELA
GUYANA
SURI-
NAME
FRENCH
GUIANA
BRAZIL
AMAZON
RIVER
57 W

found to contain *DIELDRIN*, *ENDOSULFAN*, *CHLORDANE* and *HEPTACHLOR* (van der Steege, 1987).

In 1987 and 1988, two sections of the upper Bay of Fundy in eastern Canada and three coastal areas in Suriname were declared twinned Western Hemisphere Shorebird Reserves by both national governments. The two countries share a large population of shorebirds at different times of the birds' annual cycle. For example, species such as the Semipalmated Sandpiper (*Calidris pusilla*) breed in Canada and overwinter, in large part, in Suriname (Spaans, 1978; Morrison & Ross, 1989). Although the habitats are protected as Western Hemisphere Shorebird Reserves in the two countries, the impacts of the chemicals used for rice cultivation in the birds' South American overwintering areas are poorly known. There is documentation of substantial bird mortality in the SML rice fields in Suriname in 1971 prior to the elimination in 1972 of the use of *ENDRIN* against leaf miners (*Hydrellia* spp.) and caterpillars (*Spodoptera (= Laphygma) frugiperda*) (Vermeer *et al.*, 1974). At that time, Snail Kites died regularly from intoxication by *NaPCP* (Vermeer *et al.*, 1974). There is little recent public information on what chemicals are being used and if similar levels of bird mortality may be occurring. The protection of populations of migratory shorebirds in both countries necessitates that the current situation be better understood.

The surveys described in this report examined the numbers and species of birds, especially North American shorebirds, which used the rice fields of Suriname during the birds' overwintering season. This was undertaken in order to document if recent declines in shorebird population numbers (Howe *et al.*,

1989) might be related to the use of toxic chemicals in important overwintering habitats such as the rice fields of Suriname.

The main objectives of this study were to i) investigate the extent to which shorebirds used the Suriname rice fields, ii) estimate their numbers and iii) conduct preliminary investigations on the birds' diets to determine the potential pathways by which birds might become contaminated with certain pesticides used in present rice cultivation practices.

STUDY AREA

Suriname can be divided into four distinct geological regions (Figure 1):

(1) The ***young coastal plain*** lies 0-4 m above mean sea level and consists of holocene marine swamp clays. It encompasses an area of 16,200 km^2 forming a strip 8 km wide in the east broadening to 50 km wide in the west. The more inland portion of this coastal plain between Nieuw Nickerie and Wageningen is one of the regions used for rice cultivation and where we conducted our field studies. The shoreline, used extensively by shorebirds (Spaans, 1978; Morrison & Ross, 1989), consists largely of vast tidal mudflats bordered on the higher parts by forests of black mangrove (***Avicennia germinans***). North of the rice growing zone is the Bigi Pan Multiple-Use Management Area established as a protected area by the government of Suriname on 30 December, 1987. This expansive wetland comprises approximately 68,300 hectares of land (including land flooded by fresh and brackish water) and an equal area of marine waters. The inland boundary of the Bigi Pan Multiple-Use Management Area is bordered by an increasing number of rice plantations (McCormick, 1990).

(2) The ***old coastal plain*** lies 4-11 m above mean sea level and covers an area of about 4,300 km^2 forming a coastal level approximately 20 km wide. This zone consists of swamp clays of marine origins and sand ridges of both marine and riverine origin.

(3) The ***savanna belt*** of about 10,000 km^2 lies several tens of metres above mean sea level and consists of coarse sands and loams characterised by white sand savannas.

(4) The ***interior***, or crystalline basement, contains an area of 132,000 km^2, more than 30 m above mean sea level consisting of a gently sloping dissected peneplain with hill and mountain ranges of up to 1,230 m, and predominantly covered with undisturbed neotropical rain forest.

The SML rice polders are divided into six large sections (02-07) which are further subdivided into 105 fields (1-100) containing a total of 503 rice plots (Figure 2). Fields are irrigated with water derived from the Nickerie River through a system of primary and secondary irrigation canals. The water is later drained through secondary and primary drainage canals into the Nickerie River further downstream. Rice cultivation in the SML area is highly mechanised, and seeding, fertilising and spraying chemicals is done entirely by airplane.

Two crops of rice are grown each year in the SML rice fields. The first rice growing period occurs during the long rainy season which begins in April and continues through July. The second crop is started during the long dry season (which begins in September and continues through November) and spans also the short rainy season (December-January) and the short dry season (February-March). In 1989, the period of sowing extended from the middle of

April through the beginning of July and from the middle of October through the end of December.

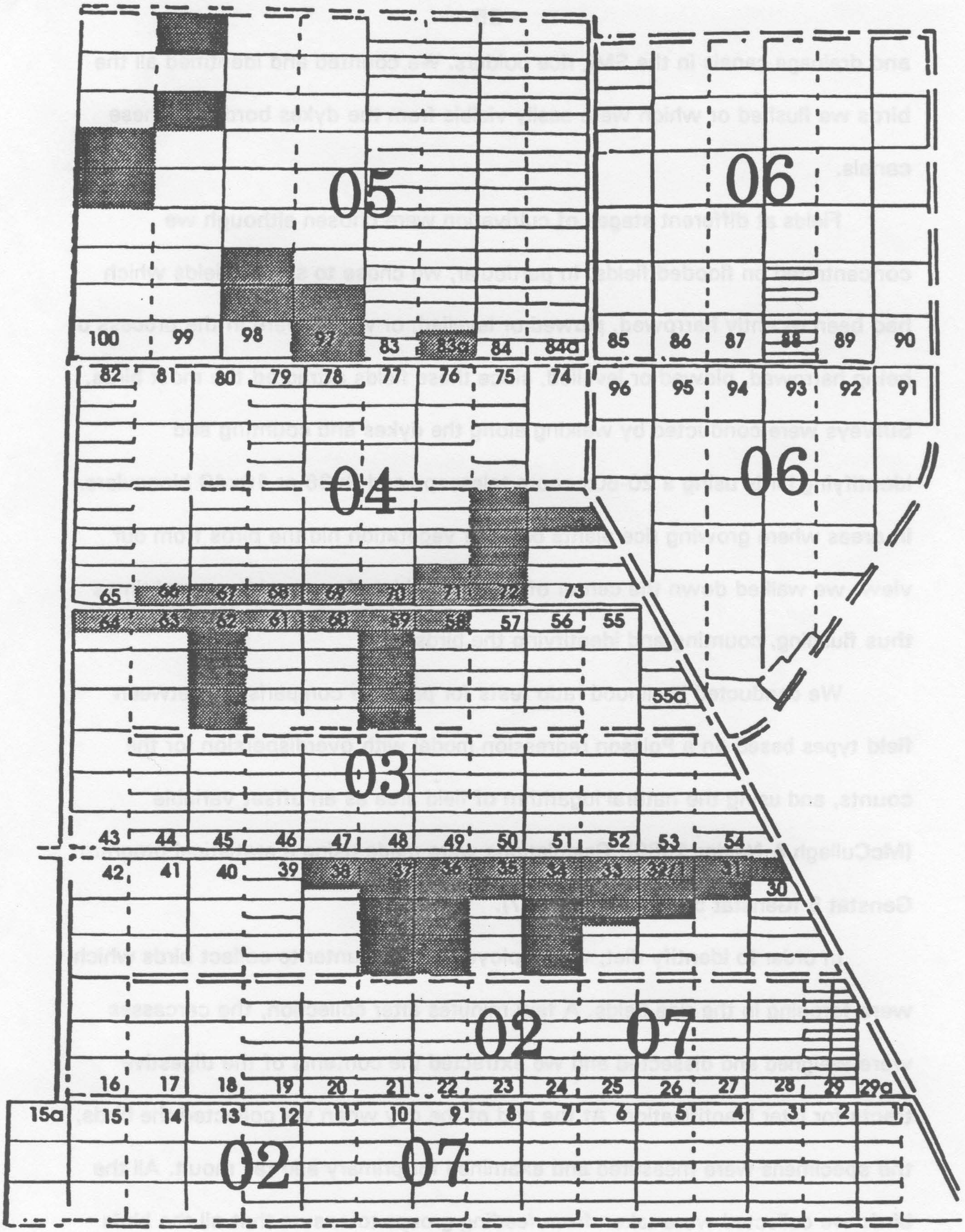
When weather permits, the stubble is burned within one week after the rice is harvested. If possible, the fields are harrowed shortly afterwards. Within two to three weeks thereafter, the fields are flooded, harrowed, plowed and levelled. Three weeks after the fields were flooded, rice is sown. The fields are fertilised on day 30, 48 and 68 after sowing. But before fertilising takes place, the fields are temporarily drained. And ten days before harvesting, which takes place four months after sowing, the fields are drained for the last time during that growing season (SML, pers. comm.). Pesticides are widely used starting a few days before sowing the rice until the end of the growing season.

METHODS

We surveyed 43 small rice fields, each being approximately 13.0 ha in area, and 19 larger fields of about 26.0 and 30.0 ha, for a total of 1,024 ha of rice fields surveyed (Figure 2). This represents 10.4% of the total potential SML rice growing area under cultivation and 20.9% of the actual area under cultivation in 1989 (SML, pers. comm.) which was surveyed for birds over a 10-day period between 9-19 November, 1989.

In order to adequately represent the whole SML polder region under cultivation, we selected rice fields in three sections (03-05, see Figure 2) which represented a wide area, both latitudinally and longitudinally, of the rice-growing area. We also walked along 9.6 km of irrigation and drainage canals (8 stretches of 1.2 km each), which represented 7.0% of the total 136.8 km of irrigation

Figure 2. Map of the SML rice fields. Shaded areas indicate the fields which were surveyed for birds in this study. Each field number is indicated by a prefix and a suffix (shown at the base of each row of fields) beginning with # 1 (e.g. 32/1, 32/2, ..., 32/6). Each field is subdivided in two or more parallel plots. Irrigation and drainage canals are indicated by full and dashed lines, respectively.



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55a
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16 17 18 19 20 21 22 23 24 25 26 27 28 29 29a
15a 15 14 13 12 11 10 9 8 7 6 5 4 3 2

and drainage canals in the SML rice polders. We counted and identified all the birds we flushed or which were easily visible from the dykes bordering these canals.

Fields at different stages of cultivation were chosen although we concentrated on flooded fields. In particular, we chose to survey fields which had been recently harrowed, plowed or levelled, or which were in the process of being harrowed, plowed or levelled, since these fields attracted the most birds. Surveys were conducted by walking along the dykes and counting and identifying birds using a 20-60x zoom telescope and 8x36 or 10x40 binoculars. In areas where growing rice plants or other vegetation hid the birds from our view, we walked down the center of the rice field and crossed it several times thus flushing, counting and identifying the birds.

We conducted likelihood ratio tests for pairwise comparisons between field types based on a Poisson regression model with overdispersion for the counts, and using the natural logarithm of field area as an offset variable (McCullagh & Nelder 1989). Calculations were made using a statistical program Genstat 5 (Genstat 5 Committee 1987).

In order to identify diet, we employed a local hunter to collect birds which were foraging in the rice fields. A few minutes after collection, the carcasses were weighed and dissected and we extracted the contents of the digestive tracts for later identification. At the end of the day when we collected the birds, the specimens were measured and examined for primary and tail moult. All the birds we collected were taken from feeding groups to ensure that all the birds had food in their digestive tracts. The contents of the digestive tracts were stored in 70% alcohol. These were later sorted and identified in The Netherlands after our return from Suriname. With regards to pesticide use, we interviewed the foremen responsible for each of the four large sections we surveyed and obtained information regarding which processes the fields had undergone in the last few months. We specifically requested, and received, information regarding which pesticides were sprayed in the fields we surveyed.

RESULTS

1. Avian Use of the SML Rice Fields and Canals

We recorded 37 species of birds in the rice fields and 14 species along the secondary irrigation and drainage canals that we surveyed (Tables 1 and 2). There were no significant differences in abundances between the two types of canals, either for individual species or for the total number of birds, although there tended to be more birds in drainage canals (Table 3). The variation about the means, however, was high, while the sample sizes were small (see Table 3).

Twenty species of shorebirds were identified on the rice fields although two species predominated: the Lesser Yellowlegs (*Tringa flavipes*) and the Least Sandpiper (*Calidris minutilla*). Along the canals we recorded two species which we did not observe on the cultivated rice fields. These were the Purple Gallinule (*Porphyrula martinica*) and the Snail Kite (Table 2).

In contrast to the canals, the rice fields we surveyed were not randomly selected, since we were focussing on fields which were recently flooded and on flooded fields which were in the process of being harrowed, plowed or levelled, or which had very recently undergone this process. Moreover, each rice field was attractive to the birds for only a very short period of time. As a result, birds fed on the same fields for only a few days. Hence, it is not possible to extrapolate directly our census results to all the SML rice fields in Wageningen for an estimate of the total population using the site. To obtain an estimate of the total numbers of birds using the rice fields in November 1989, we multiplied the mean bird density of each species in each habitat type by the total area occupied by each habitat type and summed the resulting population numbers by habitat type. The area of each rice field habitat type was calculated by multiplying the average proportion of time a field was at each stage of cultivation by the total area of the rice fields under cultivation at that time (Table 10). Since fields are burned, flooded, harrowed, plowed, levelled and seeded throughout a large part of the season, the total area of each habitat type is directly related to the average time a field is in that stage of cultivation. To these totals we added the numbers computed for the canals (Table 5), and arrived at a total number for the whole SML rice field area.

Five species of birds occurred in the SML rice fields and canals in numbers exceeding 1,000 birds (Table 7): Great Egret (*Casmerodius albus*; 2,100), Cattle Egret (*Bubulcus ibis*; 1,500), Wattled Jacana (1,450), Lesser Yellowlegs (2,500-2,600) and Least Sandpiper (2,500-3,000). And of these, Jacanas were the most numerous in the canals where we estimated a total of 1,300 birds. The total number of birds using the SML rice field area therefore amounted to 15,000-16,000 birds or 3.1-3.3 birds/ha rice field in cultivation at that time.

If the 37 species we recorded in the rice fields (not including canals) are broken down into five distinct groups, shorebirds (of which 98.0% were breeding birds from North America) were clearly the most numerous group of birds foraging in these fields (7,500 birds or 62.2%) followed by herons and egrets (4,000 or 33.2%) and terns (535 or 4.4%) for a total of approximately 12,000 birds estimated to be using the 9,800 hectares of SML rice fields (Table 7). Except for rails, all the birds we saw in the cultivated rice fields were observed foraging. We assume that the crakes and the Azure Gallinule (*Porphyrula flavirostris*) we saw were also foraging, although they were usally flushed from the vegetation which kept them hidden from our view.

Along the canals, shorebirds were still predominant but here 95.0% of the birds (39.3% of all birds along the canals) consisted of Wattled Jacanas in comparison to 2.0% of the shorebirds reported for the rice fields. Along the canals, rails were similarly much more prevalent (18.2%) than in the rice fields (0.2%). For the group of herons and egrets, the difference was not as large (37.3% along the canals against 33.2% in the rice fields) but the species composition in the two habitats was quite different. Most birds seen along the canals were roosting, or were assumed to be roosting, because many were flushed from the trees which were present along some of the canals. This was especially true for the Black-crowned Night-Heron (*Nycticorax nycticorax*) and the Purple Gallinule. Nevertheless, there were no differences in the average number of birds per canal surveyed between canals with trees and those without trees, either for individual species or in total numbers between canal types (Table 4). This is probably due to the large numerical variation between canals and the small sample size (only three canals did not have trees).

The Peregrine Falcon (*Falco peregrinus*), the only species of raptor we saw in the rice fields except for a single Osprey (*Pandion haliaetus*), probably preyed upon the yellowlegs although we never saw a kill of a yellowlegs by a Peregrine nor any falcon carrying a kill which could be identified as being a shorebird. We did, however, witness the kill of a Snowy Egret (*Egretta thula*) in a rice field by a juvenile male Peregrine Falcon on 16 November. The falcon had quickly consumed a portion of the Egret by the time we recovered it for positive identification, a matter of only a few minutes.

2. Habitat Choice

The birds we counted proved to be unequally distributed over the seven habitat types we surveyed (Table 6). We encoutered the fewest birds in fields with ripe rice ready for harvest (0 birds/ha) and in fields which had been recently harvested (0.4 birds/ha, difference between the two habitat types significant for Solitary Sandpiper (*Tringa solitaria*) and the group of "other species" only). The latter habitat type included fields with (up to) 40 cm-tall stubble and fields which were either (partly) burned or harrowed. Either type could be dry or rain-flooded. During, and after, flooding the fields with irrigation water, densities of birds increased to 11.1 birds/ha (Table 6, increase significant for Cattle Egret, Black-bellied Plover (*Pluvialis squatarola*), Lesser Golden-Plover (*Pluvialis dominica*), Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs and the total number of birds). Up to 88% of the increase resulted from the influx of Cattle Egrets (3.8 birds/ha), Greater Yellowlegs (1.0 birds/ha) and Lesser Yellowlegs (4.6 birds/ha) into these fields. All three species were absent from these fields prior flooding (Table 6). A further increase, to a maximum of 34.3 birds/ha, took place when farmers started harrowing, plowing or levelling the flooded fields (Table 6, increase significant for Great Egret, Snowy Egret, Lesser Golden-Plover, Wattled Jacana, Semipalmated Sandpiper, Least Sandpiper, White-rumped Sandpiper (*Calidris fuscicollis*), Gull-billed Tern (*Sterna nilotica*), Yellow-billed Tern (*Sterna superciliaris*), the group of "other species" and the total number of birds). Almost 50% of the increase following flooding resulted from an increase in the number of Great Egrets; 19% was due to increasing numbers of yellowlegs and another 12% due to increasing numbers of Yellow-billed Terns. These fields represented the only habitat type in which Yellow-billed Terns occurred in significant numbers (2.8 birds/ha) during our surveys. After these agricultural activities had stopped, or were interrupted for some days, the densities (all species combined) decreased to 4.8 birds/ha (Table 6, decrease significant for all species (groups) except the Cattle Egret, Lesser Golden-Plover, Lesser Yellowlegs and Solitary Sandpiper). Although all species declined in numbers when agricultural activity decreased, the decreasing numbers of Great and Cattle Egrets, yellowlegs and Yellow-billed Terns contributed up to 80% of this decline.

When the wet fields were seeded, the Cattle Egret, Wattled Jacana, Gull-billed Tern and the Yellow-billed Tern were no longer seen in these fields (Table 6, difference with flooded fields with recent activities, however, not significant). The numbers of Lesser Yellowlegs also declined (Table 6, decrease, however, not significant). But when all species were combined the densities of birds in these fields increased to 7.0 birds/ha (Table 6, increase significant for Black-bellied Plover, Semipalmated Sandpiper, Least Sandpiper, White-rumped Sandpiper and the group of "other species"). The larger density of birds resulted mainly because of an increase in the numbers of Least Sandpipers (0.1 birds/ha before seeding against 4.8 birds/ha after seeding).

A particular habitat type censused during the surveys consisted of harvested fields which, due to the poor economic conditions at the time of our study, were left as fallow land for many months (fields # 100/5 and 100/6). These fields were covered with grasses and growing rice (rhysomial growth) which attracted large numbers of Great Egrets (4.5 birds/ha), Snowy Egrets (0.9 birds/ha) and Least Sandpipers (2.5 birds/ha), the second highest density for this sandpiper in the seven habitat types surveyed (Table 6, difference with harvested fields significant in all three cases). For all species combined, the density of birds in this habitat type amounted to 8.0 birds/ha (Table 6, total number of birds, however, not significantly different from the total number of birds in harvested fields).

3. Food Analysis

Our censuses showed that recently-flooded fields and flooded fields which were in the process of being harrowed, plowed or levelled (or had been harrowed, plowed or levelled very recently) attracted the most birds (Table 6). For this reason, we collected birds in these habitat types in order to obtain data on the diets of the birds feeding in the rice fields. Furthermore, we concentrated our efforts on those groups of species which occurred in the largest numbers (i.e. egrets and yellowlegs). In total, we collected 17 specimens of 7 species: Great Egret (4), Snowy Egret (1), Cattle Egret (2), Wattled Jacana (1), Greater Yellowlegs (2), Lesser Yellowlegs (6) and Solitary Sandpiper (1). All specimens, except the Snowy Egret, were in social feeding flocks when collected. The Snowy Egret was obtained a few minutes after it had been caught and killed by a Peregrine Falcon. Detailed information about the fields where the birds were collected and on the biometrics, moult and the contents of the digestive tracts, is given in the separate Appendix (Hicklin and Spaans, 1992).

The food remains were divided into five major groups: insects, spiders, fish, amphibians and mammals (Table 8). All the 17 birds collected proved to have eaten insects, with average prey numbers ranging from 1.0 food items/bird in the Wattled Jacana to 42.5 items/bird in the Cattle Egret. A relatively large number of prey items was also found in the Snowy Egret (18.0 items/bird).

The insects belonged to five orders: Odonata, Orthoptera, Hemiptera, Dictyoptera and Coleoptera (Table 9). Odonata (dragonflies) were found in three of the four Great Egrets (on average, 15.0 items/bird) and in one of the two Cattle Egrets (0.5 items/bird). Almost all dragonflies found in the Great Egrets were nymphs of Libellulidae, most probably *Pantala flavescens*. Orthoptera were found in all seven species investigated, but only in significant numbers in the Great Egret (12.5 items/bird) and the Cattle Egret (31.5 items/bird). In the other species, the mean number per bird ranged from less than 1 item/bird to 3 items/bird. The Orthoptera found in the Great and Cattle Egret were either Acrididae (grasshoppers) or Gryllidae (crickets). Those found in the yellowlegs and the Solitary Sandpiper were most likely Gryllotalpidae (mole-crickets). Dictyoptera were found in the two Cattle Egrets we collected (6.0 items/bird) and in one of the Lesser Yellowlegs (0.2 items/bird). Hemiptera were only found in the Snowy Egret (5.0 items/bird) and in the Lesser Yellowlegs (0.3 items/bird). The five Hemiptera found in the Snowy Egret were Naucoridae (water boatmen). All species except the Wattled Jacana had adult Coleoptera or larvae in their digestive tract but it only occurred in significant numbers in the Lesser Yellowlegs (15.7 items/bird; in the other species, the mean number per bird ranged from less than 1 item/bird to 8 items/bird).

Spiders were found in all species except the Great Egret and the Solitary Sandpiper with a frequency of occurrence of 100% in the Snowy Egret, Cattle Egret and Wattled Jacana. Large numbers of spiders were found in the Cattle Egret (19.0 items/bird), and ranged from 0.5 to 3.0 items/bird in the other four species. Three families of spiders were identified: Lycosidae, Salticidae and Oxyopidae. Lycosidae were found in both Egrets and shorebirds. Salticidae were confined to the Cattle Egret and the Lesser Yellowlegs. Oxyopidae were only found in the Lesser Yellowlegs.

Fish were found only in the Great Egret (75% frequency of occurrence; 4.3 items/bird). Amphibians (frogs and toads) were present in the digestive tracts of the Snowy Egret (1.0 items/bird), the Cattle Egret (100% frequency of occurrence, 2.0 items/bird) and the Greater Yellowlegs (50% frequency of occurrence, 1.0 items/bird).

Mammals were found in all four Great Egrets with an average of 1.8 items/bird. The species found consisted of the Cane Mouse (*Zygodontomys* *brevicauda*) and the Common House Mouse (*Mus musculus*). The Cane Mouse is one of the common cricetine rodents in the coastal area of Suriname, and in agricultural areas in particular (Husson, 1978). According to Husson (1978) the species causes much damage to the rice fields in the Wageningen-Nieuw Nickerie area when feeding on rice. The Common House Mouse is probably widespread in the coastal region near human settlements, but seems to survive well entirely outdoors, away from human habitation (Husson, 1978).

4. Use of Toxichemicals

The rice plants in the SML rice fields can be seriously affected by a wide variety of plants and animals (van Halteren, 1972; Vermeer *et al.*, 1974). They can be harmed by fungi, algae and a variety of grasses and dicotyledons which reduce the yield and quality of the rice. Invertebrates which are important in this respect are nematodes, insects, snails and slugs. Vertebrates which pose a major and consistent problem in the rice fields include various species of rodents, and certain birds such as the Black-bellied Whistling-Duck (*Dendrocygna autumnalis*), Purple Gallinule and some seed-eating species. In order to reduce plants and animals which may affect rice plants, a variety of control measures are applied including: i) flooding and draining of fields (depending on the species which are to be controlled), ii) thorough cultivation of the ground, iii) use of resistant rice varieties and iv) spraying herbicides, insecticides, molluscicides and fungicides, as well as trapping and scaring (birds) and killing or poisoning (mammals).

According to van Halteren (1972), chemicals are sprayed to reduce damage by algae, grasses, dicotyledons, *Pomacea* snails and a wide variety of insects such as waterweevils (*Helodytes foveolatus*), army worms (*Spodoptera* (= *Laphygma*) *frugiperda*), leaf miners (*Hydrellia* spp.), rice loopers (*Mocis latipes*) and rice leaf folders (*Vehilius celeus*), planthoppers (*Sogatodes orizicola*), grasshoppers (*Conocephalus cinereus*), spider mites (*Acarina* spp.), shield bugs (*Tibraca limbatriventris*) and paddy bugs (*Oebalus poecilus*). Vermeer *et al.* (1974) also mention fungi, leafhoppers (*Draeculacephala clypeata*), white (*Rupela albinella*) and brown borers (*Diatrae saccharalis*). However, according to van Halteren (1972), damage by leafhoppers is minor and damage caused by stemborers is easily controlled without spraying chemicals. Van Halteren (1972) further states that fungi are not a problem in Suriname and does not consider the use of chemicals as seed-rice treatment (see also Table 11).

Chemicals applied to the SML rice fields from the middle of October 1988 through the middle of October 1989 included *BAYLUSCIDE, BRESTAN* (molluscicides against *Pomacea* snails), *PROPANIL* (herbicide against grasses), *2,4-D* (herbicide against dicotyledons), *AMBUSH, AZODRIN, KARATE, BASRA/OSBAC, ETROFOLAN* (insecticides), and *DOWPON* and *GRAMOXONE* (herbicides against grasses and dicotyledons). In 1989, *KARATE* and *BASRA/OSBAC* were only applied to compensate for a shortness of *AMBUSH* and *AZODRIN*, respectively, because of the poor economic situation at that time which prevented the SML company from restoring its supplies. The total quantity of chemicals used on the SML rice fields in 1988/1989 is shown in

Table 11. The chemicals applied in 1965-1971 (Vermeer *et al.*, 1974) but no longer used (with the quantity used annually for an 8,000 ha complex in those years in brackets) include *NaPCP* (50,000 kg), *METHYL PARATHION* (1965-1970: 40,000 liters; 1971: 14,000 liters), *ENDRIN* (1966-1971: 8,000 liters), *TOXAPHENE* (1970-1971: 2,000 liters), *DIQUAT* (1970-1971: 2,000 liters), *PANOGEN* (1969-1971: 2,000 liters), *CARBARYL* (200 kg, only used in 1971), and *DDT* and *DIELDRIN* (1965-1970: unspecified amounts). The chemicals applied in the course of our study (9,800 ha but only half of the area actually under cultivation) but not in 1965-1971 include *DOWPON* (230 kg), *GRAMOXONE* (2,218 liters), *BRESTAN* (6,734 kg), *AMBUSH* (396 kg), *KARATE* (17 kg), *BASRA/OSBAC* (5,034 liters) and *ETROFOLAN* (70 kg).

The spraying of chemicals is continuous throughout the rice growing season (see Table 12 for the main chemicals used in 1989, SML, pers. comm.), although some of the spraying later in the season can be skipped from the schedule. *BRESTAN* is applied the week before sowing the rice against *Pomacea* snails and sometimes 6-7 weeks after sowing to control algae. *AMBUSH* is mainly used in the early stages of the rice growth, one week before sowing against waterweevils, and the first two weeks after sowing against caterpillars (various species). *AZODRIN* is predominately used from 2 weeks after sowing onwards to protect crops against leaf miners, borers and rice bugs. The herbicides *PROPANIL* and *2,4-D* are applied 3 and 4 weeks after sowing, respectively. In November 1989 we regularly found *AZODRIN* baits (poisoned corn) against rodents especially in areas with many fallow fields.

In order to assess the potential threats to birds because of the pesticides which were applied in the SML rice fields in 1989 we used the DT_{50} (= loss of 50% of toxicant in the physical-chemical environment), the acute oral LD_{50} (= dose required to kill 50% of the test organism) which is "probably the most convenient and reliable means available for comparing the inherent toxicity of chemicals" (Hudson *et al.*, 1984) and the LC_{50} (= concentration required to kill 50% of the test organisms). Most of the pesticides applied to the rice fields in 1989 were chemicals which break down rather quickly in the physical-chemical environment (Worthing and Hance, 1984). However, this does not apply to *BRESTAN*. All chemicals, except *AZODRIN*, show high LD_{50} values for mammals and birds. *AZODRIN* proved to be very toxic to mammals (hence the use of *AZODRIN* baits to control rodents in the rice fields) and birds (Hudson *et al.*, 1984; Smith, 1987). *AZODRIN* also shows a high degree of cumulative action for an organophosphate (Hudson *et al.*, 1984). *AMBUSH* is very toxic to fish. Of the four herbicides applied, *BRESTAN* and *AZODRIN* are moderately toxic (Worthing and Hance, 1984).

DISCUSSION

1. Numbers and Species Composition

During the 10 days we surveyed the SML rice field complex, we found a wide variety of aquatic birds using the area for foraging. We recorded 39 species of non-passeriform birds of an estimated population of 15,000-16,000 birds with almost 50% being North American shorebirds. Local egrets and herons were also abundant, and, because of their body size (from an average 180 g for the Striated Heron (*Butorides striatus striatus*) to an average of 1,600 g for the White-necked Heron (*Ardea cocoi*), see Haverschmidt, 1968), the total quantity of food the local birds consumed would have been much higher than the biomass taken by the migrant shorebirds.

In order to ascertain if there were recent changes in the numbers and species of birds using the SML rice fields and canals, we compared the results of our surveys with those published by Vermeer *et al.* (1974) undertaken in the same rice fields, and at the same time of year, 18 years earlier in 1971 (see Vermeer *et al.*, 1974, Table 2, p. 220).

The most striking differences are that we failed to see 10 of the 33 species listed in Vermeer *et al.* (1974) and identified 16 species which they had not recorded. The most surprising feature is that the birds we failed to see, but reported as relatively common in Vermeer *et al.* (1974), were 8 species of birds of prey. The other two species which we did not record were the Tricolored Heron (*Egretta tricolor*) and the Black-bellied Whistling-Duck.

The birds of prey completely lacking from all our surveys were Black Vulture (*Coragyps atratus*), Turkey Vulture (*Cathartes aura*), White-tailed Kite (*Elanus leucurus*), Long-winged Harrier (*Circus buffoni*), Savanna Hawk (*Buteogallus meridionalis*), White-tailed Hawk (*Buteo albicaudatus*), Crested Caracara (*Polyborus plancus*) and Yellow-headed Caracara (*Milvago chimachima*). The most common species of predatory bird seen in 1971 was the Black Vulture which Vermeer *et al.* (1974) reported seeing daily in the SML rice fields in maximum numbers ranging between 101-1,000 birds. We did not see a single Black Vulture in the course of our surveys of the same rice fields in 1989. The same applies to the Turkey Vulture, Long-winged Harrier and White-tailed Hawk which Vermeer *et al.* (1974) reported to be present daily in 1971 in maximum numbers ranging between 11-100 birds. Less common, but present daily in 1971 in maximum numbers ranging between 1 and 10 birds, were the Savanna Hawk, White-tailed Kite, Crested Caracara and Yellow-headed Caracara.

The other most striking negative population changes between the 1971 and the 1989 surveys were the large decreases in Snail Kites, Purple Gallinules, Gull-billed Terns and probably Snowy Egrets, and the disappearance of Black-bellied Whistling-Ducks.

Of the 16 species which were not reported in 1971 but seen in 1989 were 11 shorebird species, two species of rails, one species of heron, one species of duck and one species of bird of prey. These were: Yellow-crowned Night-Heron (*Nyctanassa violacea*), Blue-winged Teal (*Anas discors*), Peregrine Falcon, (Yellow-breasted) Crake (*Porzana* cf. *flaviventer*), Azure Gallinule, Black-bellied Plover, Lesser Golden-Plover, Collared Plover (*Charadrius collaris*), Wilson's Plover (*Charadrius wilsonia*), Hudsonian Godwit (*Limosa haemastica*), Ruddy Turnstone (*Arenaria interpres*), Sanderling (*Calidris alba*), Semipalmated Sandpiper, White-rumped Sandpiper, Stilt Sandpiper (*Calidris himantopus*) and Common Snipe (*Capella gallinago*). None of these species, except the Black-bellied Plover and the Semipalmated Sandpiper, were numerous in 1989 (Table 1).

In the present study, the Least Sandpiper was the most abundant shorebird we saw in the rice fields (36.6% of the shorebird population we computed for all the SML rice fields, not including canals). And the numbers of Lesser Yellowlegs we recorded amounted to 33.9% of the estimated total number of shorebirds using the SML rice fields. The two species of yellowlegs accounted for 43.9% of the total. Shorebirds made up the dominant avian group accounting for 62.2% of all birds observed in the rice fields.

Surveys by Morrison and Ross (1989) in South America showed that Suriname is of exceptional importance for yellowlegs and that it was clearly the centre of distribution for these species on the north coast of South America (p. 169). They recorded a total of 66,400 birds which represented 80.3% of the north coast total and 72.8% of the population for the continent. Their coastal surveys did not include the birds in inland rice fields, such as those at Wageningen, which covers only a small portion of the total rice-growing area in Suriname and the neighbouring Guianas. Our results provide emphasis to the importance of rice fields to overwintering yellowlegs. This may also apply to the Least Sandpiper, since Spaans (1978) mentions a maximum number of

50,000-100,000 Least Sandpipers in the coastal lagoons and swamps of Suriname during the peak of migration.

The 11 species of shorebirds we saw and which were not recorded by Vermeer *et al.* (1974) most probably reflects the fact that our study focussed explicitly on shorebirds. Species we saw in small numbers (e.g. Common Snipe, Hudsonian Godwit, Collared Plover, Wilson's Plover) were probably also present in 1971 but in such small numbers that they could have been easily missed.

We also saw larger numbers of Greater Yellowlegs in 1989 because we probably devoted more time distinguishing between the two Yellowlegs species. In 1971, Vermeer *et al.* (1974) reported seeing a daily maximum >1,000 Lesser Yellowlegs on the SML rice fields, compared with our estimate of 2,500-2,600. Greater Yellowlegs were estimated in 1971 to occur daily in numbers ranging between 11-100 birds, compared with our estimate of 750 birds.

Species such as the Semipalmated, Least, Western (*Calidris mauri*) and White-rumped Sandpipers and Semipalmated Plover (*Charadrius semipalmatus*), are known to occur in large numbers either on the coastal mudflats or in the coastal lagoons and swamps of Suriname (Spaans, 1978; Morrison & Ross, 1989). We did not observe any movement of shorebirds between the inland rice fields and the coast in the course of our study. And we did not see on a regular basis, or in any substantial numbers, those species seen more commonly along the intertidal coastal zone, such as Semipalmated and Western Sandpipers and Short-billed Dowitchers (*Limnodromus griseus*) within our study area. It therefore appeared to us that the shorebirds which foraged in the rice fields were more or less sedentary.

2. Habitat Choice and Food

Most species of birds we recorded in cultivated rice fields occurred at highest densities in recently-flooded fields, in flooded fields which were in the process of being harrowed, plowed or levelled (or for which this had been done very recently) and in recently-seeded fields. The same holds for all species combined. Thus rice fields are most attractive to birds from 3 weeks before, to 2 weeks after, the sowing of rice and in particular during and just after flooding, harrowing, plowing and levelling. So the fields are maximally attractive to the birds for a few days per growing season per crop.

Prey eaten by the birds in these fields includes a wide variety of invertebrate and vertebrate species. All species eat insects and/or spiders. The Wattled Jacana and all but one of the North American shorebirds, the Greater Yellowlegs, seem to rely entirely on insects and spiders. Snowy Egrets, Cattle Egrets and Greater Yellowlegs also took amphibians while Great Egrets ate fish and mammals.

The food items we found in the digestive tracts of the Egrets were similar to those reported in Vermeer *et al.* (1974) for Egrets shot in the same rice fields in 1971. As reported in Vermeer *et al.* (1974), we found exclusively spiders, insects and amphibians in the digestive tracts of the Cattle Egret, and, to a great extent, insects and fish in those of the Great Egret. Vermeer *et al.* (1974) did not find mammals in the stomachs of the latter species, as we did. Instead they reported amphibians as a food item in this species. Like us, Vermeer *et al.* (1974) found a high proportion of spiders and insects in the Snowy Egrets they collected. They did not, however, find any amphibians. In contrast, we failed to find any fish. The insect fauna found in the present study, and Vermeer *et al.*'s (1974) were very similar. However, they found a large number of Diptera (flies), which were completely lacking in our samples.

3. Rice Cultivation and Birds

This study reveals that rice fields in tropical South America are major feeding areas used by both indigenous ardeids, rails and jacanas and overwintering shorebirds. We do not exactly know which type of freshwater marshes were in the area before the SML rice fields were created. However, our observations of the marshes in the Wageningen area suggest that the rice fields mainly replaced long grass marshes covered with cattails (*Typha angustifolia*). The avifauna of these marshes is not well studied. On 14 November, we conducted a survey in *Typha* marshes that were converted, but never actually used, as rice fields in the area south of the road between Wageningen and Coronie (see Figure 1). Our census (23 ha) yielded: 1 Anhinga (*Anhinga anhinga*), 4 herons, 10 whistling-ducks, 41 Snail Kites, 7 rails, 6 Limpkins (*Aramus guarauna*), 78 Wattled Jacanas and 1 North American shorebird. This is considerably different from the avifauna we recorded in the SML rice fields which suggests that egrets and North American shorebirds have greatly benefitted from the transformation of *Typha* marshes to rice fields. We do not know, however, if species originally inhabiting the *Typha* marshes have decreased in numbers. We recommend, therefore, that further studies be conducted in freshwater marshes in Suriname to get more insight into this matter in order to propose areas which could be set aside as nature areas, if necessary, from the point of view of conserving biodiversity.

To protect the rice against pest species, the SML rice fields are regularly sprayed with chemicals. In Wageningen, the spraying of chemicals occurs from one week before sowing until a few days before the rice is ready for harvest. During the period that these rice fields are attractive to birds, *AMBUSH* and *BRESTAN* are the primary chemicals sprayed: *AMBUSH* 6-7 days (= 0.9 week) before sowing, *BRESTAN* 3 days (= 0.4 week) before the rice is seeded. Harrowing, plowing and levelling in the flooded fields ends on average 6-7 days before sowing (Table 10). This means that all birds feeding in this habitat run the risk of foraging in fields sprayed with *AMBUSH* (if applied, see Table 12) and 44% (0.4/0.9) of the birds in fields sprayed with *BRESTAN*. Of the 15 species and species-groups distinguished (species with more than 25 birds in the 62 sampling counts, the rest lumped as "others", see Table 1), 12 (80%) have a risk of less than 50% of foraging in fields sprayed with *AMBUSH* and a risk of less than 40% of feeding in fields sprayed with *BRESTAN* (Table 13). Species which scored low (less than 20% chance to feed in fields sprayed with *AMBUSH* and less than 10% in fields sprayed with *BRESTAN*) include the Great Egret, Snowy Egret, Cattle Egret, Solitary Sandpiper, and Gull-billed and Yellow-billed Tern. And those species which scored high (more than 50% chance to feed in fields sprayed with *AMBUSH* or *BRESTAN*) include the Black-bellied Plover (58.9% for each chemical), White-rumped Sandpiper (88.8% for each chemical) and Least Sandpiper (91.0% and 90.5%, respectively). These high percentages are directly related to the high proportion of the population which foraged in recently-seeded rice fields (Black-bellied Plover 58.9%, Least Sandpiper 90.2%, White-rumped Sandpiper 88.8%). The two calidridine species are therefore the two target species which should take priority first for pesticide analysis if the impacts of spraying *AMBUSH* and *BRESTAN* on North American shorebirds in the rice-growing areas of Suriname are to be further investigated.

In November 1989, only half of the SML rice fields were actually in cultivation. In section 05 some fallow fields (e.g. # 100/5-6) appeared to be very attractive to birds, in particular Great Egrets (4.5 birds/ha), Snowy Egrets (0.9 birds/ha), and Least Sandpipers (2.5 birds/ha). According to the SML employees working in that section, large numbers of rodents had developed in these fallow fields. To control the rodents, *AZODRIN* baits were put out on the dams that surrounded these fields. Although we did not find any dead rodents, we saw Great Egrets taking dead mice and probably some of the mice we found in the digestive tracts of the four Great Egrets we collected in section 05 may in fact have been poisoned. Unfortunately, the rodents were not analysed for *AZODRIN* or any toxic chemical so that we cannot reach any firm conclusion about this. *AZODRIN* might have also been responsible for the disappearance of several local species of birds of prey.

We never witnessed the burning of stubble during our stay in the SML area, a process which is known to attract large numbers of birds of prey. It seems to us, however, most unlikely, that the absence of burnt fields was the only reason for the nearly complete absence of birds of prey. In this respect, it is interesting that the Peregrine Falcon, the only bird-eating bird of prey using the SML rice fields during our study, is a migrant from the north.

AZODRIN, which is regularly sprayed in fields with maturing rice (which we did not survey), could also be the cause for the decline in Purple Gallinules. According to Hudson *et al.* (1984) and Smith (1987), *AZODRIN* is very toxic to birds. And on this basis, we recommend that further research be conducted on the possible impacts of *AZODRIN* on egrets, birds of prey and Purple Gallinules.

The data we collected suggest that the potential threats to birds by pesticides which were applied to the SML rice fields in 1989 were high, especially with regard to *AZODRIN*. It is known to be very toxic for mammals and birds, has a high degree of cumulative action, and is moderately toxic to fish. It was used with bait to control rodents where the densities of mice and Great Egrets were high. The potential threats of *BRESTAN*, which does not break down quickly and is moderately toxic to fish, and *AMBUSH*, which is very toxic to fish, were relatively high. This was because of their application just before, and a few weeks after, sowing of the rice when large proportions of the populations of Black-bellied Plover, Least Sandpiper and White-rumped Sandpiper foraged in recently-seeded rice fields.

During our surveys of the SML rice fields in November 1989 we never found a sick or dead bird. This strongly contrasts with the situation in late October to the middle of December in 1971 when several sick and dead Great Egrets, Snowy Egrets and Cattle Egrets, Black-crowned Night-Herons and Wattled Jacanas were found in, and in close proximity to, the SML area. Vermeer *et al.* (1974) found the carcasses of 50 Snail Kites beneath two night roosts just outside the rice fields. The Snail Kites apparently succumbed to PCP poisoning due to an intensive application of *NaPCP* in the rice fields at that time. The other dead and sick birds found in 1971 most probably died from *ENDRIN* intoxication because of the high concentration *ENDRIN* in the birds' tissues and because their presence coincided with a period of intensive application of *ENDRIN* in the rice fields. Fortunately, *NaPCP* and *ENDRIN* are no longer applied which may be the reason why we failed to find any dead and sick birds although we walked through many fields which were attractive to birds.

In summary, there is an obvious need for data on pesticide residues in bird tissues of some species of birds in Suriname in order to determine if present rice cultivation practices may be impairing the reproductive rates of some species and/or posing a serious threat to the wintering populations of Peregrine Falcons, the only species of raptor now using the SML rice fields in winter.

Lesser Yellowlegs are most likely not accumulating toxics in their tissues when foraging in the rice fields in Suriname. There is also no evidence that there is any decline in population numbers of this species. Howe *et al.* (1989) has shown that populations of Lesser Yellowlegs have actually increased by 46% in North America over the period 1972-1983 but that the Greater Yellowlegs, the less numerous Yellowlegs species in Suriname, has declined by 29%. The numbers of Greater Yellowlegs in rice fields would not appear to account for hemispheric declines in the population numbers of this species.

The large mortalities in Snail Kites, egrets, herons and jacanas in 1971, recorded in Vermeer *et al.* (1974), strongly suggests that Suriname's resident birds, especially raptorial species, may be in greater jeopardy than migrant overwintering populations, except perhaps for the Peregrine Falcon.

ACKNOWLEDGEMENTS

We thank Dr. George Finney for making this research project possible and for important support to PWH upon his return from Suriname. We also wish to express our most grateful thanks to Mr. Stanley Malone, head of the Suriname Forest Service when this study was undertaken, for securing comfortable accommodations for us in Nickerie and providing transportation and field assistance.

The major source of funding for AS's participation was provided by the Canadian International Development Agency (CIDA). Financial support was also obtained from Environment Canada's Latin American Program (LAP), through the efforts of Colleen Hyslop, and the Canadian Wildlife Service - Atlantic Region.

Muriel Held provided valuable field assistance and Hank Reichart gave much advice and guidance. Jan van der Steege was most helpful to PWH especially in the early stages of this project. Kris Mohadin and co-workers of STINASU provided logistic support. When staying in Paramaribo we enjoyed the hospitality of the Reicharts and Marga Werkhoven.

The contents of the digestive tracts of the birds we collected were sorted by Alewijn Brouwer. The organisms were identified to the species (group) level by Dr. P.J. van Helsdingen (spiders), Dr. M.S. Hoogmoed (amphibians), Dr. C. Smeenk (mammals) and Dr. J. van Tol (Odonata, Orthoptera, Dictyoptera, Hemiptera) of the Nationaal Natuurhistorisch Museum, Leiden.

To all the above we express our sincere thanks for making this study possible.

LITERATURE CITED

Genstat 5 Committee 1987. *Genstat 5 - Reference Manual.* Oxford University Press, Oxford. 749 pp.

Halteren, P. van. 1972. *Pests and Diseases of Rice in Suriname*. SML, Wageningen, Suriname. 79 pp.

Haverschmidt, F. 1968. *Birds of Surinam*. Oliver & Boyd, Edinburgh and London. 445 pp.

Hicklin, P.W. and A.L. Spaans. 1992. *The Birds of the SML Rice Fields in Suriname. Appendix.* Canadian Wildlife Service, Atlantic Region, Sackville. 100 pp.

Howe, M.A., P.H. Geissler and B.A. Harrington. 1989. Population trends of North American shorebirds based on the International Shorebird Survey. Biological Conservation 49: 185-199.

Hudson, R.H., R.K. Tucker and M.A. Haegele. 1984. *Handbook of Toxicity of Pesticides to Wildlife.* Resource Publication 153. U.S. Fish and Wildlife Service, Washington, D.C. 90 pp.

Husson, A.M. 1978. *The Mammals of Suriname*. Brill, Leiden. 569 pp.

McCormick, K.J. 1990. *Bigi Pan Multiple-Use Management Area. Management Plan*. Environment Canada (Canadian Wildlife Service)/Ministry of Natural Resources (Surinam Forest Service), Paramaribo. 32 pp.

McCullagh, P. and J.A. Nelder. 1989. *Generalized Linear Models*. Chapman and Hall, London. 511 pp.

Morrison, R.I.G. and R.K. Ross. 1989. *Atlas of Nearctic Shorebirds on the Coast of South America.* Canadian Wildlife Service, Ottawa. 2 Vols. 325 pp.

Smith, G.J. 1987. *Pesticide Use and Toxicology in Relation to Wildlife: Organophosphorus and Carbamate Compounds*. Resource Publication 170. U.S. Fish and Wildlife Service, Washington, D.C. 171 p.

Spaans, A.L. 1978. Status and numerical fluctuations of some North American waders along the Surinam coast. Wilson Bull. 90: 60-83.

Steege, J.G. van der. 1987. *The Biological Composition of the Estuarine Area between Burnside (District Coronie) and Wageningen (District Nickerie) in Suriname.* Unpubl. Rept. Suriname Forest Service, Paramaribo. 42 pp.

Vermeer, K., R.W. Risenbrough, A.L. Spaans and L.M. Reynolds. 1974. Pesticide effects on fishes and birds in rice fields of Suriname, South America. Environ. Pollut. 7:217-236.

Worthing, C.R. and R.J. Hance. 1991. *The Pesticide Manual: a World Compendium*. BCPC, Farnham. 1141 p.

TABLES

Table 1. The numbers (and percentages) of fields and the numbers (and percentages) of birds counted over 62 cultivated rice fields (1,024 ha) surveyed on 9-19 November, 1989, in Wageningen, Suriname.

Species[1]	Numbers (%) of fields in which the species was observed		Numbers (%) of birds	
White-necked Heron	5	(8)	11	(0.1)
Great Egret	19	(31)	1,935	(21.0)
Snowy Egret	24	(38)	415	(4.5)
Little Blue Heron	14	(23)	19	(0.2)
Cattle Egret	9	(15)	1,396	(15.2)
Striated Heron	5	(8)	19	(0.2)
Black-crowned Night-Heron	2	(3)	2	(0.0)
Yellow-crowned Night-Heron	1	(2)	1	(0.0)
Blue-winged Teal	1	(2)	1	(0.0)
Osprey	1	(2)	1	(0.0)
Peregrine Falcon	3	(5)	4	(0.0)
Limpkin	3	(5)	4	(0.0)
(Yellow-breasted) Crake[2]	7	(11)	10	(0.1)
Azure Gallinule[3]	2	(3)	2	(0.0)
Black-bellied Plover	15	(24)	166	(1.8)
Lesser Golden-Plover	13	(21)	110	(1.2)
Collared Plover	2	(3)	2	(0.0)
Wilson's Plover	1	(2)	1	(0.0)
Semipalmated Plover	4	(6)	18	(0.2)
Wattled Jacana	11	(18)	159	(1.7)
Greater Yellowlegs	29	(47)	624	(6.8)
Lesser Yellowlegs	26	(42)	2,684	(29.1)
Solitary Sandpiper	17	(27)	48	(0.5)
Spotted Sandpiper	8	(13)	11	(0.1)
Upland Sandpiper	1	(2)	1	(0.0)
Hudsonian Godwit	1	(2)	1	(0.0)
Ruddy Turnstone	1	(2)	1	(0.0)
Sanderling	1	(2)	4	(0.0)
Semipalmated Sandpiper[4]	5	(8)	130	(1.4)
Least Sandpiper	16	(23)	802	(8.7)
White-rumped Sandpiper	5	(8)	119	(1.3)
Stilt Sandpiper	2	(3)	2	(0.0)
Common Snipe	1	(2)	1	(0.0)
Gull-billed Tern	8	(13)	107	(1.2)
Yellow-billed Tern	7	(11)	391	(4.2)
Large-billed Tern	4	(6)	10	(0.1)
Total	62	(100)	9,212	(100)

[1]scientific names of species not mentioned in the text: *Egretta caerulea* (Little Blue Heron), *Actitis macularia* (Spotted Sandpiper), *Bartramia longicauda* (Upland Sandpiper) and *Phaetusa simplex* (Large-billed Tern); [2]originally noted as "small rails", most of them probably belonged to this species; [3]originally noted as "large rails", but some were positively identified as Azure Gallinules; [4]sometimes mixed with Western Sandpipers.

Table 2. The numbers and species of birds counted along eight 1.2 km-long secondary irrigation (irr.) and drainage canals (dr.) surveyed on 9-19 November, 1989, in Wageningen, Suriname.

Species	Canal[1]							
	1 (irr.)	2 (dr.)	3 (irr.)	4 (dr.)	5 (irr.)	6 (dr.)	7 (irr.)	8 (dr.)
White-necked Heron	0	0	0	0	0	0	0	1
Great Egret	0	2	0	0	0	1	3	0
Snowy Egret	0	0	0	0	0	1	1	0
Little Blue Heron	0	0	0	0	0	1	0	0
Cattle Egret	1	3	0	0	0	0	0	0
Striated Heron	5	9	0	4	1	12	1	0
Black-crowned Night-Heron	12	13	0	0	0	0	0	1
Snail Kite	0	1	0	0	1	0	0	0
Purple Gallinule	12	17	0	0	0	0	0	0
Azure Gallinule	0	5	1	0	0	0	0	0
Limpkin	0	0	2	1	0	0	0	0
Wattled Jacana	2	1	6	48	5	0	9	5
Spotted Sandpiper	0	0	0	0	0	0	1	3
Large-billed Tern	0	1	0	0	0	0	0	0
Total	32	52	9	53	7	15	15	10

[1]numbers 1, 2, 4, 5 and 6 with one to four trees along canal.

Table 3. Mean numbers of birds (± s.d.) counted along four secondary irrigation canals and four drainage canals in the SML rice-growing area in Wageningen, Suriname.

Species	Irrigation canal	Drainage canal
White-necked Heron	0	0.3 ± 0.5
Great Egret	0.8 ± 1.5	0.8 ± 1.0
Snowy Egret	0.3 ± 0.5	0.3 ± 0.5
Little Blue Heron	0	0.3 ± 0.5
Cattle Egret	0.3 ± 0.5	0.8 ± 1.5
Striated Heron	1.8 ± 2.2	6.3 ± 5.3
Black-crowned Night-Heron	3.0 ± 6.0	3.5 ± 6.4
Snail Kite	0.3 ± 0.5	0.3 ± 0.5
Purple Gallinule	3.0 ± 6.0	4.3 ± 8.5
Azure Gallinule	0.3 ± 0.5	1.3 ± 2.5
Limpkin	0.5 ± 0.9	0.3 ± 0.5
Wattled Jacana	5.5 ± 2.9	13.5 ± 23.1
Spotted Sandpiper	0.3 ± 0.5	0.8 ± 1.5
Large-billed Tern	0	0.3 ± 0.5
Total	15.75 ± 11.35	32.50 ± 23.19

Table 4. Mean numbers of birds (± s.d.) counted along four secondary irrigation canals and four drainage canals, with (1-4) and without trees, in the SML rice-growing area in Wageningen, Suriname.

Species	Canals with trees (n=5)	Canals without trees (n=3)
White-necked Heron	0	0.3 ± 0.6
Great Egret	0.6 ± 0.9	1.0 ± 1.7
Snowy Egret	0.2 ± 0.4	0.3 ± 0.6
Little Blue Heron	0.2 ± 0.4	0
Cattle Egret	0.8 ± 1.3	0
Striated Heron	6.2 ± 4.3	0.3 ± 0.6
Black-crowned Night-Heron	5.0 ± 6.9	0.3 ± 0.6
Snail Kite	0.4 ± 0.5	0
Purple Gallinule	5.8 ± 8.1	0
Azure Gallinule	1.0 ± 2.2	0.3 ± 0.6
Limpkin	0.2 ± 0.4	0.7 ± 1.2
Wattled Jacana	11.2 ± 20.7	6.7 ± 2.1
Spotted Sandpiper	0	1.3 ± 1.5
Large-billed Tern	0.2 ± 0.4	0
Total	31.8 ± 20.9	11.3 ± 3.2

Table 5. The mean numbers of birds (± s.d.) in secondary irrigation and drainage canals and the estimated total numbers of each species for all the secondary irrigation and drainage canals (136.8 km) surveyed on 9-19 November, 1989, in the SML rice-growing area in Wageningen, Suriname.

Species	Number/km	Estimated total number
White-necked Heron	0.13 ± 0.35	18
Great Egret	0.75 ± 1.17	103
Snowy Egret	0.25 ± 0.46	34
Little Blue Heron	0.13 ± 0.35	18
Cattle Egret	0.50 ± 1.07	68
Striated Heron	4.00 ± 4.47	547
Black-crowned Night-Heron	3.25 ± 5.73	445
Snail Kite	0.25 ± 0.46	34
Purple Gallinule	3.63 ± 6.84	497
Azure Gallinule	0.75 ± 1.75	103
Limpkin	0.38 ± 0.74	52
Wattled Jacana	9.50 ± 15.83	1,300
Spotted Sandpiper	0.50 ± 1.07	68
Large-billed Tern	0.13 ± 0.35	18
Total	24.13 ± 19.13	3,305

Table 6. Mean numbers of birds per ha in the SML cultivated rice fields surveyed on 9-19 November, 1989, in Wageningen, Suriname. Statistical differences between successive stages of rice cultivation are also indicated (* = $0.01 < P < 0.05$, ** = $0.001 < P < 0.01$, *** = $P < 0.001$).

Species	Fallow fields[1]		Harvested fields[2]		Recently flooded fields[3]		Flooded fields with agricultural activities[4]		Flooded fields with recent activities[5]		Recently seeded fields[6]		Ripe rice fields[7]
Great Egret	4.5	**	0.1		0.3	***	11.7	***	0.1		0.1		0
Snowy Egret	0.9	**	0		0.2	***	1.9	***	0.2		+[8]		0
Cattle Egret	0		0	**	3.8		3.4		1.0		0		0
Black-bellied Plover	0		0	**	0.4		0.3	**	+	**	0.4	**	0
Lesser Golden-Plover	0		+	**	0.3	*	0.1		0.1		0.1		0
Wattled Jacana	0		0		0.1	**	0.7	**	0.2		0		0
Greater Yellowlegs	+		0	**	1.0		2.1	***	0.4		0.4		0
Lesser Yellowlegs	0		0	*	4.6		7.8		2.6		0.1		0
Solitary Sandpiper	+		0.1		0.1		0.1		+		+		0
Semipalmated Sandpiper[9]	0		0		+	***	0.8	***	0	*	0.1		0
Least Sandpiper	2.5	***	0		0.2	*	1.3	**	0.1	***	4.8	***	0
White-rumped Sandpiper	+		0		0	**	0.3	**	+		0.7	***	0
Gull-billed Tern	0		0		0.1	***	0.7	***	+		0		0
Yellow-billed Tern	0		0		0.1	***	2.8	***	+		0		0
Others[10]	0.1		0.2		0.1	*	0.3	**	0.1	*	0.2	**	0
Total	8.0		0.4	**	11.1	**	34.3	***	4.8		7.0	*	0
Number of fields	2		9		8		7		24		4		8
Total area (ha)	58.5		132.9		166.4		135.4		324.1		107.25		99.3

[1]fields # 100/5-6; [2]fields # 31/1, 38/1, 63/1, 64/1, 66/1, 67/1, 70/1, 71/1-2; [3]fields # 32/1-3, 36/1-2, 62/1-3; [4]harrowing, plowing, levelling: fields # 36/3, 72/1-2, 5, 73/5, 98/2-3; [5]fields # 33/1-4, 34/1-6, 37/1-3, 59/1-6, 72/3-4, 6, 83A/1-2; [6]fields # 97/1-2, 99/7, 9; [7]fields # 30/1, 35/1-2, 58/1, 60/1, 61/1, 68/1, 69/1 (difference between ripe rice fields and harvested fields significant (**) for Solitary Sandpiper and the group of "other" species); [8]< 0.05 birds/ha; [9]sometimes mixed with Western Sandpipers; [10]species for which we had less than 25 birds found in our total sample.

Table 7. Estimated total numbers of birds using the SML rice fields and canals on 9-19 November, 1989 (this study) and in October-December, 1971 (Vermeer *et al.*, 1974) in Wageningen, Suriname.

Bird species	Number in rice fields in 1989[1] A	B	Number along canals in 1989[2]	Total number in 1989[3]	Total number in 1971[4]
Great Egret	1,720	2,000	103	2,100	101-1,000
Snowy Egret	327+	400	34	450	>1,000
Cattle Egret	1,430	1,430	68	1,500	>1,000
Striated Heron	100	100	547	650	1-10
Black-crowned Night-Heron	0	0	445	450	1-10
Purple Gallinule	0	0	497	500	>1,000
Black-bellied Plover	299+	300-350	0	300-350	0
Lesser Golden-Plover	139+	150-200	0	150-200	0
Wattled Jacana	150	150	1,300	1,450	101-1,000
Greater Yellowlegs	735	750	0	750	11-100
Lesser Yellowlegs	2,518	2,500-2,600	0	2,500-2,600	>1,000
Solitary Sandpiper	107+	100-150	0	100-150	11-100
Semipalmated Sandpiper	148+	150-200	0	150-200	0
Least Sandpiper	2,342	2,500-3,000	0	2,500-3,000	1-10
White-rumped Sandpiper	347+	350-400	0	350-400	0
Gull-billed Tern	112+	125	0	125	>1,000
Yellow-billed Tern	385+	400	0	400	11-100
Others[5]	213	225	311	550	p.m.[6]
Total	11,072+	11,630-12,480	3,305	15,000-16,000	

[1]A: not including fallow fields, for the calculation of the numbers see text, B: including fallow fields; [2]taken from Table 5; [3]figures rounded of; [4]estimates, no extrapolation of counts; [5]species with less than 25 birds in the 62 rice fields or 8 canals counted; [6]White-necked Heron 11-100, Little Blue Heron 11-100, Tricolored Heron 1-10, Black-bellied Whistling-Duck 101-1,000, Black Vulture 101-1,000, Turkey Vulture 11-100, White-tailed Kite 1-10, Snail Kite 101-1,000, Savanna Hawk 1-10, White-tailed Hawk 11-100, Long-winged Harrier 11-100, Osprey 1-10, Yellow-headed Caracara 1-10, Crested Caracara 1-10, Limpkin 11-100, Semipalmated Plover 1-10, Upland Sandpiper 1-10, Spotted Sandpiper 1-10, Large-billed Tern 11-100, Barn Owl (*Tyto alba*) 11-100.

Table 8. Frequency of occurrence (%) and mean number of prey items per bird from the digestive tracts of birds collected in flooded fields in the process of being harrowed, plowed or levelled (or which had been very recently harrowed, plowed or levelled).

Bird species	Types of foods									
	Mammals		Amphibians		Fish		Spiders		Insects	
	%	mean	%	mean	%	mean	%	mean	%	mean
Great Egret (4)[1]	100	1.8	0	-	75	4.3	0	-	100	28.3
Snowy Egret (1)[2]	0	-	100	1.0	0	-	100	3.0	100	18.0
Cattle Egret (2)[3]	0	-	100	2.0	0	-	100	19.0	100	42.5
Wattled Jacana (1)[4]	0	-	0	-	0	-	100	1.0	100	1.0
Greater Yellowlegs (2)[5]	0	-	50	1.0	0	-	50	0.5	100	5.5
Lesser Yellowlegs (6)[6]	0	-	0	-	0	-	67	1.3	100	17.3
Solitary Sandpiper (1)[7]	0	-	0	-	0	-	0	-	100	3.0

[1]field # 98/8; [2]field # 99/2; [3]field # 89/1; [4]field # 89/1; [5]fields # 83/1, 98/1; [6]fields # 83/1, 83A/3, 98/1; [7]field # 83/1.

Table 9. Taxonomic Orders and Families of the insects (total number of food items in brackets following name of prey) recovered from the digestive tracts of three ardeids and four shorebird species (number of birds examined in brackets) collected in flooded fields in the process of being harrowed, plowed or levelled (or which had been very recently harrowed, plowed or levelled).

Great Egret (4):
Odonata, Libellulidae, cf. *Pantala flavescens* (58 nymphs), undetermined (2)
Orthoptera, Acrididae (1), Gryllidae (18), ?Gryllidae (31)
Coleoptera, ?Dytiscidae (1 larva)
Undetermined insects (2)

Snowy Egret (1):
Orthoptera (3)
Hemiptera, Naucoridae (5)
Coleoptera (1; 7 larvae)
Undetermined insects (2)

Cattle Egret (2):
Odonata (1)
Orthoptera, Acrididae (1), ?Acrididae (7), Gryllidae (55)
Dictyoptera (12)
Coleoptera (1)
Undetermined insects (8)

Wattled Jacana (1):
Orthoptera (1)

Greater Yellowlegs (2):
Orthoptera, either Gryllotalpidae or Gryllidae (3)
Coleoptera (7; 1 larva)
Undetermined insects (1)

Lesser Yellowlegs (6):
Orthoptera, either Gryllotalpidae or Gryllidae (2), ?Orthoptera (2)
Dictyoptera (1)
Hemiptera (1 larva and 1 nymph)
Coleoptera, Carabidae (3), Curculionidae (8), undetermined (79; 4 larvae)
Undetermined insects (2: 1 either Notonectidae or Hydrophilidae, 1 larva)

Solitary Sandpiper (1):
Orthoptera, either Gryllotalpidae or Gryllidae (1)
Coleoptera (2)

Table 10. Computation of the total area of each habitat type we surveyed in rice fields under cultivation in November 1989. Only those habitats in which we found birds are included in the calculations.

Habitat type	Weeks present per cycle	% of total cycle (23.5 weeks)[1]	Area (ha) (% x 4,900 ha)[2]
Harvested field before flooding	3.5	14.9	730
Flooded field			
(a) before cultivation[3]	1.0	4.3	210
(b) during cultivation[3]	0.6	2.6	130
(c) after cultivation[3]	0.9	3.8	190
Recently-seeded fields	2.1[4]	8.9	440

[1]5-7 weeks before seeding plus 17. 5 weeks (4 months) growth period of rice; [2]area under cultivation in 1989; [3]cultivation: harrowing, plowing and levelling; [4]10 days after seeding the rice is 10-15 cm high, we have assumed that after another 5 days plants will have become too high to be attractive for the birds.

Table 11. Quantities of chemicals used in the SML rice fields from the middle of October 1988 through the middle of October 1989 (SML, pers. comm.). Amounts are in liters unless otherwise noted.

Chemical	First crop (4,511 ha)	Second crop (5,652 ha)	Total (10,163 ha)
Herbicides:			
PROPANIL	9,060.0	12,733.5	21,793.5
2,4-D	4,400.0	5,993.5	10,393.5
DOWPON	-	230.0 kg	230.0 kg
GRAMOXONE	1,220.0	998.0	2,218.0
Molluscicides:			
BAYLUSCIDE	4.0 kg	38.0 kg	42.0 kg
BRESTAN	3028.0 kg	3,705.5 kg	6,733.5 kg
Insecticides[1]:			
AMBUSH	131.1	264.6	395.7
AZODRIN	9,103.5	10,362.5	19,466.0
KARATE	10.4	6.4	16.8
BASRA/OSBAC	-	5,033.5	5,033.5
ETROFOLAN	-	70.0 kg	70.0 kg

[1]Target species: waterweevils, leaf miners, rice loopers, rice leaf folders, planthoppers, grasshoppers, shield bugs, paddy bugs, leafhoppers, and white and brown borers.

Table 12. Spraying schedule for chemicals in relation to the number of days before/after sowing the rice in the SML rice fields in 1989 and the quantities applied per ha, and target species (SML, pers. comm.).

Rice stage (days before/after)	Chemical applied	Quantity	Target species	Remarks
6-7 before	*AMBUSH*	0.1 liters	Waterweevils	Sometimes
0-7 before	*BRESTAN/ BAYLUSCIDE*	?	*Pomacea* snails	Same
3-8 after	*AMBUSH*	0.3 liters	Caterpillars	
14-16 after	*PROPANIL*	3 liters	Grasses and caterpillars	
	AMBUSH	0.03 liters		
	AZODRIN	3 liters		
21-22 after	*AZODRIN*	3 liters		If necessary
24-28 after	*AZODRIN*	0.3 liters		
28 after	*2,4-D*	3 liters	Weeds	At high coverage of *Luziola spruceana*
30-40 after	*AZODRIN*	0.5 liters	Borers	If necessary
44 after	*BRESTAN*	0.75 kg	Algae	If necessary
48-68 after	*AZODRIN*	0.15 liters	Borers	If necessary
80-82 after	*AZODRIN*	0.3 liters	Paddy bugs	If necessary repeating spraying after 7-8 days

Table 13. Numbers of birds per rice field habitat type (only habitat types for rice fields under cultivation and with feeding birds present are included), and average proportion (%) of bird population running the risk of feeding in fields sprayed with *BRESTAN* and *AMBUSH*.

Bird species	Harvested fields	Recently flooded fields	Flooded fields with agricultural activities[1]	Flooded fields with recent activities[1]	Recently seeded fields	Total	% population at risk *BRESTAN*	*AMBUSH*
Great Egret	73	63	1,521	19	44	1,720	3.0	3.7
Snowy Egret	0	42	247	38	+	327	5.2	11.6
Cattle Egret	0	798	442	190	0	1,430	5.9	13.3
Black-bellied Plover	0	84	39	+	176	299	58.9	58.9
Lesser Golden-Plover	+[2]	63	13	19	44	139	37.4	45.3
Wattled Jacana	0	21	91	38	0	150	11.3	25.3
Greater Yellowlegs	0	210	273	76	176	735	28.4	34.3
Lesser Yellowlegs	0	966	1,014	494	44	2,518	10.4	21.4
Solitary Sandpiper	73	21	13	+	+	107	0	0
Semipalmated Sandpiper	0	+	104	0	44	148	29.7	29.7
Least Sandpiper	0	42	169	19	2,112	2,342	90.5	91.0
White-rumped Sandpiper	0	0	39	+	308	347	88.8	88.8
Gull-billed Tern	0	21	91	+	0	112	0	0
Yellow-billed Tern	0	21	364	+	0	385	0	0
Others	146	21	39	19	88	313	30.7	34.2
Total	292	2,373	4,459	912	3,036	11,072	31.0	35.7

[1]harrowing, plowing, levelling; [2]<0.05 birds/ha.