SOME ECONOMIC EFFECTS OF OUTBREAKS OF BLACK FLIES (*SIMULIUM LUGGERI* NICHOLSON AND MICKEL) IN SASKATCHEWAN[1]

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ABSTRACT

Larvae of Simulium luggeri *Nicholson and Mickel were first detected in the South Saskatchewan River in 1968, coincidental with appearances of aquatic weeds. They became abundant in both the South and North branches in Saskatchewan by 1971. Damaging outbreaks occurred for the following reasons: larvae readily drifted downriver and colonized extensive beds of weeds,* S. luggeri *is multivoltine, adults dispersed widely and attacked most mammals including people, swarming about heads causing stress and hyperactivity. During outbreaks, grazing and breeding activities of livestock were interrupted and lactation reduced. Increased incidence of stress-related injuries and diseases including broken limbs, keratitis, mastitis, calfhood scours and pneumonia occurred.*

Chronic outbreaks of S. luggeri *have occurred every summer since 1975 in east-central Saskatchewan. Use of methoxychlor larvicide reduced potential severity of many outbreaks. The most destructive outbreaks occurred in 1978 when black flies spread onto about 38,000 km^2 of east-central Saskatchewan and caused measurable economic losses in about 5,700 km^2. Losses to beef producers in 1978 were estimated to have exceeded $2.9 million and included unrealized weight gains, delayed conceptions, fatalities, replacement of debilitated bulls and increased costs for labour, veterinarians' services, fence repairs and supplementary feeding. Losses to dairy producers were estimated to have exceeded $57,000. Milk production from severely affected cows did not return to normal until after new lactation cycles commenced, sometimes several months after outbreaks ceased in the fall.*

Producers responded in several ways, for example by changing management practices, by reducing or eliminating herds, by converting pasture lands to less productive uses, and by submitting petitions to governments for improved control of larvae.

RÉSUMÉ

En 1968, la mouche noire, Simulium luggeri *Nicholson & Mickel, commençait à se reproduire dans la rivière Saskatchewan. L'apparition de* S. luggeri *a coincidé avec l'envahissement de la rivière par la flore aquatique. Selon l'auteur, des attaques sévères de mouche noire se sont produites pour les raisons suivantes: les larves sont aisément entraînées par le courant et s'attachent aux vastes bancs de plantes aquatiques; la mouche noire est plurivoltine; les insectes adultes sont capables de coloniser de vastes superficies et ils s'attaquent à la plupart des mammifères, y compris l'homme; les insectes ont tendance a s'attaquer à la tête des animaux, causant chez ceux-ci des signes de stress et d'hyperactivité. Au cours des attaques de mouche noire, on a observé que les animaux cessaient de brouter et de se reproduire et que les vaches en lactation produisaient moins de lait. On a aussi noté un nombre accru de blessures et de maladies causées par le stress, telles que membres rompus, kératite, mastite, diarrhée du veau et pneumonie.*

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[1]Contribution No. 866 of the Research Station, Saskatoon

Les attaques de mouche noire se sont produites de façon chronique chaque été depuis 1975 dans la région centre-est de la Saskatchewan. L'emploi du larvicide méthoxychlor a contribué à réduire la sévérité de plusieurs attaques. Les attaques les plus sévères se sont produites en 1978, les mouches noires infestant près de 38 000 km² et causant des dommages mesurables sur près de 5 700 km². En 1978, les pertes subies par les producteurs de boeuf de boucherie ont été estimées à plus de 2.9 millions de dollars. Ces pertes ont resulté des faits suivants: gains de poids plus lents, conceptions retardées, pertes d'animaux, ainsi que coûts de remplacement des taureaux malades, de la main d'oeuvre supplémentaire, des soins vétérinaires, des réparations aux clôtures et des suppléments alimentaires. Par ailleurs, les producteurs laitiers ont subi des pertes estimées à plus de 57 000 $. Il fut observé que le rendement des vaches laitières sérieusement atteintes ne redevenait normal qu'après le début d'un nouveau cycle de lactation, qui ne survenait parfois que plusieurs mois après la disparition des mouches noires, en automne. Les producteurs ont combattu la mouche noire de différentes façons: en modifiant leurs méthodes de gestion, en réduisant ou en éliminant complètement les troupeaux, en utilisant les pâturages à des fins moins productives, ou en pétitionnant pour l'amélioration du contrôle des larves.

INTRODUCTION

Every summer since widespread outbreaks of the black fly *Simulium luggeri* Nicholson and Mickel commenced in 1976 in east-central Saskatchewan, residents have demanded government assistance with abatement. Methoxychlor larvicide is effective (Fredeen, 1974, 1975) and its use in the Saskatchewan River apparently is not permanently harmful to non-simuliid fauna (Fredeen, 1983). However, use of larvicide cannot be condoned without unequivocal proof of need. The purpose of this paper is to compile and assess evidence of losses to beef and dairy cattle producers in Saskatchewan resulting from outbreaks of *S. luggeri*.

Populations of black fly larvae in both branches of the Saskatchewan River in Saskatchewan were dominated by *S. arcticum* until the mid-1970's. From this river sporadic outbreaks of *S. arcticum* spread widely into surrounding farmlands killing numerous animals (Rempel and Arnason, 1947; Fredeen, 1958). Major outbreaks of *S. arcticum* ceased in 1948 with the advent of chemical larviciding (Fredeen, 1953, 1977(a)) but minor outbreaks continued because of downstream drift of eggs and larvae from untreated sections.

In early years, the Saskatchewan river usually was deep and turbid throughout much of the ice-free season with beds of sand and rocks completely free of vegetation. In 1968, completion of a hydroelectric dam on the South Saskatchewan River, 115 km south of Saskatoon (about 350 km above its confluence with the North Saskatchewan River) (Fig. 1) created a reservoir 250 km long, a complete barrier to further migration of larvae down that river (Fredeen, 1977(b)). By 1971 the South Saskatchewan River below the reservoir had become relatively shallow during ice-free months due to storage of water for wintertime generation of hydropower (Fig. 2, S.S.R.). The reservoir served as a sink for suspended solids, and the combination of shallow, clear water in the river below the dam allowed sufficient insolation to encourage, for the first time, growth of massive beds of algae[1] and broad-leaved plants[2] on the river bed. Growths of aquatic plants undoubtedly also were enhanced by nutrients released from urban and rural communities. This is evident today when comparing growths above and below large cities on the Saskatchewan River.

In 1975 similar trends became evident in the North Saskatchewan River (Fig. 2, N.S.R.). Relatively shallow, clear water replaced the large, turbid summertime volumes of previous years. This was due in part to drought conditions which greatly reduced runoff in a major

[1]Mainly *Cladophora glomerata* (L.) Kutzing

[2]The four most common species are *Ceratophyllum demersum* L., *Myriophyllum exalbescens* Fernald, *Potamogeton crispus* L., *P. pectinatus* L.

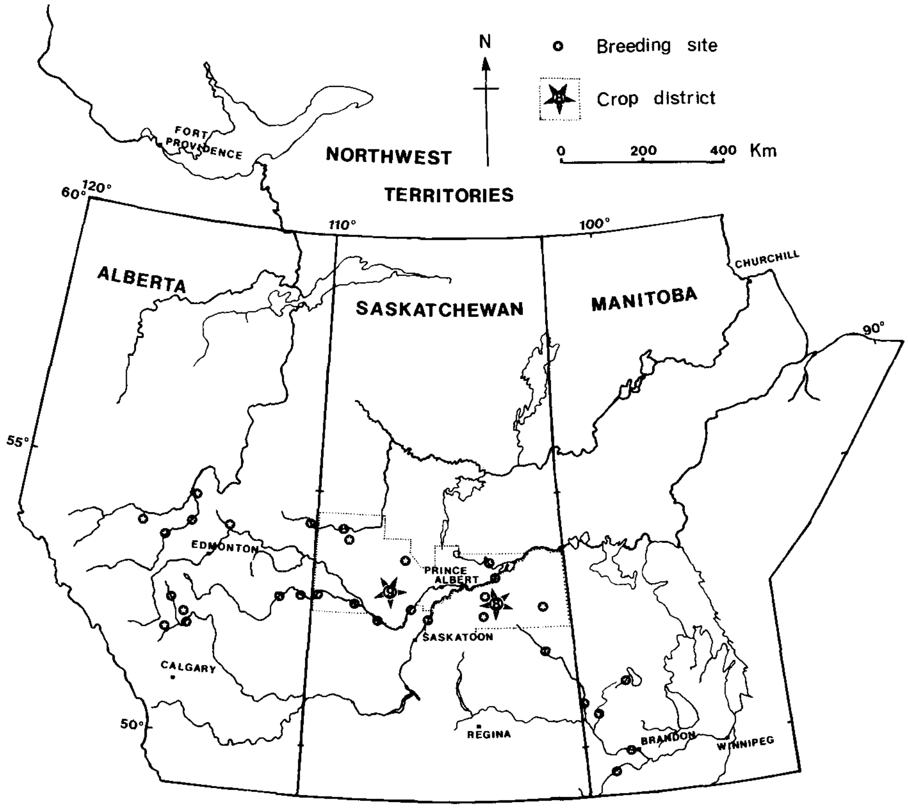

Fig. 1. Map of Alberta, Saskatchewan and Manitoba indicating sites where immature stages of *Simulium luggeri* were collected from the Saskatchewan River in southern Saskatchewan and Alberta, and from other river systems. The boundaries of Crop Districts 8 and 9 outline regions in Saskatchewan where most outbreaks occurred in recent years.

portion of that watershed, and in part to completion of two hydroelectric reservoirs in the foothills, Brazeau in 1962 and Abraham Lake in 1972. Together they controlled about half of the volume of water reaching the lower end of the North Saskatchewan River. Extensive summertime beds of algae and aquatic broad-leaved plants appeared, especially between Edmonton, Alberta and North Battleford, Saskatchewan. Paterson and Nursall (1975) suggested that the presence of algae below Edmonton was the result of increased nutrient content (chiefly nitrates) in that portion of the river. Weed beds above North Battleford are occupied mainly with larvae of *S. vittatum* Zetterstedt, a species relatively tolerant of organic pollution.

These environmental changes in both branches of the Saskatchewan River discouraged accumulation and development of larvae of *S. arcticum* which prefer to attach to clean boulders in fast-flowing water, but encouraged invasions of *S. luggeri*, *S. vittatum*, *S. meridionale* Riley,

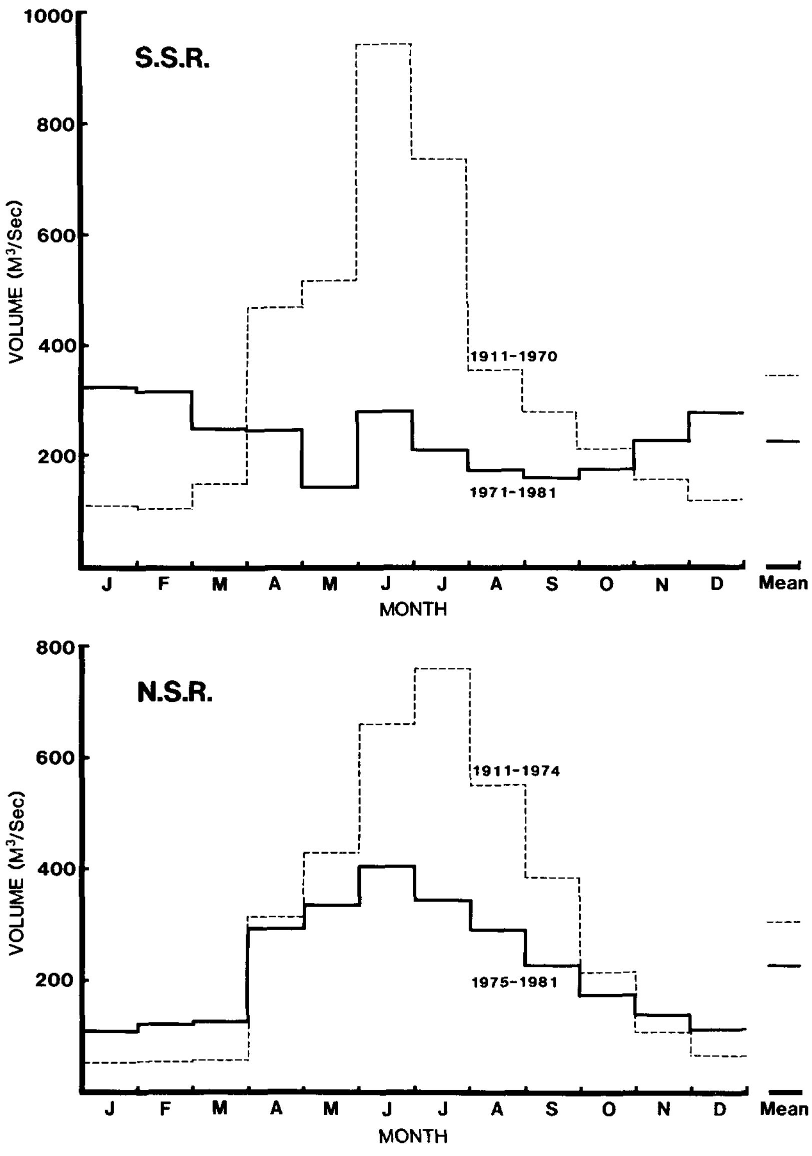

Fig. 2. Average monthly volume flows in the Saskatchewan River: S.S.R. = South Saskatchewan River at Saskatoon, 1911 through 1970, and 1971 through 1981; N.S.R. = North Saskatchewan River 1911 through 1974, and 1975 through 1981 (Environment Canada 1980 (a), 1981, 1982).

TABLE 1. MAXIMUM DENSITIES OF LARVAE AND PUPAE OF FOUR SPECIES OF BLACK FLIES OBSERVED ON NATURAL AND ARTIFICIAL SUBSTRATES IN THE NORTH AND SOUTH SASKATCHEWAN RIVERS IN SASKATCHEWAN (NUMBER/CM^2)

	North Saskatchewan River near Prince Albert, Sask.				South Saskatchewan River near Birch Hills, Sask.			
	S. arcticum	*S. luggeri*	*S. meridionale*	*S. vittatum*	*S. arcticum*	*S. luggeri*	*S. meridionale*	*S. vittatum*
1947 to 1968	100+	<1	<1	<1	100+	<1*	<1	<1
1969	8	0	<1	<1	8	<1	<1	3
1970	91	<1	<1	<1	–	–	–	–
1971	49	3	<1	<1	–	–	–	–
1972	36	6	<1	<1	–	–	–	–
1973	34	1	<1	18	–	–	–	–
1974	3	<1	<1	<1	–	–	–	–
1975	35	10	<1	<1	–	–	–	–
1976	12	32	<1	1	–	–	–	–
1977	13	128	<1	20	3	37	<1	16
1978	2	65	2	13	3	61	<1	15
1979	2	70	6	316	1	12	<1	6
1980	4	98	9	370	1	17	<1	20
1981	9	64	26	469	1	30	<1	52

*In the South Saskatchewan River larvae of *S. luggeri* were first detected in 1968.

and other species which prefer to attach to leaves of aquatic plants (Fredeen, 1981).

RECENT TRENDS IN SPECIES OF BLACK FLIES INHABITING THE SASKATCHEWAN RIVER IN SASKATCHEWAN

Methods

Annual trends in maximum densities of larvae of the four main species of black flies inhabiting the north and south branches of the Saskatchewan River in Saskatchewan are shown in Table 1. Until 1969, populations of larvae were estimated by counting numbers attached to rocks collected from rapids. In 1969 accuracy of estimates presumably was improved when we began to anchor artificial substrates for larvae to attach to (metre-length pieces of rope) (Fredeen and Spurr, 1978). Between 1969 and 1976 larvae were counted at weekly intervals for only a few weeks in late spring each year or until chances of outbreaks of *S. arcticum* were considered to have ended for the year (*S. arcticum* generally peaked in May or June). But beginning in 1977, weekly samples were collected throughout each summer from both branches of the Saskatchewan River because the newly-established *S. luggeri* was multivoltine and larvae were abundant and had to be monitored throughout much of the ice-free season.

South Saskatchewan River

Populations of larvae in the South Saskatchewan River were dominated by *S. arcticum* each spring until about 1977 (Table 1). The final major outbreak of *S. arcticum* believed to have originated at least in part from the South Saskatchewan River, occurred June 13 to 18, 1967. In that outbreak 43 animals were known to have been killed in communities extending southeastwards more than 100 km from Prince Albert.

Larvae of *S. luggeri* (indicating a breeding population) were first collected from the South Saskatchewan River in July and August, 1968. But it was not until 1977 that we commenced regular weekly collections from that river and these showed that *S. luggeri* had replaced *S. arcticum* as the dominant species. Previously, I had found it breeding only in small, weedy rivers across Manitoba, Saskatchewan and Alberta (Fig. 1). Shewell (1958) reported it from the Churchill River on Hudson Bay and from the Mackenzie River and tributaries as far north as Norman Wells, N.W.T. The earliest observed outbreak of *S. luggeri*, believed to have originated from the South Saskatchewan River, occurred on August 22, 1972 when this species was identified in swarms causing cattle to run. Since then outbreaks of varying severity have originated from the final 150 km of this river every year.

North Saskatchewan River

The final recorded outbreak of *S. arcticum* of economic proportions from the North Saskatchewan River occurred in mid-June 1972. During that outbreak at least 19 cattle were killed near a section of that river upstream from Prince Albert.

In 1971 and 1972, during tests of artificial substrates, there were significant increases in numbers of larvae of *S. luggeri* in samples collected in late summer from several sites in the North Saskatchewan River indicating establishment of a breeding population in that river. Previously, larvae had been collected from the North Saskatchewan River only from restricted sites below the mouths of small tributaries.

In May through October 1975, the volume of the North Saskatchewan was greatly reduced (to about 50 percent of long-term means) and coincidentally by early June, larvae of *S. luggeri* became unusually abundant. In May, 1976 its larvae outnumbered those of *S. arcticum* in the

North Saskatchewan for the first time (Table 1) and within a month the first widespread outbreaks of *S. luggeri* began from that river. Since then, larvae of *S. luggeri* have remained relatively abundant, especially in the final 300 km of the North Saskatchewan River before its confluence with the south branch, and in the entire 130 km of the main Saskatchewan River between the confluence and Tobin Lake at Nipawin (Fig. 1). Although numbers of larvae of *S. vittatum* began to surpass those of *S. luggeri* by 1979 (Table 1), significant outbreaks of that species have not been reported yet, perhaps because livestock appear to be relatively tolerant of it. Larvae of *S. arcticum* still occur regularly although in small numbers every year in both branches of the Saskatchewan River, indicating potential for staging a comeback should conditions change in its favor.

CHRONOLOGY OF OUTBREAKS OF *S. LUGGERI* FROM THE SASKATCHEWAN RIVER

1976

In 1976, larvae of *S. luggeri* accumulated on artificial substrates (rope pieces) anchored in the North Saskatchewan River in rapids 22 km below Prince Albert, Saskatchewan at an average rate of 1550 larvae per metre of rope per week during May and June. A maximum density of 32 larvae per cm^2 of substrate surface (Table 1) was observed on June 22. Populations were not measured in the South Saskatchewan River that year. Although the maximum density observed in the North Saskatchewan was three times larger than that observed in 1975 there were no concerns about possibilities of damaging outbreaks because *S. luggeri* had not been known to lethally poison animals as did its predecessor, *S. arcticum*. Also there had been no complaints of black fly attacks on livestock in 1975, although a year or more later some producers did recall that their cattle had been noticeably bothered by black flies in 1975.

Environmental changes in 1976 that may have accounted, at least in part, for observed increases in numbers of larvae included greatly reduced river volumes and higher water temperatures. Ice on the North Saskatchewan River broke up a week earlier than normal that spring, and water volumes in both branches remained much below normal throughout May, June and July. Also mean daily air temperatures in May were 17 percent above normal and hours of sunshine 32 percent above normal. For all of these reasons, river water in both branches of the Saskatchewan River warmed up more rapidly than normal that spring, attaining daily maxima of 20°C 3 to 4 weeks earlier than in previous years. Also, because relatively low water levels and low water turbidities had allowed greatly increased insolation, growths of aquatic weeds (favored attachment sites for larvae of *S. luggeri*) and planktonic algae (which served as food) were increased.

During ice-free months in earlier years, water turbidities as high as 7270 mg/L were reported for the South Saskatchewan River and 3050 mg/L for the North Saskatchewan (Environment Canada, 1980 (b)). Microscopic examination of turbid water showed phytoplankters to be very scarce but numbers were not recorded.

In 1976, weekly measurements of turbidity indicated summertime maxima of only 52 mg/L for the south branch at Birch Hills and 99 mg/L for the north branch near Prince Albert. Phytoplankters were so abundant that the water was greenish, but numbers were not counted. In 1978, under similar turbidity conditions (maxima of only 97 mg/L for the south branch and 211 for the north), maxima of 550 and 1100 phytoplankters per 0.001 mL of river water were recorded for these two branches.

Weather conditions, especially air temperatures, also generally favored black fly attacks on animals. Attacks by *S. luggeri* are most vigorous between about 20 and 25° C, and daily maximum temperatures above 20° C were recorded on 21 days in May, 19 in June, 28 in July and 28 in August.

In 1976, pupae of *S. luggeri* were first collected on May 25. The first report of outbreaks in 1976 came from Mr. Glen Love, who had a mixed farm between the north and south branches of the Saskatchewan River about 30 km east of Prince Albert. He first observed black flies around his cattle on the afternoon of May 29. From then on until June 8 his livestock were so severely attacked when outside during daylight hours that they had to be fed and watered indoors. Mr. Love marketed most of his cattle on June 8 to avoid further costs of supplementary food and labour. Black fly swarms at that time consisted of 98 percent *S. luggeri* with about 2 percent *S. arcticum*, *S. meridionale* and *S. vittatum*.

During that first week of June, livestock throughout a 7,000 km^2 area, extending some 30 km on either side of the entire Saskatchewan River between Prince Albert and Nipawin (Fig. 3), were severely attacked by *S. luggeri* every day. Producers claimed that their cattle were continually surrounded by clouds of black flies during daylight hours and that attacks were especially severe before thunderstorms on June 3 and 4. Smudges were kept burning throughout the region, even in the largest community pastures. There were numerous complaints from people who claimed they also were bitten. Even with repellents, black flies swarmed around them so thickly that they could not avoid breathing them in.

Cooler weather (daily maxima of 13 to 20°C) on 11 days between June 8 and 26 was believed responsible for several lulls in outbreaks. There was also a decline in numbers of larvae in the river until after second generation larvae appeared in June. However, between June 26 and July 15 swarms of *S. luggeri* again severely affected livestock and people in widespread areas, including an additional 10,000 km^2 of rural and urban lands to the south, and 6,000 km^2 of recreational lands to the north, extending almost as far north as La Ronge (Fig. 3). This second series of outbreaks declined noticeably by mid-July, apparently due in part to a single injection of methoxychlor larvicide into the North Saskatchewan River on July 7.

A third series of widespread outbreaks in 1976 occurred throughout most of August and September and lasted until warm weather ended in the fall.

In summary, residents in some 23,000 km^2 of agricultural and recreational areas in Saskatchewan complained in 1976 of black fly outbreaks, by telephone calls and letters to federal and provincial offices in at least ten centres. Complaints of damage to livestock came from producers from diverse regions totalling about 2,500 km^2. There were three major periods of attack, probably related in part to production of at least three generations of *S. luggeri*. Ninety-five to 99 percent of the black flies in attacking swarms were *S. luggeri*. The remainder were *S. arcticum*, *S. meridionale* and *S. vittatum* as indicated by sweep net collections.

1977

The larval monitoring program was greatly enlarged in 1977 with artificial substrates (rope pieces) anchored and exchanged weekly in six sites, May through August. Comparisons of rates of accumulation of larvae with rates in 1976 were possible only for May and June, and only for one site located in rapids 22 km below Prince Albert on the North Saskatchewan River. There, larvae accumulated at an average rate of 7,000 larvae per metre of rope per week through May and June and 7,180 for May through August. This indicated an unusually large, persistent drift of larvae downstream into the larvicide-treated section of the river throughout the summer. The

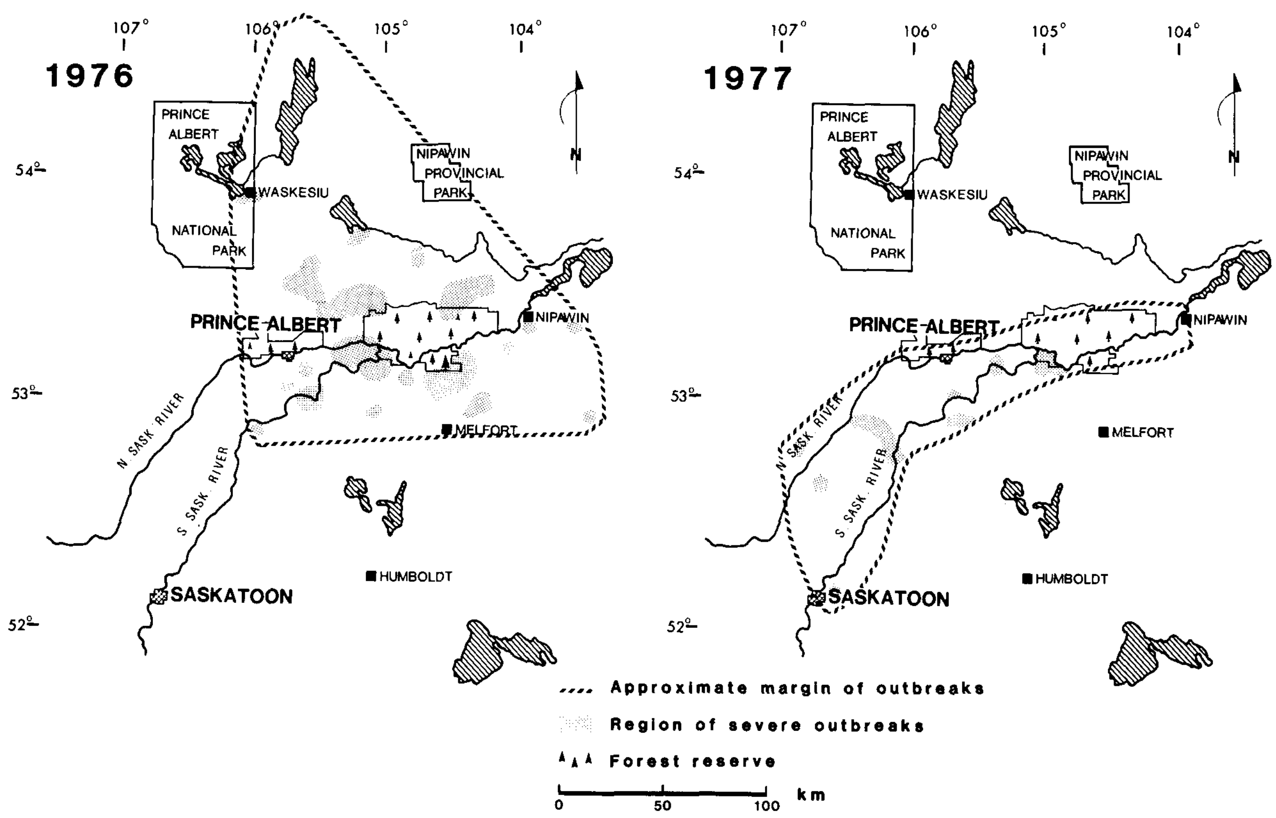

Fig. 3. Maps of central Saskatchewan showing approximate areas subjected to outbreaks of *Simulium luggeri* in 1976 and 1977, and specific localities from which most complaints of damage were received.

May-June rate was about 4.5 times larger than for the same period in 1976. A maximum density of 128 larvae/cm^2 of substrate surface occurred on May 10 (Table 1).

Each of the north and south branches of the Saskatchewan River was injected at one site with methoxychlor larvicide on each of three dates in 1977 (Fredeen, 1983). Treated sites were rapidly repopulated that summer. For example, following injections on July 4, numbers of larvae on artificial substrates 42 km downstream in the south branch initially declined by 78 percent but returned to pre-treatment levels within seven days. In the north branch 61 km downstream from the injection point in that river, numbers of larvae initially declined by 85 percent but a week later were 2.4 times larger than before treatment! In the main Saskatchewan River, an additional 71 km downstream from those monitored sites, numbers of larvae on artificial substrates declined by 75 to 95 percent following each injection, but within three weeks exceeded pre-treatment numbers.

Attacks on livestock commenced during the last week of May, but practically ceased by June 3. They recommenced June 29 and continued sporadically throughout the remainder of the summer whenever the weather was suitably warm. The total area where black flies were seen included some 6,000 km^2, generally within 10 to 15 km of either branch of the Saskatchewan River (Fig. 3). Severe outbreaks were reported from about 400 km^2 of farmlands.

1978

The worst outbreaks of *S. luggeri* on record occurred in 1978. In May through August, a mean density of 3180 larvae attaching weekly to metre-length rope-piece substrates anchored in the North Saskatchewan River indicated a high rate of drift of larvae downstream into treated sections of that river. Larvicide was injected three times into the North Saskatchewan River, all at Prince Albert, 25 km above the monitoring site. (This was unlike the previous year when only one of the injections was made above the monitoring site.) Four days after the first injection on May 26, numbers of larvae attached to artificial substrates had declined by 77 percent. Seven days later numbers were still 48 percent lower than before the injection. However, an unusually high rate of downriver drift of larvae following the second injection on June 20 caused a 2.9 fold increase in density, rather than the expected decrease within one week. Two weeks after that injection, density had increased even more, to 3.8 fold that seen before the injection. One week after the third and final injection on August 8, numbers of larvae had declined by 62 percent and two weeks afterwards, were still 48 percent lower than before the injection.

In the South Saskatchewan River mean weekly numbers, May through August, increased from 1,400 in 1977 to 3,340 in 1978. This occurred despite four larvicide injections 32 km above the monitoring site. The first injection, May 26, was considered successful and caused an 84 percent reduction in numbers of larvae during the first week and a further decline to 95 percent by the end of the second week. The second injection, June 20, was not successful because within one week, numbers of larvae had increased by 1.4 fold pre-treatment values and by the end of the second week, by 3.1 fold. One week after the third injection, on July 21, numbers of larvae had declined by 70 percent but, by the end of the second week, numbers had increased by a factor of 5.3 over those seen before the injection. Reductions of 69 and 76 percent were observed after the fourth injection on August 8, perhaps not so much because of that injection, but because of the normal seasonal decline at that time of the year.

In the main Saskatchewan River 70 km downriver from the confluence of the two branches, mean densities of larvae attaching weekly to artificial substrates May through August increased from 275 per week in 1977 to 1,600 per week in 1978. Drift of larvae out of the branches following larvicide injections was responsible for much of this increase. Although numbers declined by 51 percent following the first injections into both branches on May 26, they increased six-fold following the second pair of injections on June 20 and 65-fold after the third injections (south branch only) on July 21! After the fourth and final pair of injections on August 8, numbers declined by 99 percent but this decline may have been due partly to a normal seasonal trend not related to larviciding. Results in general indicated, as in previous years, that injections of larvicide into the two branches of the river could not guarantee reductions in the main river below the confluence, but that dangerous increases might occur instead, especially during June and July.

Casual observations at sites additional to the three regular monitoring sites in 1978 indicated that each larvicide injection did reduce numbers of larvae in at least a portion of the river. However, in general, these treatments failed to prevent massive outbreaks for at least three reasons: 1) The first injections were made at least 1 week too late, delayed until May 26 because of a lengthy hatching period of overwintered eggs that year. This was a mistake, because, by that date, adults of *S. luggeri* had already commenced emerging. These eventually laid sufficient eggs to allow production of massive numbers of second-generation larvae. 2) The weedy South Saskatchewan River should have been injected at several sites on each date instead of at only one. 3) The main Saskatchewan River downstream from the confluence of the two branches also should have been injected in June, July and August. By May 26 adults of *S. luggeri* already were causing cattle to stampede in pastures eastward from Prince Albert, mainly along the South Saskatchewan River. By May 31 many herds in more than 5,000 km^2 of farmlands between Prince Albert and Nipawin (Fig. 4) were reported to be under very severe attack, and by June 3 black flies had moved north, against prevailing winds, through some 20 km of dense woodlands in the uninhabited Nisbet Forest from the main Saskatchewan River, to commence what was to be about 16 weeks of continuous harassment of people and livestock in the Smeaton, Choiceland, and White Fox areas. Six days of northerly winds in late May and early June also carried dense swarms southward, and by June 3 reports of severe black fly problems were coming from as far south as Wynyard, some 170 km south of the nearest point of emergence on the Saskatchewan River. Strong easterly winds on June 5, 6, 9, 10, 12 and 13 then carried many of these black flies even further, to more than 40 km southwest of Saskatoon (Fig. 4). These black flies apparently had travelled more than 300 km from their origin.

In summary, livestock and people in an area probably exceeding 38,000 km^2 were affected by black flies in 1978. Almost one-seventh of this area, about 5,700 km^2, was subjected repeatedly to very severe attacks until after a second set of larvicide treatments on June 20, and sporadically thereafter until late September. Outbreaks in 1978 were more severe and widespread than in any year since outbreaks commenced in 1972.

1979

Minor outbreaks of relatively short duration occurred throughout an 18,000 km^2 area in central Saskatchewan in 1979 (Fig. 4). Black flies were reported mainly from areas adjacent to, and between, the two branches of the Saskatchewan River. Severe outbreaks were reported from areas totalling only about 750 km^2, immediately adjacent to the Saskatchewan River between Prince Albert and Nipawin.

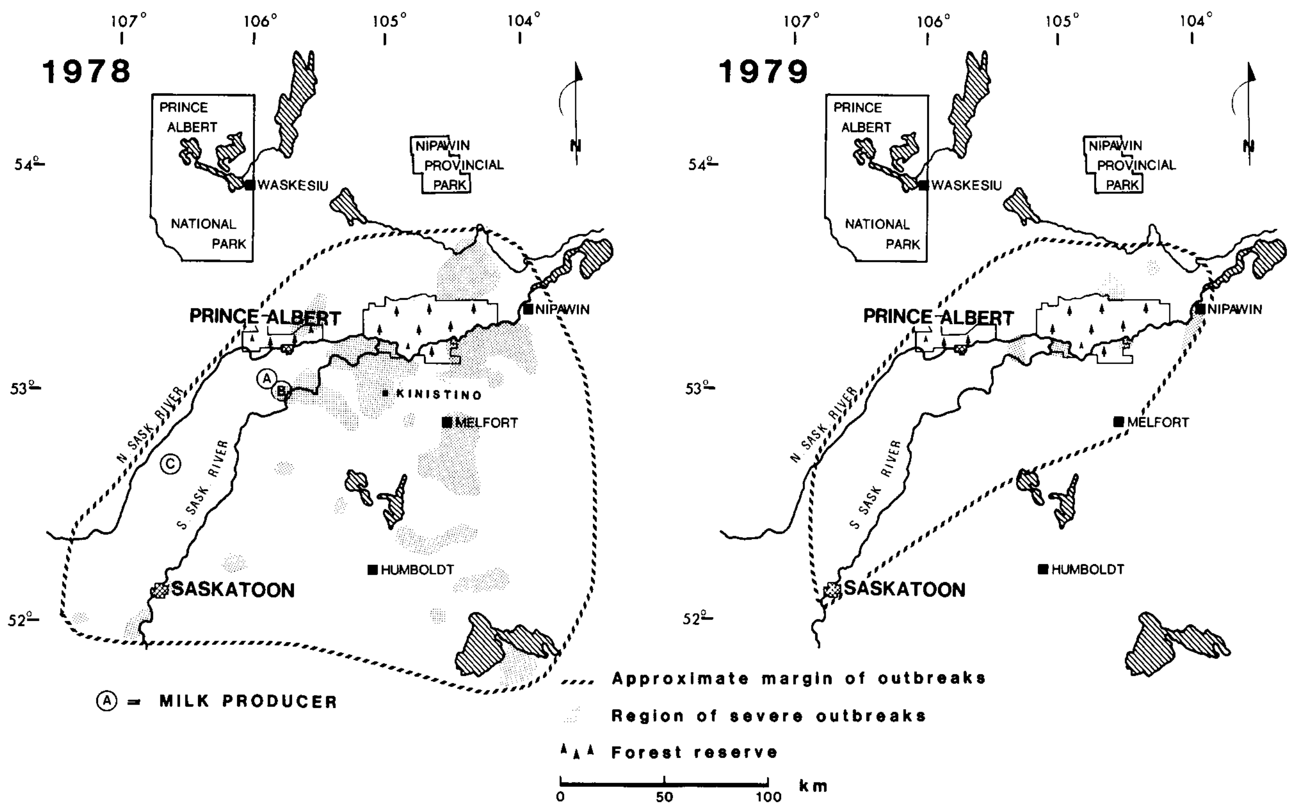

Fig. 4. Maps of outbreaks in 1978 and 1979.

Numbers of larvae accumulating weekly May through August on metre-length rope pieces anchored in the North Saskatchewan River averaged 3,340, numbers similar to those seen in 1978. However, few larvae were allowed to pupate because of five timely injections (one in two locations) of methoxychlor larvicide. Mean densities of larvae in the South Saskatchewan River were only about one-tenth those seen in 1978 due not only to three timely injections of larvicide but also to the use of several injection sites in this weedy river.

For the first time, the main Saskatchewan River below the confluence was injected. Four consecutive injections (one in two sites) prevented most larvae which may have drifted downriver from the two branches from maturing.

Livestock producers were particularly satisfied with results of the larval abatement program in 1979 and petitioned federal and provincial governments that the program be continued in future years.

1980

In 1980 outbreaks again were relatively minor and although black flies were reported at one time or another from about 20,000 km^2, severe outbreaks occurred in only about 400 km^2, mainly near the rivers as in 1979 (Fig. 5).

Densities of larvae in both branches of the river were unusually high in May but timely treatments with larvicide prevented many from maturing. Mean numbers from May through August were similar to those observed in 1979: 3,310 larvae per metre of rope in the north branch and 540 in the south. Larvicide was injected only once, on May 16 into the north branch and twice, at two locations each time into the south branch. The main river below the confluence was not injected because populations of larvae remained very low there all summer.

1981

Outbreaks were less troublesome in 1981 than in 1980 with black flies being reported from only about 7,400 km^2 (Fig. 5).

Mean weekly numbers of larvae of *S. luggeri* declined from those seen in 1980 to 1,570 per metre of rope in the north branch, but increased slightly to 670 in the south branch. Larvicide was injected four times into the north branch, three times into the south branch and once below the confluence of the branches.

FACTORS CONTRIBUTING TO DAMAGING OUTBREAKS OF *S. LUGGERI*

My first experience with an outbreak of *S. luggeri* occurred on August 6 and 7, 1951 when I observed horses stampeding under attack from black flies that were emerging from the relatively small Battle River about 20 km west of North Battleford, Saskatchewan. Numbers of black flies (all *S. luggeri*) were relatively small and effects were negligible. This species had been named only the previous year by Nicholson and Mickel (1950) from specimens collected in Minnesota and Wisconsin. The authors believed at that time that *S. luggeri* was occasionally bothersome to horses but not to people.

As long as *S. luggeri* was restricted to breeding in small prairie rivers, potential for creating damaging outbreaks was limited. But when it commenced breeding in the Saskatchewan River, potential with regard to intensity, duration and areas affected increased manyfold. At first there seemed no reason for concern because larvae became abundant only in late summer, and numbers waned quickly with advent of cooler temperatures in August and September.

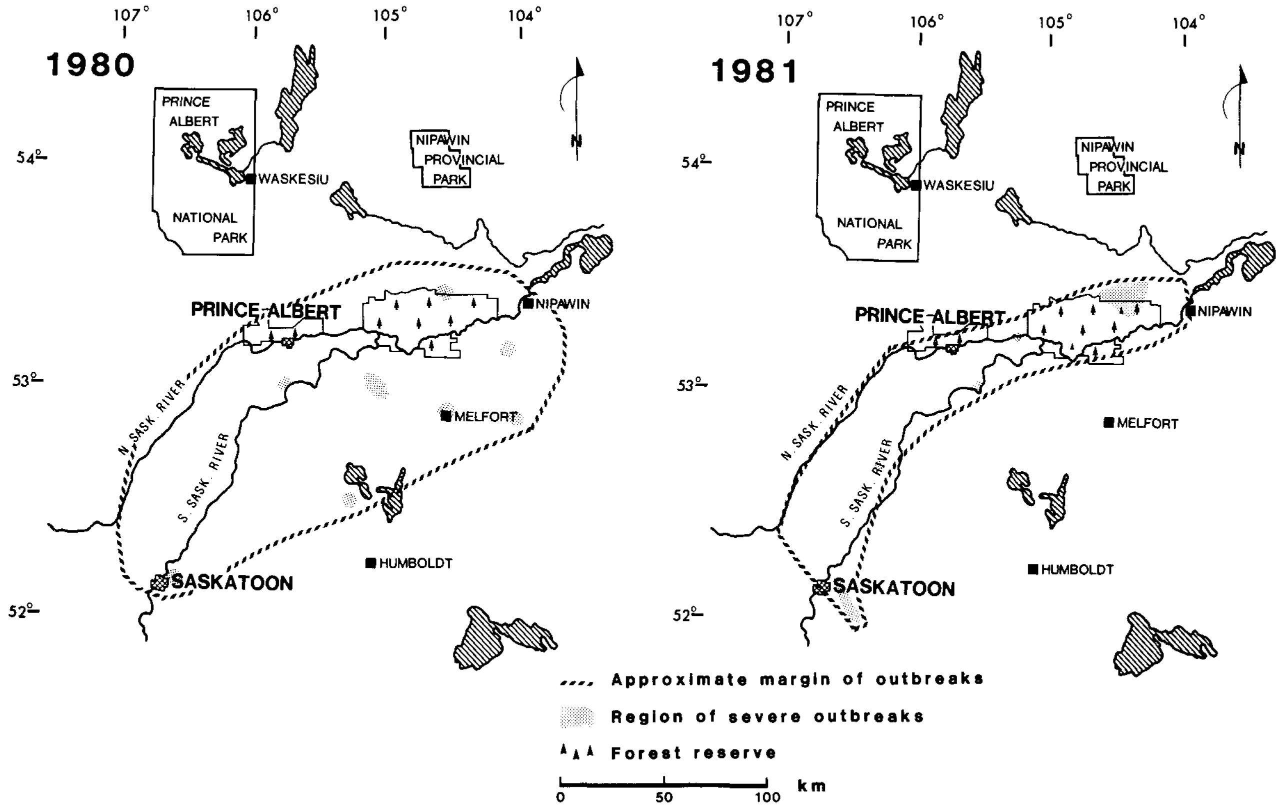

Fig. 5. Maps of outbreaks in 1980 and 1981.

Furthermore, during occasional brief outbreaks no animals were killed as had happened frequently with *S. arcticum.*

It was not until 1976 that the first summer-long outbreaks of *S. luggeri* from the Saskatchewan River occurred. Those outbreaks became so severe by mid-summer that larviciding was initiated using strategies initially developed to prevent outbreaks of*S. arcticum* (Fredeen, 1974, 1975). But whereas an outbreak of *S. arcticum* usually could be prevented with a single injection of methoxychlor larvicide into the Saskatchewan River, such a treatment proved relatively ineffective against *S. luggeri.* Research in subsequent years indicated several reasons why outbreaks of *S. luggeri* of economic proportions developed, and why major failures occurred in a larviciding program that had been used successfully against *S. arcticum.*

Major outbreaks occurred because:

1. Immense numbers of larvae of *S. luggeri* were capable of inhabiting weed beds in the Saskatchewan River, and since the species was multivoltine,numbers tended to increase during succeeding generations May through August each summer, sometimes in spite of larvicide treatments. Enormous numbers of larvae frequently drifted downriver from untreated sections for natural reasons still under investigation.

2. Adults were capable of dispersing great distances on the wind. The Saskatchewan River had the potential for producing such enormous numbers of black flies that even long-distance movements did not disperse the black flies too thinly to prevent them from disturbing livestock. In 1978 *S. luggeri* drifted on northerly winds and created problems as far away as Wynyard, some 170 km south of the Saskatchewan River. Then, when winds changed to easterly for a few days, some of these same black flies were redirected toward Saskatoon and beyond, apparently travelling a total distance of more than 300 km.

S. luggeri also regularly infiltrated forested areas against prevailing winds. Pastures along the northern edge of the Nisbet Forest reserve near Choiceland and Smeaton were chronically affected by dense swarms of *S. luggeri* regardless of wind directions. Every summer swarms moved through trees, often against prevailing winds, at least 30 km from breeding sites in the Saskatchewan River.

3. *S. luggeri* adults caused hyperactivity, panic and stampeding in livestock by swarming densely around the animals' heads. Animals ceased grazing and breeding when under severe attack. Calves could not nurse properly when herds were tightly packed and in constant turmoil and with peripheral animals forcing themselves into the herds. Calves also suffered malnutrition when milk flow from cows was reduced. Also, since *S. luggeri* adults bit animals around their eyes and udders, they may well have been instrumental in carrying disease organisms responsible for bovine keratitis and mastitis. Increased incidences of these diseases as well as stress-related diseases such as hoof rot in mature animals, and pneumonia and scours in calves always accompanied severe outbreaks of *S. luggeri.* In comparison, *S. arcticum* adults did not swarm intensively around animals' heads but concentrated their attacks along underlines, often unnoticed by victims. No animals died suddenly after being bitten by *S. luggeri* as had happened frequently with *S. arcticum* (Fredeen, 1981). However, during outbreaks of *S. luggeri* some animals died during stampedes, suffered broken limbs and had to be destroyed, or died from stress-related diseases. Pastures were unevenly grazed when cattle refused to stay in rich lowlands. Supplementary feeding was required, especially for bulls, as well as additional veterinary and labour services.

4. Unlike those of *S. arcticum*, adults of *S. luggeri* actively attacked people as well as other warm-blooded animals, except birds.

5. A major cause for ineffectiveness of larviciding against *S. luggeri* became apparent in later years when tests showed that a single injection of methoxychlor into the shallow, weedy Saskatchewan River often was not effective beyond 20 to 30 km downstream. In comparison, a single injection into the North Saskatchewan River in 1973 (fairly weed-free at that time) had been reasonably effective against *S. arcticum* larvae throughout at least 160 km (Fredeen, 1975).

6. An unexpected effect of larvicide treatments was that certain larvae removed from the Saskatchewan River (south branch in particular) apparently drifted downstream to reattach in suitable sites, often in the main Saskatchewan River downstream from the confluence of the south and north branches (Fredeen, 1983). Major outbreaks in 1977, 1978 and 1982 (not discussed in this paper) were believed to have resulted, at least in part, from downstream accumulations of reattached larvae following larvicide treatments further upstream.

For these reasons, sporadic outbreaks of *S. luggeri* continued to plague portions of east-central Saskatchewan in 1976 through 1982 during development of abatement strategies and studies of environmental effects of larvicide injections into the Saskatchewan River.

COMPLAINTS FROM RESIDENTS IN REGIONS AFFECTED BY OUTBREAKS IN 1978

Outbreaks of *S. luggeri* in 1978 were more widespread and damaging than in any year since outbreaks commenced in 1972. In 1978 I received more than 100 written complaints and petitions from at least 46 mailing centers, and many telephone calls from these and other districts. Most complaints of sustained severe attacks came from within about 100 km of the river, but others came from up to or even beyond 200 km (Fig. 4). In many districts there were few remissions from outbreaks from June through August.

A selection of quotations from people personally attacked in 1978 included: "dense swarms of black flies attacked like angry bees all day; many people wore netting when working outside, others carried portable smudges; repellents did not provide sufficient protection; fence and machinery repairing, construction work, telephone line repairs and other outside jobs were at times impossible, even with use of repellents; repellents did not prevent densely-swarming black flies from entering nose, mouth, eyes and ears; some people required medical attention for bites; rural and urban people alike lost many days of out-of-doors work and recreation, children and older people were unable to work or play out-of-doors; farm work was neglected when cattle required so much additional attention; air cleaners on tractors required daily servicing to remove black flies."

Remarks from people concerned about welfare of livestock in 1978 (owners, veterinarians and government employees) included: "milk production greatly reduced when animals unable to graze; increased incidence of mastitis believed caused by black flies which sometimes caused udders to drip with blood; cows with irritated udders produced less milk and could not tolerate nursing calves; cattle were in constant motion and stampeded frequently because of black flies swarming densely around their heads; a stampeding herd tore down a fence; cattle refused to graze outside until after sunset and thus required supplementary food; cattle bunched on hilltops or near farmyards; where there was access to mud or manure beds, cattle stood or lay in them; cattle crowding into a shed pushed out rear wall; cattle became noticeably thinner in pastures instead of showing expected weight gains; cattle unable to breed; bulls became impotent because of black fly attacks; calves burnt when pushed by herds into smudges; cattle broke shoulders and limbs during stampedes; cattle in feed lots sold prematurely to avoid further weight losses; greatly increased incidences of bovine keratitis, mastitis, foot rot, calfhood scours and pneumonia blamed on extraordinary physical and nutritional stresses imposed by severe black fly attacks; livestock owners found it difficult to approach or herd animals in pastures; extra riders hired to cope with hyperactive herds; horses difficult to manage when under attack; horses, cattle, sheep and hogs had to be fed indoors; dogs severely bitten; moose and elk submerged themselves in water and were oblivious to human presence."

COMPLAINTS FROM PATRONS AND MANAGEMENT OF ONE LARGE PASTURE

Following the severe outbreaks of 1978, Mr. Stephen Burkell, Director of Pastures for the Prairie Farm Rehabilitation Administration for northeastern Saskatchewan, and I were invited to attend an annual meeting of directors and management of the James Smith Pasture to discuss complaints. This pasture, with an area of 3,230 ha, is located north of Kinistino (Fig. 4) and has, as its northern boundary, the main Saskatchewan River from whence repeated outbreaks of *S. luggeri* had emerged in 1978 and in two previous years.

Eight hundred and forty cows, many accompanied by suckling calves had been received into this pasture during the last week of May in 1978 and discharged 140 days later in mid-October. Patrons had expected cows and suckling calves to gain significantly in weight and had expected timely conceptions of cows from use of 35 high quality, purebred bulls. Management had expected minimal handling problems and uniform grazing of grasslands. Due to severe and prolonged outbreaks of *S. luggeri* these expectations were not realized.

Approximately 260 ha of lowlands in this pasture, including some of the richest grasslands, were not grazed in 1978. Although cattle were herded into those lowlands several times that summer, they would not stay because of continuous presence of black flies. Instead, cattle often congregated on overgrazed hilltops, apparently to take advantage of winds.

Management reported that five purebred bulls out of the 35 in service that summer had to be replaced when they became impotent due to severe debilitation and infections of the sheath and scrotum from black fly bites. Replacement costs totalled $11,250.00 among bulls alone, despite daily supplemental feeding and adequate veterinarian services (Table 2).

Of 840 breeding cows in that pasture in 1978, there were only two fatalities attributed directly to black fly attacks (Table 2). Both animals suffered broken limbs during stampedes and had to be destroyed. Prompt attention saved many other sick animals, especially those with bovine keratitis (pinkeye), mastitis and foot rot.

Another loss, more difficult to assess, was an increase in proportions of cows showing delayed conceptions (Table 2). Our observations during outbreaks in 1978 confirmed producers' complaints that breeding was completely interrupted whenever animals came under severe attack. Mr. Allan Blair, Livestock Specialist for Saskatchewan Agriculture in east-central Saskatchewan, estimated that more than 20 percent of all cows in outbreak areas conceived at least one month later than expected in 1978. A calf born one month late the following year would have been about 30 kg lighter than expected at weaned-calf sales in the fall. The average price for weaned calves in Saskatchewan in the fall of 1979 was $2.20/kg, indicating losses of $66.00 for each weaned calf born one month later than expected. Thus if 20 percent of the cows in this pasture were affected in 1978, the resultant 168 conceptions, late by only one month each would have caused a loss of more than $11,000.00 in the following year (Table 2). Losses from conceptions delayed for more than one month were not estimated. Allan

Blair estimated that the number of cows not conceiving at all in 1978 increased by at least two percent over that observed in 1977. However, conception rates also vary between herds according to culling and other management practices.

Ryan and Hilchie (1980) reported that, in areas of central Alberta affected by severe outbreaks of *S. arcticum* from the Athabasca River in 1978, 44 percent of calves born the following year were later than expected. In areas less affected by outbreaks, 21 percent of all calves were born later than expected. They also reported that non-conception rates varied from 8.41 to 12.17 percent in severely affected regions, but only 1.26 to 6.35 percent in areas less affected.

The major loss among beef cows in the James Smith pasture undoubtedly consisted of unrealized weight gains. Livestock owners and pasture managers unanimously claimed that their animals had lost weight during the 140-day grazing season in 1978 whereas past experience had led them to expect gains of about one kg per day. Photographs taken of herds in that pasture indicated that animals actually appeared thin when compared with unaffected animals from pastures further south. However, animals were not weighed in or out of the James Smith pasture and thus owners' claims could not be verified. To estimate values of unrealized weight gains I have used data obtained in 1982 from two herds of purebred hereford cattle pastured near Choiceland, Saskatchewan. In one of those herds, partly protected from attacks by *S. luggeri* with use of fenvalerate-impregnated ear tags (Bovaid[R], cows with suckling calves showed average individual weight gains of 0.967 ± 0.342 kg per day, whereas cows from an adjacent "unprotected" herd showed average gains of only 0.508 ± 0.270 kg per day, a difference of about 0.46 kg per day. Bovaid[R]-"protected" dry yealings without calves showed an average advantage of about 0.57 kg per day over "unprotected" dry yearlings. Thus for the James Smith herd, of 838 surviving cows I have assigned weight gains of 0.5 kg per day per cow in 1978 instead of 1.0 kg that might have been realized had there been no black flies. Even this partial loss would have cost producers $102,655.00 (Table 2).

There were 700 suckling calves in the James Smith pasture in 1978 and deaths of 12, valued at $4,230.00, could be attributed directly to black fly attacks. Some of these calves had suffered fatal trampling injuries; others had died from nutritional and physical stress-related diseases such as scours and pneumonia. But again, main losses were unrealized weight gains due in part to delayed conceptions the previous year as discussed above and in part to hyperactivity and inability to suckle or graze properly in 1978. Milk production from beef cows in 1978 would have suffered long-term reductions similar to those for dairy cows, discussed later. Owners claimed that the average weight of a weaned calf from this pasture at fall sales of weaned calves was about 135 kg as compared to about 180 kg for weaned calves from pastures further south and less affected by black flies. This indicated that unrealized weight gains for suckling calves in the James Smith pasture averaged 0.32 kg per day per calf. Producers did not provide proof of these claims. Thus I have calculated losses on the basis of data obtained from test herds near Choiceland in 1982 and Prince Albert in 1979. At Choiceland, suckling calves from a herd partly protected from black flies for 100 days with the use of Bovaid[R] ear tags, gained an average of 0.121 kg more per day than similar calves in a nearby "unprotected" herd. Similar tests with Aberdeen Angus near Prince Albert in 1979 showed that calves from a herd protected for about 18 days with permethrin spray gained, on the average, 0.092 kg more per day than calves from a nearby "unprotected" herd.

Thus, while there were no reasons to doubt producers' claims of unrealized weight gains of 0.32 kg per calf per day for animals severely affected in the James Smith pasture in 1978, I have assigned losses of 0.1 kg per calf per day. This would have amounted to an average loss for the 140-day grazing season of $28.00 per calf for a herd total of $19,260.00 (Table 2). This would have been additional to losses caused by delayed conceptions calculated earlier.

While compensatory weight gains could have occurred after black fly outbreaks ceased in the fall, losses calculated from unrealized weight gains described above for pastured cattle should be considered real losses for producers. Many animals, especially suckling calves and yearlings, were sold in the fall soon after leaving summer pastures, before compensatory gains could occur. Other animals, overwintered on home farms, could have achieved compensatory gains only at the expense of forages grown in home pastures or of forages especially harvested for use in winter.

Thus, total losses, conservatively estimated for the 140-day grazing season in 1978, in this one community pasture, apparently exceeded $150,000.00 (Table 2). Costs not included in these calculations were veterinarians' fees and medications required to treat 260 cases of bovine keratitis, mastitis, foot rot, scours and pneumonia in excess of those treated the previous year, as well as costs of supplementary feeding, fence repairs, daily smudge building, increased animal insurance costs and hirings of extra riders to handle hyperactive herds and to monitor herds for sick animals.

ESTIMATED FINANCIAL LOSSES TO BEEF PRODUCERS IN AREAS OF EAST-CENTRAL SASKATCHEWAN AFFECTED BY SEVERE OUTBREAKS OF *S. LUGGERI* IN 1978

Regions where repeated complaints of damage to livestock originated during outbreaks in 1978 (Fig. 4) included about 5,700 km^2 (approximately 0.5 percent of Saskatchewan's Crop District 6, 13.0 percent of District 8 and 1.5 percent of District 9). Cattle populations in those portions of the three districts included at least 650 bulls, 11,000 beef cows, 9,500 suckling calves, 1,100 dairy cattle and 7,000 other cattle (mainly 1- to 2-year old steers, heifers and bulls). Practically all would have been either purebred or high-quality crossbred animals. Some bulls and other cattle would have had access to indoor feeding during outbreaks.

In September, 1978, 39 livestock owners in six municipalities (Numbers 399, 400, 429, 430, 459 and 460, Fig. 6) were asked by the local Agricultural Representative, Eugene Bendig, to complete a form indicating effects of black fly outbreaks on their farms that year. Eleven reported that animals had to be housed much of the summer, three reported premature sales of animals including some animals blinded by bovine keratitis believed transmitted by infected black flies, and 10 reported fatalities caused by black flies of 14 calves, nine yearlings, three cows and three bulls. All claimed that pastured animals became thinner during the summer and also that outbreaks caused prolonged and severe disruptions of all outdoor activities.

George O'Bertos, Director, Saskatchewan Lands Branch, Tisdale, reported that in every provincial community in his jurisdiction, 12 to 20 calves in each population of 800 to 1,000 calves per pasture were killed by black flies that summer. These calf fatalities of 1.5 to 2.0 percent were comparable to the loss of 1.72 percent reported that same year for the James Smith pasture.

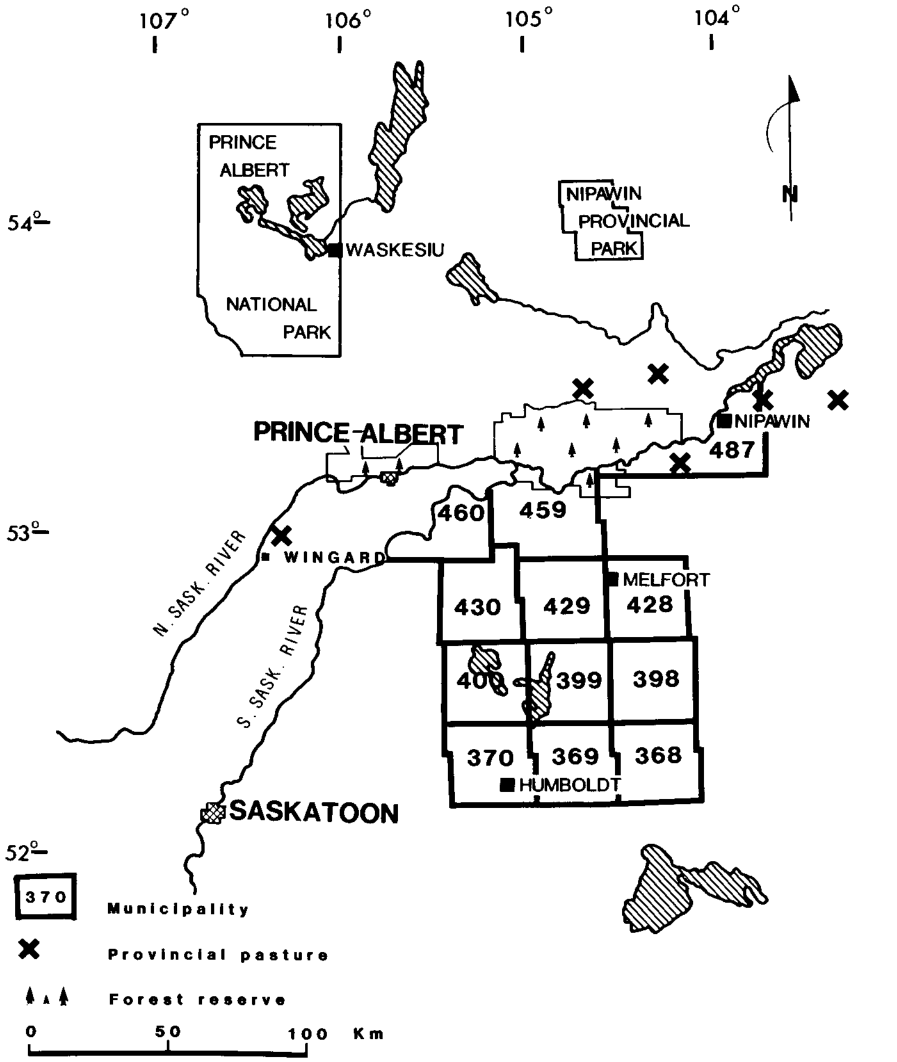

Fig. 6. Map of central Saskatchewan showing locations of 6 provincial community pastures in which cattle were reported to have been affected by black flies in recent years, and 12 municipalities affected by different intensities of outbreaks of *Simulium luggeri* in 1976 through 1981.

TABLE 2. ESTIMATED VALUES OF BEEF CATTLE LOSSES IN THE JAMES SMITH COMMUNITY PASTURE NORTH OF KINISTINO, SASKATCHEWAN DUE TO REPEATED OUTBREAKS OF BLACK FLIES, *SIMULIUM LUGGERI* IN 1978.

Category	Number of animals in pasture	Type of loss	Animals affected (no.)	(%)	Net loss per affected animal ($)	Total value of losses ($)
Bulls	35	Fatalities	0	0.00	–	–
		Replacements	5	14.30	2,250.00[1]	11,250.00
Cows	840	Fatalities	2	0.24	787.50[2]	1,575.00
		Delayed conceptions	168	20.00	66.00[3]	11,088.00
		Unrealized weight gains	838	99.76	122.50[4]	102,655.00
Calves	700	Fatalities	12	1.72	360.00[5]	4,320.00
		Unrealized weight gains	688	98.28	28.00[6]	19,260.00
TOTAL LOSSES						150,148.00

[1]Replacement cost ($3,000.00) minus commercial sale value ($750.00).

[2]Estimated 450/kg animal at $1.75/kg.

[3]Conception estimated to be at least 1 month late, with the weaned calf weight about 30 kg lighter than expected the following year with an average value of $2.20/kg.

[4]Estimated 70 kg unrealized weight gain/cow at the end of the 140-day grazing season, with an average value of $1.75/kg.

[5]Estimated 180 kg/weaned calf at $2.00/kg in the fall of 1978.

[6]Estimated 14 kg unrealized weight gain/calf at the end of the 140-day suckling season at $2.00/kg.

These data suggest that effects of outbreaks in 1978 on livestock outside the James Smith pasture were similar to those within. On that basis the following losses were calculated: If one-seventh of the 650 bulls died or required replacement at an average net loss of $2,250 per bull, losses from this source would have totalled $209,000. An estimated 26 beef cows and 160 suckling calves, valued at more than $78,000, may have been killed. If 20 percent of the 11,000 beef cows suffered delayed conceptions equivalent to single oestrus cycles with an average net loss of $66 per calf at weaned calf sales the following year, losses from this source alone would have totalled $145,200. But the largest financial losses would have resulted from unrealized weight gains for 11,000 beef cows, 9,500 suckling calves and 7,000 weaned cattle. Despite claims by most producers that their animals had actually lost weight during the summer-long outbreaks in 1978, I estimated from our tests reported earlier that suckling calves may have gained an average 0.1 kg per day (14 kg for the grazing season) and cows and weaned cattle 0.5 kg per day (70 kg for the season) instead of anticipated seasonal gains of 28 kg and 140 kg under black fly-free conditions. On this basis, unrealized weight gains for some 9,500 calves in severely affected areas in 1978 may have cost producers at least $266,000 and for some 18,000 cows and immature cattle, $2,205,000. Accumulated losses for all classes of beef cattle in severely affected areas thus were estimated to have exceeded $2,903,000. These losses were calculated for only those areas totalling about 5,700 km^2 considered to be severely affected by black fly outbreaks in 1978. Losses in an additional 32,000 km^2 less severely affected (Fig. 4) were not included in these calculations. Also excluded were estimates of costs of supplementary feeding, especially for cattle kept indoors, supplementary feeding, especially for cattle kept indoors, supplementary labour, veterinary services, repairs to fences and barns, and increased insurance against future losses. Thus, actual losses to the entire beef cattle industry in east-central Saskatchewan in 1978 were believed to have been much larger than the $2,903,000 shown in these calculations.

TRENDS IN CATTLE POPULATIONS IN PROVINCIAL COMMUNITY PASTURES AFFECTED BY BLACK FLY OUTBREAKS

Livestock producers anticipate advantages in committing cattle to community pastures. These pastures offer expansion of production beyond home pasture capacities as well as opportunities for quality grazing and quality breeding from registered herd sires or artificial insemination (A.I.). However, in large pastures animals cannot be given the same kind of individual attention available in small home pastures. Producers claimed that during black fly outbreaks their animals were subjected to severely debilitating stresses causing weight losses, sickness and missed oestrus cycles whether in natural or A.I. breeding programs. Because of this some producers ceased committing cattle to large pastures in regions prone to outbreaks of *S. arcticum* until 1973 and of *S. luggeri* after 1975. However, their places in pasture quotas generally were filled by other producers hopeful of improvements in black fly control measures.

There are three types of community pasture organizations in Saskatchewan: provincial, federal and co-operative. To investigate complaints from producers and pasture managers, numbers of cattle committed annually to six provincial community pastures in municipalities frequently affected by black flies (those bordering the Saskatchewan River between Wingard and Nipawin) (Fig. 6) were compared with numbers in all other 48 provincial community pastures in the province, 1969 to 1981, inclusive (Saskatchewan Agriculture,, 1970-1982).

On average, less than 85 percent of official carrying capacities of "affected pastures" was used 1969 to 1981, inclusive, as compared with more than 89 percent for pastures in the remainder of the province (Fig. 7A). The difference was significant ($P = 0.05$). Pasture managers reported that some of the richest lowland areas often were undergrazed because cattle congregated on windy hilltops to avoid black fly attacks. Reduced usage of "affected" pastures was particularly noticeable before 1973 and after 1977.

Percentages of breeding cows among populations of mature cattle committed to "affected" pastures each year were consistently lower (some by as much as 14 percentage points) than populations in pastures in the remainder of the province ($P = 0.01$) (Fig. 7B). This supports claims by some owners that they withheld breeding cows with expectations of obtaining improved conception rates in home pastures.

Percentages of suckling calves among breeding cows committed to "affected" pastures were lower than in other provincial pastures in nine of the 13 years (Fig. 7C) but means for the 13 consecutive years did not differ significantly. In particular, conception rates appear to have been reduced during black fly outbreaks 1969 to 1973 (*S. arcticum*?) and 1976 to 1981 (*S. luggeri*) as claimed by livestock owners. In 1979, 6.5 percent fewer cows were accompanied by calves in "affected" pastures than in other provincial pastures, suggesting that average conception rates had been reduced by that amount during the severe outbreaks of 1978.

TRENDS IN CATTLE POPULATIONS AND LAND-USE PATTERNS IN DISTRICTS SUBJECTED TO CHRONIC OUTBREAKS OF *S. LUGGERI*, 1976 THROUGH 1981

Many livestock producers in outbreak areas stated that they reduced or even eliminated herds because black flies rendered their operations less profitable than expected. While numbers of dairy and beef cattle did decline in the entire province, 1975 to 1981, presumably for economic reasons, reductions were greatest in Crop District 8 (Figs. 1, 8) (Saskatchewan Agriculture,, 1976, 1982). During those seven years, numbers of beef cattle declined by 27 percent in Crop District 8, 19 percent in District 9, and 21 percent in the remainder of the province. Numbers of dairy cattle declined by 32, 20 and 6.5 percent in those same three districts.

On a finer scale, largest declines occurred in municipalities bordering the Saskatchewan River (Fig. 6, Table 3). In three such municipalities where average distance from farm to river was about 13 km, dairy cattle numbers declined by 70.3 percent between 1971 and 1981 (Statistics Canada, 1973, 1983). Numbers of "other" cattle declined by 29.2 percent. At an average distance of 43 km, numbers declined by 52.5 and 15.1 percent, at 74 km by 47.3 and 1.7 percent, and at 101 km by 54.0 and 11.7 percent for dairy and "other" cattle, respectively.

Amounts of land devoted to improved pasture declined by 32.4 percent between 1971 and 1981 in municipalities averaging 13 km from the river, by 46 percent at 43 km and by 6.9 percent at 74 km, but increased by 10.4 percent at 101 km (Table 3). Amounts of land devoted to cultivated crops did not change in inverse proportions as expected. However, much of the land adjacent to the valley of the Saskatchewan River is classified as unsuitable for cultivation on account of steep contours, stoniness, light soil textures subject to wind erosion, and even high water tables. Thus it appears that some land withdrawn from use as cultivated pastures may have been abandoned when it became uneconomical to produce livestock. For instance, on farms averaging 13 km from the river in the three municipalities studied, 1,237 ha of land formerly classified as pastures, were unaccounted for in the Canadian Census of 1981,

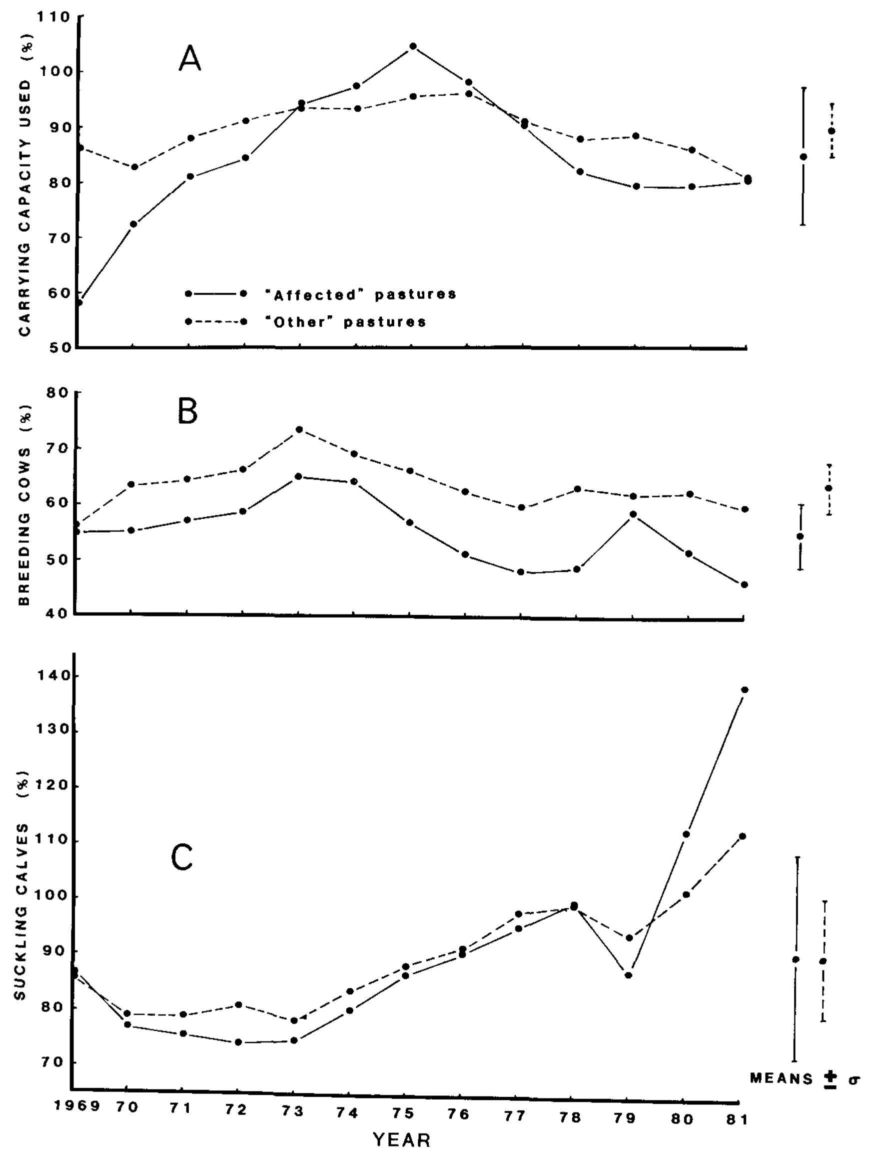

Fig. 7. Trends in populations of mature cattle, breeding cows and suckling calves, 1969 through 1981, committed to six provincial community pastures (see Fig. 6 for locations), in municipalities adjacent to the Saskatchewan River between Wingard and Nipawin in Saskatchewan (a region affected by chronic outbreaks of black flies), compared with numbers committed to community pastures in the remainder of the province: A - populations of mature cattle expressed as percentages of carrying capacities of those pastures; B - populations of breeding cows - expressed as percentages of total adult cattle assigned to those pastures; C - populations of suckling calves expressed as percentages of total breeding cows assigned.

TABLE 3. TRENDS IN CATTLE POPULATIONS, AND IN LAND AREAS DEVOTED TO IMPROVED PASTURES AND TO CULTIVATED CROPS, BETWEEN 1971 AND 1981, IN FOUR SETS OF MUNICIPALITIES LOCATED AT DIFFERENT DISTANCES FROM THE SASKATCHEWAN RIVER

Municipalities[1]	Average from river (km)	Trends, 1971 to 1981 (%)[2] Cattle (excluding dairy cows)	Dairy cows	Improved pasture	Cultivated crops
368, 369, 370	101	-11.7	-54.0	+10.4	+ 6.3
398, 399, 400	74	- 1.7	-47.3	- 6.9	+ 2.3
428, 429, 430	43	-15.1	-52.5	-46.0	+ 7.1
459, 460, 487	13	-29.2	-70.3	-32.4	+ 0.1

[1]See Figure 6 for locations of municipalities in relation to the Saskatchewan River.
[2]Calculated from census data (Statistics Canada, 1973, 1983).

suggesting abandonment.

LOSSES SUSTAINED BY MILK PRODUCERS DURING OUTBREAKS OF *S. LUGGERI*

Many dairy herds in central Saskatchewan are either kept indoors or at least allowed free access to barns. By 1982, in those areas around Prince Albert chronically affected by black fly outbreaks, only five of 18 producers still pastured their milking cows outside all summer. A number of other dairies ceased operations in recent years because they were unwilling to convert, in the face of chronic black fly outbreaks, to housing that would have been both capital and labour intensive.

Data about milk-shipments were obtained from three dairies for five consecutive years, 1977 to 1981, to determine whether outbreaks of *S. luggeri* affected productivity. None of 15 other dairies visited near Prince Albert were able to provide uninterrupted data for this 5-year period or even for the one year especially investigated, 1978. Dairies "A" and "B" (Fig. 4, 1978) were located in a region subjected to relatively severe outbreaks of *S. luggeri* at least during the first three summers of this study. Outbreaks at "c" were less severe. I did not obtain data from regions completely free of black fly outbreaks.

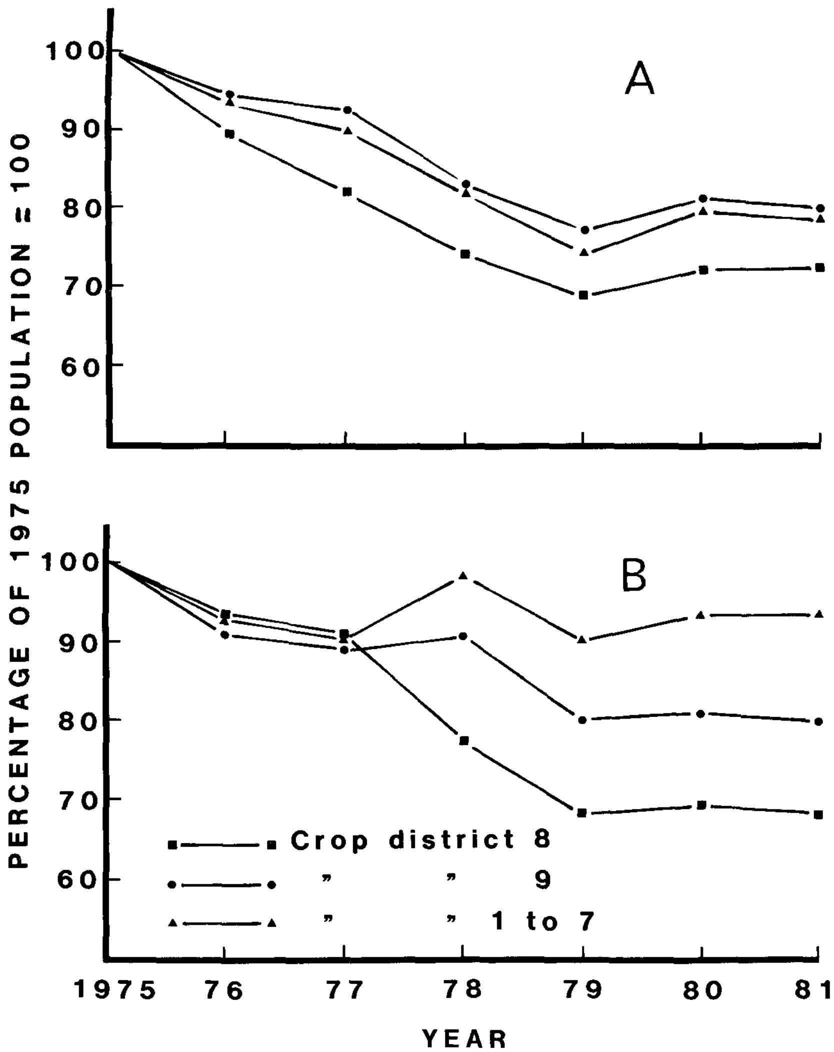

Fig. 8. Annual trends in populations of cattle on Saskatchewan farms expressed as percentages of 1975 populations in Crop Districts 8 and 9 (see Fig. 1 for locations) near the Saskatchewan River, and in the remainder of Saskatchewan: A - beef cows; B - milking dairy cows.

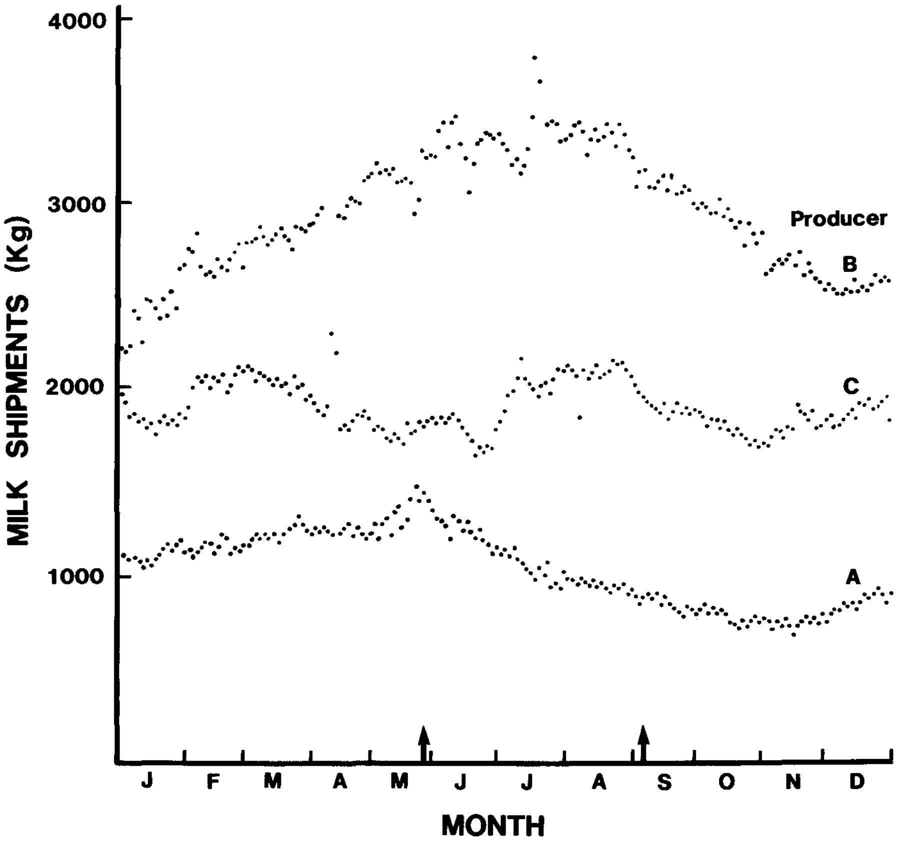

Fig. 9. Milk shipments (2-day accumulations) throughout 1978 from three dairies in areas of central Saskatchewan affected by chronic outbreaks of black flies (*Simulium luggeri*) (see Fig. 4, 1978, for locations of dairies). Arrows indicate commencement of outbreaks on May 26 and approximate ending 74 days later on September 7, 1978.

Producer "A" always pastured his milking cows outside all summer because of an abundance of rough, wet pasture lands that could not be used for grain or hay crops. He always provided supplementary cut fodder, outside, as required, in addition to the usual grain concentrates at milking time.

Milking cows of producer "B", located five to six km southeast of "A" were confined to the barn at all times. Producer "C" was located about 75 km southwest of "A" and "B", and although his cattle spent much time out-of-doors, they were allowed free access indoors at all times. He reported that his animals voluntarily remained indoors during fly outbreaks and were fed there.

These dairymen attempted to maintain uniformly high production to fulfill official milk quotas by providing high quality rations and by having cows freshen at uniform intervals. They reported that milk production increased significantly after cattle commenced grazing new grass

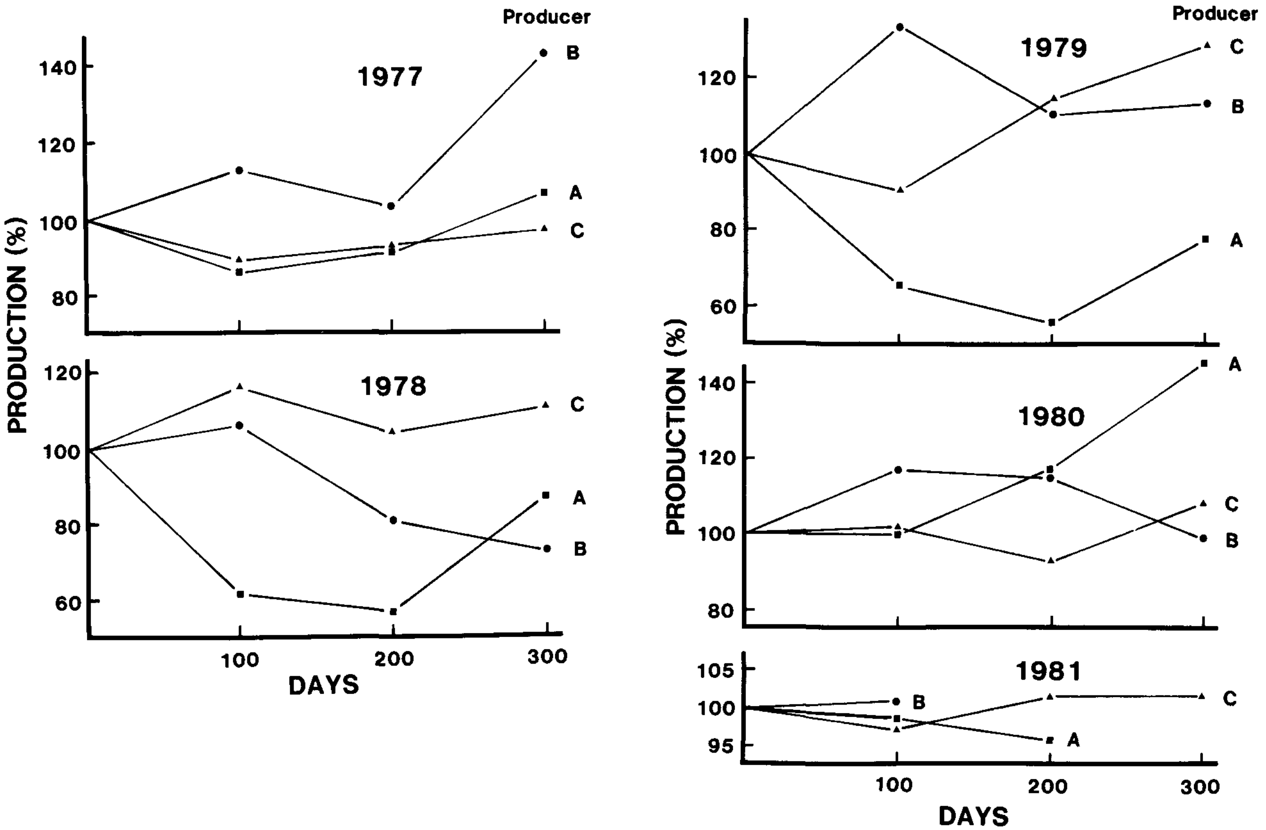

Fig. 10. Trends in volumes of milk shipments from three dairies in central Saskatchewan (see Fig. 4 for locations) in each of 5 years, 1977 through 1981. The "100-percent" starting point each year indicates average daily production throughout 10 days immediately before the beginning of outbreaks. Successive points thereafter at intervals of 100, 200 and 300 days after commencement of outbreaks represent percentages of that "pre-outbreak" production each year, also calculated from 10-day means.

TABLE 4. MILK PRODUCTION FROM THREE DAIRIES IN CENTRAL SASKATCHEWAN BEFORE AND AFTER COMMENCEMENT OF BLACK FLY OUTBREAKS (*S. LUGGERI* N. AND M.) ON MAY 26, 1978.

	Average daily production during two 175-day periods, one immediatedly before and one immediately after commencement of outbreaks			Value of difference per cow per day**
Producer*	Before (kg)	After (kg)	Difference (kg)	($)
A	585	480	-105	-0.95
B	1395	1605	+210	+0.71
C	954	974	+ 20	+0.11

*See Fig. 4 for locations of these dairies.
**Average number of lactating cows for producer A = 30, B = 80, C = 50. These producers received $0.27 gross per kg of milk.

in the spring, but that it declined when black fly outbreaks commenced a few weeks later unless animals were protected. Producer "A" reported that production did not return to expected levels during lulls in outbreaks but only after affected animals commenced new lactation cycles, in many instances long after outbreaks had ceased in the fall. This was particularly noticeable when stress had been severe and long-lasting, as in 1978. Milk shipment data provided by "A" indeed showed both immediate and long-term effects (Fig. 9). In 1978 outbreaks commenced on May 26 and a decline of 3.0 percent in milk production was already evident in the 2-day accumulation shipped on May 27. By the time outbreaks ended in early September production had declined by about 40 percent from what it had been during the week before outbreaks commenced on May 26. This decline did not end until mid-November, about 175 days after outbreaks had commenced. In contrast, production from herds "B" and "C" increased during this same 175-day outbreak period (Table 4). Similar long-term effects from outbreaks of *S. luggeri* were noted in 1979, but not in 1977, 1980 or 1981 (Fig. 10) when outbreaks of black flies south of Prince Albert were relatively light.

In 1978 producers received $0.27 per kg of raw milk. Throughout the first 175 days after outbreaks commenced on May 26, the decline in production in herd "A" resulted in an average reduction in gross returns of $0.95 per cow per day when compared with average production in that same herd throughout 175 days immediately preceding May 26 (Table 4). In contrast, production increased in herds "B" and "C" between these same two 175-day periods, resulting in average increases in gross returns of $0.71 and $0.11 per cow per day. Production trends in herds "A" and "C" may be compared because both herds were pastured during the summer of

1978. Management in those two herds differed mainly in that herd "A" grazed out-of-doors all the time but herd "C" had free access to a barn especially during outbreaks and were fed indoors as required. The difference in average gross returns between these two herds for the two consecutive 175-day periods was $1.06 per cow per day for a total of $185.50 per cow. Total confinement indoors as in herd "B" resulted in an even larger improvement in gross returns.

In those portions of Crop Districts 8 and 9 totalling some 5,700 km² that were most severely affected by black flies in 1978, there were estimated to have been about 310 lactating dairy cows (including herd "A"), which did not have free access to barns during outbreaks. Assuming that those animals were affected similarly to those in herd "A", lost production would have exceeded $57,500 during the first 175 days after outbreaks commenced. Additional to this would have been costs of supplementary feeding, veterinary services, extra manpower required to handle hyperactive herds, as well as general milk volume reductions in an additional 32,000 km² of farm lands that were less severely affected by black flies. Producers also claimed that there were some delayed conceptions as noted for beef cattle. Thus total losses to the dairy industry in Saskatchewan due to outbreaks of *S. luggeri* in 1978 must have greatly exceeded $57,500.

DISCUSSION AND CONCLUSIONS

The purpose of this paper was to catalogue losses attributed to outbreaks of the black fly *S. luggeri* in Saskatchewan, and to attempt to evaluate losses to determine whether demands for abatement programs by livestock producers and other residents of east-central Saskatchewan were justified.

Residents in this part of Saskatchewan have had to contend with black fly problems since the earliest days of settlement because the Saskatchewan River has always provided breeding sites for large numbers of larvae. Until about 1976, outbreaks of *S. arcticum* could be expected every year. Larvae of *S. luggeri* replaced those of *S. arcticum* when the river became shallow, clear and weedy every summer, mainly due to upstream storage of water in new hydropower reservoirs. Annual outbreaks of *S. luggeri* commenced on a large scale in 1976 and have continued to the present time although moderated on many occasions by experimental injections of methoxychlor larvicide into the Saskatchewan River.

Animals did not die suddenly after attacks by *S. luggeri* as had happened with *S. arcticum*. Nevertheless, outbreaks of *S. luggeri* inflicted significant losses for several reasons. Losses were enhanced, in part, by emergence of enormous numbers of adults from larvae breeding in vast new weed beds in the Saskatchewan River. Also because *S. luggeri* is multivoltine, in the absence of larviciding, numbers increase during summer months. In 1978 during the worst outbreaks on record, black flies emerged from the river throughout late May to late September and spread into at least 38,000 km² of surrounding countryside. About one-seventh of this area was subjected repeatedly to severely damaging outbreaks that year. Searches for larvae in other nearby breeding sites such as the Carrot and Torch Rivers showed that only the Saskatchewan River was capable of producing outbreaks of such magnitude. *S. luggeri* swarmed aggressively around heads of animals on most warm days that summer forcing animals into almost continuous hyperactivity. Animals stampeded readily, spent much time on windy hilltops and greatly reduced breeding activities. People were unable to perform normal outdoor activities because they too were attacked. Producers, who generally had been satisfied with the abatement program developed to prevent outbreaks of *S. arcticum*, demanded similar protection from outbreaks of *S. luggeri*. But whereas single larvicide injections, sometimes confined to a single branch of the Saskatchewan River, generally were sufficient to prevent outbreaks of *S. arcticum*, multiple injections both as regards times and sites often were required for *S. luggeri* partly because it was multivoltine and partly because single injections were no longer effective beyond 20 to 50 km in these weedy rivers. Such an intensive larviciding program would not be considered acceptable on a continuous basis without adequate economic justification, not only because of cost of larvicide but also because of concerns for non-target organisms in the river. Larvicide for a single, annual program as intensive as that required in 1979 (Fredeen, 1983) could cost as much as $25,000 at 1983 prices. Studies of environmental effects of using methoxychlor as a larvicide, including residue persistance and long-term effects on non-target invertebrates, indicated that environmental effects were negligable and might be tolerated in the event of proof of need for larviciding (Fredeen *et al.* 1975; Fredeen, 1983).

Studies of outbreaks of *S. luggeri*, from 1976 to the present time and especially of severely disruptive outbreaks in 1978 showed that losses to livestock owners could greatly exceed the cost of even the most expensive larviciding program envisaged. Losses from a single large pasture (James Smith Community Pasture) containing about 1,575 beef animals were estimated to have exceeded $150,000 in 1978. Losses included costs of replacing purebred bulls which had become impotent due to severe debilitation, fatalities of cows and calves, unrealized weight gains and losses due to delayed conceptions. About 20 percent of the cows were said to have missed being bred for at least one oestrus cycle that summer and numbers of cows not bred at all increased by at least 2.0 percent from the previous year. Not included in the calculations were costs of supplementary feeding, fence repairs, wages for extra riders, increased insurance costs, veterinarians' fees and medications for about 260 cases of pinkeye, foot rot, scours and pneumonia additional to those seen the previous year.

The James Smith pasture represented less than 0.6 percent of the entire area that was severely affected by outbreaks in 1978 judging by telephone calls, letters and personal interviews with producers. In this 5,680 km² area there were many herds of beef cattle containing about 650 bulls, 11,000 cows, 7,000 weaned cattle and 9,500 suckling calves. Losses estimated on the same basis as those for the James Smith pasture exceeded $2,900,000. Again, calculations did not include many miscellaneous costs, nor any losses in the remaining 32,000 km² of farmlands that were occasionally affected by outbreaks in 1978.

Dairy producers, who were unable to provide housing and indoor feeding for their milking animals, also suffered considerable losses. Average gross financial returns from two pastured herds in 1978, one having free access to a barn during outbreaks and one without access to shelter, differed by $185.50 per animal for the first 175 days after outbreaks commenced on May 26, when compared with returns during 175 days immediately preceding outbreaks. Total losses for some 310 unprotected milking cows in 5,680 km² of severely affected farm lands in 1978 were estimated to have exceeded $57,500. Calculations did not include production losses from the remaining 32,000 km² of farm lands affected by lighter outbreaks that year or costs of supplementary feeding, management or veterinarians' services.

Fear of chronic outbreaks caused many beef and dairy cattle producers to reduce or even eliminate herds in recent years. Data from provincial and federal government sources indicated that trends in animal populations and land-use patterns differed between regions affected by chronic black fly outbreaks and the rest of the province. For instance, between 1975 and 1981 in Crop District 8 (relatively most affected by outbreaks), numbers of beef cattle declined by 27 percent and dairy cattle by 32 percent. In the remainder of Saskatchewan, numbers declined by 21 and 6.5 percent during these same six years. Pasture lands were either converted to less productive uses or abandoned.

Concerns about black fly outbreaks have not lessened since *S. luggeri* replaced *S. arcticum* in the Saskatchewan River in the early 1970's. Summer-long outbreaks of *S. luggeri* have on occasion caused enormous losses to livestock producers. In addition, people are attacked so vigorously that sometimes they are not able to work out-of-doors. Control measures against *S. luggeri* must be continued and it seems most logical to apply control while black flies are in the larval stages, confined to relatively limited breeding sites in the Saskatchewan River. Dispersions of adults are unpredictable and often widespread once they have left breeding sites. Alternative methods of providing protection for livestock and people are under investigation, but at present best protection is provided with larvicide used in accordance with permits renewed annually by federal and provincial authorities.

Experimental manipulation of water flow in the Saskatchewan River seems remote because approved uses already tax limited water resources. Ongoing tests with insecticides against adults of *S. luggeri* indicate that ear tags impregnated with synthetic pyrethroids may provide relief in large herds. Managers of the 3,230 ha James Smith Community Pasture, already convinced of their usefulness, have not accepted untagged animals in that pasture since the spring of 1981. Results from larvicide tests with *Bacillus thuringiensis* serotype H 14, conducted by the Canada Biting Fly Centre, Winnipeg, should be known by 1985.

It is hoped this paper will help provide a balanced view for decision makers, when used in conjunction with an earlier paper on environmental effects of use of methoxychlor larvicide (Fredeen, 1983). Environmental issues involved must be studied in the broadest sense with concerns balanced between potential effects of chemical larvicides upon non-target species inhabiting or otherwise using Saskatchewan River water, and potential effects of black fly outbreaks upon people in their terrestrial environment, if larvicide is used ineffectively or not at all.

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