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A Brief History of Biting Fly Research in Manitoba

Many people have studied biting flies in Manitoba, and I wager that every one of them at one time or another relished the thoughts of being in one of the best places in the world to conduct such research. The landscape and topography of the province favour diversity and abundance of biting flies as in few other places. There are of course species of introduced biting flies, such as horn flies and stable flies, but I don't intend to address these in this review. I want to focus on the species for which Manitoba has gained its reputation: mosquitoes (47 species – Wood et al. 1979; Stuart 2007; Iranpour et al. 2009), ceratopogonids (5 species – Borkent 2017, personal communication), black flies (40 species – Crosskey 1993; Adler et al. 2004) and tabanids (Teskey 1990). The larvae of all species in these families develop in aquatic ecosystems, whether standing water (Fig. 1; mosquitoes), running water (black flies and tabanids) or wetlands (mosquitoes, ceratopogonids and tabanids). A survey of any topographical map of Manitoba yields an impression of a province of limited relief, but with vast and varied aquatic habitats. In the north, permanent and intermittent permafrost impede drainage, providing large areas of biting fly habitat. The boreal forest lays down an insulating groundcover that can retard the rate of thaw in the soil, holding standing water throughout. Natural prairies and human modification allow for accumulation of spring snowmelt and periodic summer floodwater. Over much of the province, groundwater tables are close to the surface, and wetlands abound. Water flows along streams and rivers of all sizes as it makes its way through the Arctic watershed to Hudson Bay. These resources add up to the perfect storm for biting flies. I want to provide a brief overview, covering what I call the three generations of biting fly research: Generation One – the Northern Biting Fly Project, 1947–1955; Generation Two – The Heyday, 1966–2013; Generation Three – Modern Times, 1999–present.

Figure 1. Mosquito larvae collected in one dip from a snowmelt pool near Churchill, Manitoba.

Generation One – The Northern Biting Fly Project, 1947–1955

Certainly biting flies were an important component of investigation for the Northern Insect Survey (1947–1962), but the most intense research in Manitoba was conducted in the interests of military support at Fort Churchill during the Northern Biting Fly Project. Post WWII North America was immersed in the Cold War and the fight against communism. A small part of this preoccupation was the concern of warfare in the far north. In response, scientists from the federal Division of Entomology were deployed in collaboration with the Defence Research Board to Fort Churchill in 1951. Alongside their American counterparts, some of Canada's future best known biting fly researchers (A.E.R. Downes, W.O. Haufe, B. Hocking, D.G. Peterson, C.R. Twinn, A.S.

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West, to name a few) took to the field with objectives to investigate the biology and control of biting flies, along with the search for the perfect repellent. Riegert (1999) provided a detailed and colourful account of activities during this period in Churchill, and I refer you to his publication so I can focus more fully on Generation Two.

I cannot fail to mention important work that took place in southern Manitoba during this time. Winnipeg is renowned as the mosquito capital of Canada. Consider Dixon and Brust's (1972) estimates of 10,000,000 (July, 1967) and 9,000,000 (July, 1968) mosquito larvae per survey area around Winnipeg. John McLintock studied the mosquito fauna of the Greater Winnipeg area and published his landmark paper in 1944. This publication stood as the baseline for later research and mosquito abatement efforts in the city.

Generation Two – The Heyday, 1966–2013

There are three elements to The Heyday of biting fly research in Manitoba, each significant in their own right. The first was the arrival of A.J. Thorsteinson in the Department of Entomology at the University of Manitoba in 1959. The second was the return of Reiny Brust to the same department in 1965; the third was the establishment of the Canada Biting Fly Centre in 1979.

The Arrival of A.J. ("Thor") Thorsteinson, 1959

"Thor" can best be described as a physiological behaviourist whose early work focussed on the chemical cues responsible for stimulation and deterrence of feeding in herbivores (Galloway and Thorsteinson 2017). He had a very wide range of interest and curiosity about what he observed around him. His family owned a cottage in southeastern Manitoba, the tabanid heartland of the province, where he found that when he left their vehicle in the sun with the windows rolled down, the vehicle literally filled with horse flies. Speculation about this led him to develop a hypothesis that the flies were attracted to the heat emanating from the open windows. He devised what he initially called the heliothermal trap, one with a spherical black target, a target that would warm with the sun's energy (Thorsteinson 1958). As is so often the case, initial hypotheses are modified by additional data. Several graduate students in Thor's lab further investigated the nature of the trap, including targets of various shapes and colours. This work ultimately led to the understanding that the horse flies were most attracted not to heat, but to a black sphere (Bracken et al. 1962; Bracken and Thorsteinson 1965a, 1965b). Targets of other colours, colour patterns and shapes were less attractive. The Manitoba Horse Fly Trap (Thorsteinson *et al*. 1964), as it became known, is now used over much of the world as the standard trap for horse flies.

The development of the Manitoba Horse Fly Trap, and the early survey work undertaken in the province, formed the basis for more recent work on the biology and impact of horse flies on livestock. In 1978, Dave Smith, one of the Provincial Entomologists at the time, took me, a newly hired faculty member in the Department of Entomology, to a Manitoba Agriculture co-operative project near Whitemouth Lake in southeastern Manitoba. Livestock specialists were investigating agricultural diversification in the region, one component of which was to expand the beef and dairy industries there. Early trials were hampered by intense biting fly pressure (Fig. 2), and Dave Smith's introduction

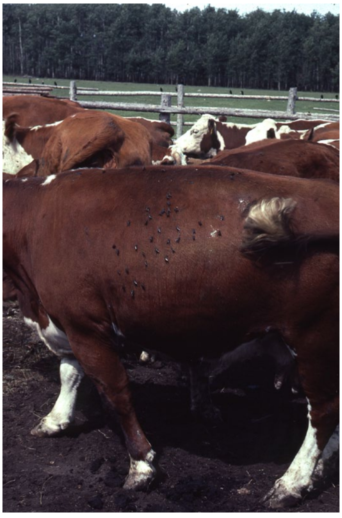

Figure 2. *Hybomita* spp. (Tabanidae) feeding on a cow, southeastern Manitoba.

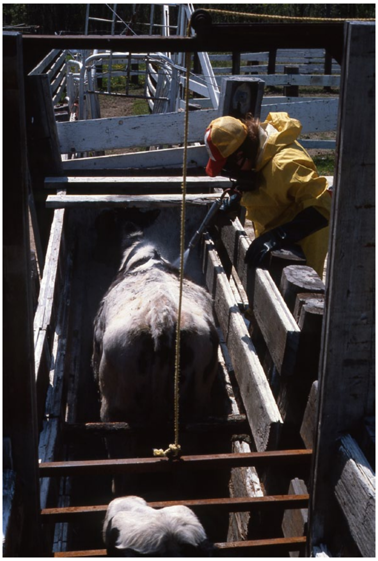

Figure 3. Application of a synthetic pyrethroid insecticide to cattle near Seven Sisters, Manitoba.

to the problem led to long-term investigations and collaboration with Manitoba livestock specialists and producers, eventually moving the study to a more permanent location near Seven Sisters. The newly developed synthetic pyrethroids were applied to pastured cattle (Fig. 3) and their behaviour was compared with untreated control animals in adjacent paddocks. This involved long, sometimes tedious, hours in the field, monitoring grazing and fly-avoidance behaviours (Ralley et al. 1993). Typically, animals begin activity early in the morning, generally relaxed and well-spaced from one another. As the temperature rises and horse fly activity increases, animals often form grazing lines, where animals on the ends attempt better positions within the line, and the line begins to move faster and faster. Forage is trampled and passed over in the process. Eventually, during the heat of the day, animals bunch together, with those on the outer fringe expending energy to force their way into the better-defended centre of the bunch. The bunch seems in constant motion, and since bunches occur when temperature and horse fly pressure are at their highest, heat stress becomes an issue. Over prolonged periods of attack, sometimes lasting weeks, animals suffer secondary infections such as pink-eye, hoof rot and respiratory complications. This research was extended to investigate biting fly pressure which was causing problems in a wood bison re-introduction project in the Waterhen area of Manitoba (Morgan 1987). Similar, though less convenient observations were conducted on the pastured bison. Animals on the project suffered intense horse fly attack, but the reproductive failures in the herd were eventually identified as having multiple sources, including herd composition, pasture management and herd nutrition, as well as biting fly attack. Throughout all these investigations, the Manitoba Horse Fly Trap was the stalwart for assessing species composition and relative abundance of horse flies (McElligott and Galloway 1991a, 1991b).

The Return of R. A. (Reiny) Brust, 1965

Reiny grew up in Manitoba and did his undergraduate degree in the Department of Entomology at the University of Manitoba. He conducted his MSc research in Thorsteinson's lab on mosquito ecology and travelled to the University of Illinois for his PhD under the supervision of the legendary William Horsfall. Reiny's PhD research took him to the northern regions of Manitoba to study various spring snowmelt mosquitoes. He eventually returned to the University of Manitoba in 1965, where he immediately waded into a new career centred on the many aspects of mosquito ecology (e.g., Brust 1968; Brust and Costello 1969; Tauthong and Brust 1976). Reiny and his students spent time in the north at Churchill and Baker Lake; he explored and developed a mosquito control strategy for Pinawa, Manitoba, and examined mosquitoes in artificial containers and rock pools. Research on reproduction and diapause was a running theme through much of his research, in snowmelt mosquitoes was well as important summer floodwater species. *Aedes vexans* (Meigen), a multivoltine summer floodwater species, is one of the most serious pest species in Manitoba. An often asked and relevant question for mosquito abatement efforts was how far could *Ae. vexans* fly. Reiny initiated the most ambitious and successful dispersal experiments conducted in Canada (Brust 1980). He supported an army of summer students who collected hundreds of thousands of *Ae. vexans* and *Ochlerotatus sticticus* (Meigen) larvae to be held in metre-square pools. When adults emerged, they were marked with coloured dyes and released. Adults were later collected in New Jersey Light Traps placed in concentric rings around the point of release and marked individuals identified from the piles of mosquitoes in the trap catch. This research formed the basis for extension of City of Winnipeg abatement efforts beyond the Perimeter Highway. Reiny and his students provided major contributions to the understanding of mosquito vectors of western equine encephalitis (WEE) virus, an agent that had historically contributed to the deaths of thousands of horses and caused serious disease in humans. He played an important role in managing the WEE outbreaks of 1975, 1977, 1981 and 1983 as an advisor (e.g., Bowen et al. 1976; Fraser and Brust 1976; Brust and Ellis 1976), and by providing solid research support on mosquito populations and ecology and control of the primary vector, *Culex tarsalis* Coquillett. Many students in his lab followed the gonotrophic, and seasonal and transmission cycles of *Cx. tarsalis* as related to vector potential and risk assessment for the public health sector (e.g., Henderson et al. 1979; Brust 1990; Buth et al. 1990; Fox and Brust 1994; Anderson and Brust 1995). Reiny collaborated extensively with staff at the Cadham Provincial Health Laboratory and the Laboratory Centre for Disease Control to investigate not just WEE virus, but other mosquito-borne viruses (Artsob et al. 1985; Sekla et al. 1991). This led to the discovery and description of a new virus isolated from *Cx. tarsalis* collected in Morris, Manitoba (Artsob et al. 1991). A series of projects conducted by Reiny and his colleagues involved a species of mosquito that was of no pest status at all, one that didn't even bite, *Wyeomyia smithii* (Coquillett) (Smith and Brust 1971a, b; O'Meara et al. 1981; Farkas and Brust 1985, 1986). *Wyeomyia* are found in sphagnum bogs where the eggs are laid in leaves of the purple pitcher plant, *Sarracenia purpurea* Linnaeus. No aspect of *Wyeomyia* biology was overlooked, even its overwintering strategy as larvae in frozen pitcher plant leaves (Evans and Brust 1972). When I arrived in Reiny's lab in 1973, the benches were covered by black electrical tape-covered glass chimneys occupied by his *Wyeomyia* cultures. Many aspects of its biology had been investigated by some of Reiny's earlier graduate students, but by that time, Reiny was exploring taxonomic relationships among different populations of pitcher plant mosquitoes in North America, and he maintained populations collected from as far north as The Pas in Manitoba to Holt, Florida. Natural enemies of mosquitoes and their potential for biological control (Fig. 4) also ran as a theme through Reiny's research career (e.g., Dixon and Brust 1971; Taylor et al. 1980; Galloway and Brust 1985).

Figure 4. *Culex* larvae infected by mermithid nematodes, *Romanomermis culicivorax*.

Reiny didn't limit his research to mosquitoes. He and two graduate students became involved in black fly outbreaks on the Souris River. During sequential flood years, black flies emerged from the river in enormous numbers, their feeding having serious impact on domestic poultry and livestock. Recording species composition and impact on cattle were important outcomes of this early research (Van Deveire 1981; Westwood and Brust 1981), research that laid the groundwork for examination of the environmental impact of insecticide applications to running water for control of black fly larvae in Manitoba. It had been common practice to apply DDT, and later methoxychlor, for black fly control in Canada. There was considerable controversy over the environmental impact of this approach, especially in western Canada, where these insecticides were being applied to large rivers such as the Athabasca in Alberta and the North Saskatchewan in Saskatchewan. Bob Sebastien, under Reiny's supervision, treated a riffle with methoxychlor on the Souris River at Bunclody and monitored the non-target impact on aquatic invertebrates and fish (Sebastien et al. 1989).

The Canada Biting Fly Centre, 1979–1989

The concept for the Canada Biting Fly Centre (CBFC) arose in the late 1960s to early 1970s, in part the notion of E.J. Leroux and P.S. Corbet. There was a recognized need for co-ordination of biting fly research being carried out across the country. The Canadian Agriculture Services Co-ordinating Committee and the Expert Committee on Pesticide Use in Canada supported the concept, and tenders were requested from across the country. Partly because of the strong research programme of Reiny Brust, and partly because of its central location, the University of Manitoba was chosen as the home of the new CBFC. Mary Galloway was hired as the head of the Centre, in conjunction with the CBFC Advisory Committee. The initial objectives of the CBFC were 1) to compile an inventory of biting fly specialists in Canada, 2) to determine the demand for biting fly information services, and 3) to determine the need for a nationally recognized extension and technology training facility. It is interesting to note that, in the initial survey of expertise, Mary identified 159 biting fly specialists and 74 abatement personnel, numbers that vastly exceed current resources in this country. Bernice McLeod and Randy Gadawsky soon joined the CBFC as office support and research associate, respectively, and the Centre quickly surpassed its initial objectives by beginning research activities to assess control options and carry out repellent trials. Assessment and development of bacterial agents for control of black fly larvae became an important component of CBFC research, which also engaged graduate student involvement (Burton 1984; Galloway and Burton 1984). Lloyd Dosdall succeeded Randy Gadawski as research associate when Randy left the CBFC to take on responsibilities as City Entomologist for Winnipeg. The CBFC attracted researchers from other parts of the world. For example, British entomologist, Roger Crosskey, visited Manitoba several times, when he would travel about the province collecting black flies (Crosskey 1993). Unfortunately, the gradual reduction in contract research support in Canada meant the CBFC was no longer sustainable and it closed its doors in 1989.

Generation Three – Modern Times (1999–present)

As you will notice, there is a period of overlap between the end of Generation Two (1966–2013) and Generation Three (1999–present). 2013 marked the departure of the last of the biting fly researchers from the Heyday of biting fly research, but Modern Times had already taken over. In 1999, Harvey Artsob and his staff arrived in Winnipeg to establish the new home for the Field Studies, Zoonotic Diseases and Special Pathogens section in the Canadian Science Centre for Human and Animal Health. Although Dr Artsob has since retired, Robbin Lindsay and Mike Drebot maintain an active research programme, especially on vector-borne pathogens, including activities of Research Associate, Mahmood Iranpour. There are many young scientists in Manitoba pushing back the frontiers of biting fly research today. Robert Anderson at the University of Winnipeg studies mosquito vectors, while Steve Wyard and Kateryn Rochon in the Department of Biological Sciences and Department of Entomology, respectively, at the University of Manitoba are working on various aspects of vector biology and control. Bryan Cassone is the most recent addition to the biting fly arsenal, setting up his new programme at Brandon University.

It's likely there will always be a great diversity and abundance of biting flies in Manitoba. Despite the overall reduction in resources to address biting fly problems in Canada, Manitoba still seems well positioned to tackle related issues in the future.

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