SEASONAL HISTORY OF THE BALSAM WOOLLY APHID IN COASTAL BRITISH COLUMBIA[1]

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ABSTRACT

Studies of the balsam woolly aphid at four locations in south-western British Columbia showed that there were basically two generations per year, although only a partial second generation may occur at high elevations and a partial third generation at low elevations in some years. The initiation of spring development occurred as early as February in the moderate climatic sites and as late as May in the more severe ones. The first crawlers appeared in late April, with initial peak abundance occurring from late May to the first half of July, depending on location. Thereafter crawlers were present during the remainder of the season, even into December at low elevations, with peaks in abundance occurring throughout August, September and October.

INTRODUCTION

The balsam woolly aphid, *Adelges piceae* (Ratzeburg), a native of European white fir (*Abies alba* Miller), is capable of attacking all true firs (*Abies* spp.). It has been introduced to both coasts of North America, probably through movement of nursery stock (Balch, 1952).

The insect was first found in British Columbia in 1958 (Silver and Ross, 1959) and is presently distributed over 3700 square miles of the southwestern mainland and Vancouver Island (Molnar *et al.*, 1970). Amabilis fir (*Abies amabilis* (Douglas) Forbes) has suffered heavy mortality, and grand fir (*A. grandis* (Douglas) Lindley), although more resistant to injury by the insect, has suffered appreciable mortality and deformity. Alpine fir (*A. lasiocarpa* (Hooker) Nuttall) also suffers heavy mortality but the insect is not widely distributed in stands of this species. Further spread of the aphid threatens the alpine fir stands in the interior of the province and amabilis fir stands on the coast and Vancouver Island.

A knowledge of the seasonal history is important in assessing the hazard of further spread. The aphid is a minute, parthenogenetic insect, the life cycle consisting of five stages: egg, first-instar nymph (which includes an active crawler and a settled "neosistens"), second- and third- instar nymphs and adult. Winged forms seldom occur and the only motile stage is the crawler. The aphid usually overwinters in the neosistens stage. The number of generations per year varies with climatic conditions. In Eastern Canada, one generation occurs in cool regions and a second and partial third in warmer regions (Greenbank, 1970). In western United States, up to four generations occur in mild climates at low elevations (Tunnock and Rudinsky, 1959; Mitchell *et al.*, 1961).

Studies of the seasonal history of the balsam woolly aphid were carried out in British Columbia during 1967 and 1968 to determine the number of generations per year, the time of initiation of development in the spring, and the time of year when crawlers were most abundant.

METHODS

Four study sites were located in infested stands of *A. grandis* and *A. amabilis*. The former stands were on Vancouver Island near Victoria (elev 100 ft) and Deerholme (elev 300 ft), near Duncan; the latter were on the lower mainland in the Seymour Valley (elev 800 ft) and on Mount Fromme (elev 2700 ft), both near North Vancouver. Seasonal history was determined by weekly examination of infested stems and tanglefoot[2]-covered cards. The trees selected for study varied from 12 to 20 inches dbh, had medium to heavy stem populations, and were located near the stand margins.

Study areas, on the bark were examined with a stereo microscope (approx. 20X) (Fig. 1). Light was provided by a microscope lamp, fitted with a heat absorbing lens, and powered by a small six-volt battery.

On amabilis fir, the study areas (7 to 10 on 3 trees at each location) were 1-inch squares of bark, delineated by red wax pencil and divided into quarters. A dot in the centre of each quarter facilitated orientation and "mapping" the location of aphids. On grand fir, the rough bark made this method unsatisfactory. Instead,

[1] Contribution from Pacific Forest Research Centre, 506 West Burnside Road, Victoria, B.C.

[2] Tree Tanglefoot Ltd., Grand Rapids, Michigan.

Fig. 1. Examination of bole with microscope mounted on scissor jack on portable platform and showing tanglefoot drop cards (arrows) in position on the bole.

the field of view of the stereo microscope (approx. 0.1 sq inch) was used and map pins on the bark located the positions (6 to 12 on 3 or 4 trees). The stage of development of each aphid was recorded weekly on a map of the study area.

The tanglefoot-covered cards (Fig. 2) were mounted on three or four trees at each site. Each card was supported by galvanized metal of the same size and placed in a horizontal slit cut in the bark of the tree, one at each cardinal direction (Fig. 1). The cards were replaced weekly and examined for numbers of crawlers (crawler drop). Sub-blocks marked on the

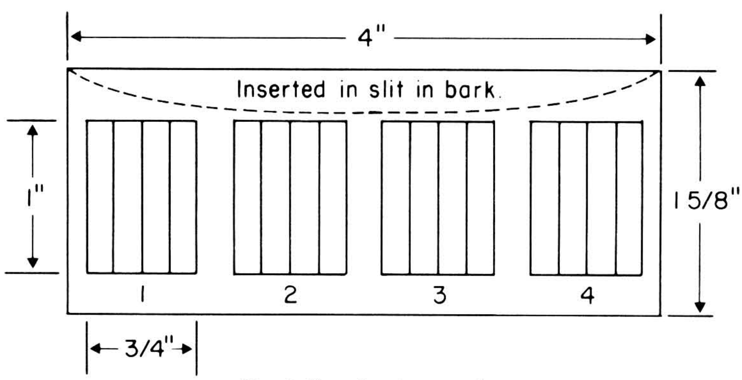

Fig. 2. Crawler drop card.

cards facilitated counting the number of crawlers in each block; when numbers were extremely high, totals for each card were estimated from counts in one sub-block chosen at random in each of the blocks.

Temperature records were obtained from hygrothermographs operated in the stands throughout the year at Deerholme and Victoria, and from mid-April (1 June, Mt. Fromme, 1967) to mid-November on the lower mainland. The thermograph records were supplemented with data from federal government weather stations. Degree-days above 42° F were calculated from the maximum and minimum temperatures (no upper threshold) (Baskerville and Emin, 1969). As a check on this technique, degree-days were also calculated for 2 one-week periods each year at each location by measuring the area above 42°F and below the trace on the thermograph charts. Although the latter were usually slightly higher, particularly at Victoria and Deerholme, differences for the total of the 4 one-week periods at any one location did not exceed 5.3%.

RESULTS AND DISCUSSION

A total of 3425 neosistentes were examined on the boles; 825 in the spring, 1548 in the summer and 1052 overwintering in the fall; 888 adults were observed. Duration of the immature stages showed no consistent differences associated with location and are grouped in Table I. However, those individuals that moulted to second instar early in the spring took longer to develop.

TABLE 1. Duration (weeks) of immature stages of balsam woolly aphid.

Season	Instar 1			Instar 2			Instar 3		
	n[1]	Mean	se[2]	n	Mean	se	n	Mean	se
Spring	Overwinter			328	2.9	0.09	338	2.2	0.06
Summer	558	5.9	0.11	445	1.1	0.03	309	1.1	0.06

1 Number of individuals
2 Standard error

The insect's seasonal history for each location and year, as determined from bark observations, is shown in Figure 3. The major difference among locations was the late initiation of spring development on the lower mainland, particularly on Mount Fromme. Between years, the major difference was the earlier appearance of adults in the spring and earlier settling of overwintering neosistentes in the fall of 1968. Although only immature stages were present on the study areas, on Vancouver Island during January, February and March, occasional adults with eggs were seen on other areas of the bole.

Crawler drop for both years at each location is shown in Figure 4. In 1967, the cards were not in place early enough to observe initiation of crawler drop except on Mount Fromme, where it occurred on 12 June. Although a few crawlers were found on the cards during February, March and April in 1968 on Vancouver Island, a major increase in numbers did not occur until mid-May. Crawlers were first found in Seymour Valley on 23 May and on Mount Fromme on 5 June.

The peaks in crawler drop (Fig. 4) indicate periods of greatest crawler abundance, with the initial peak representing progeny of the overwintering generation. Following this peak, crawlers were present continuously, with populations peaking at various times, until December. The major differences among locations were the later occurrence of the initial peak on the mainland and the lack of a second peak on Mount Fromme in 1968. The initial peak crawler drop occurred slightly earlier in 1968 than in 1967 at Victoria, whereas it occurred earlier in 1967 at Seymour. At Deerholme and Fromme this peak occurred at about the same time in both years.

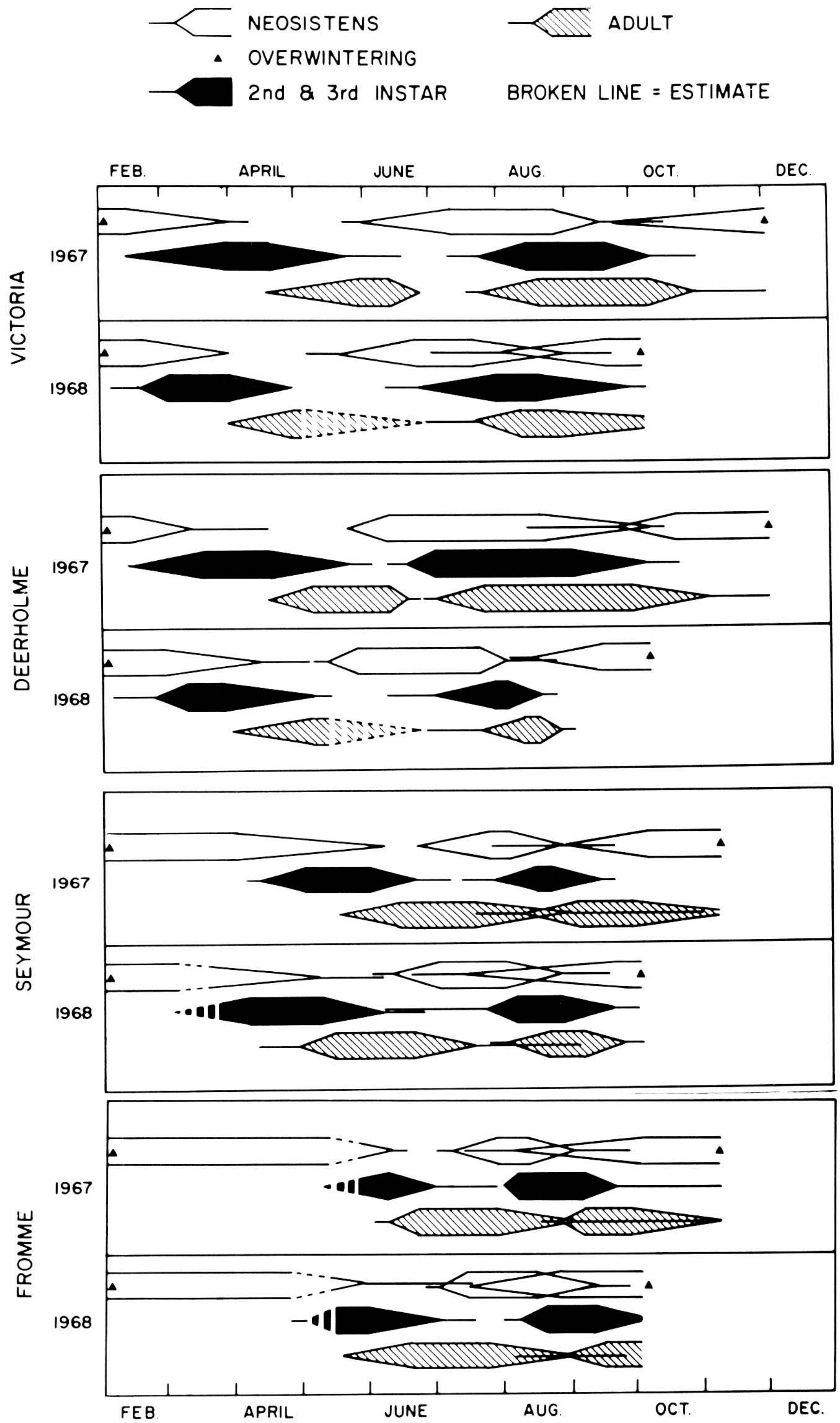

Fig. 3. Seasonal development of balsam woolly aphid on the bole at four locations, 1967 and 1968. The wide part of each bar represents the period when over 80%, and the single line less than 20%, of the maximum population of that stage was present.

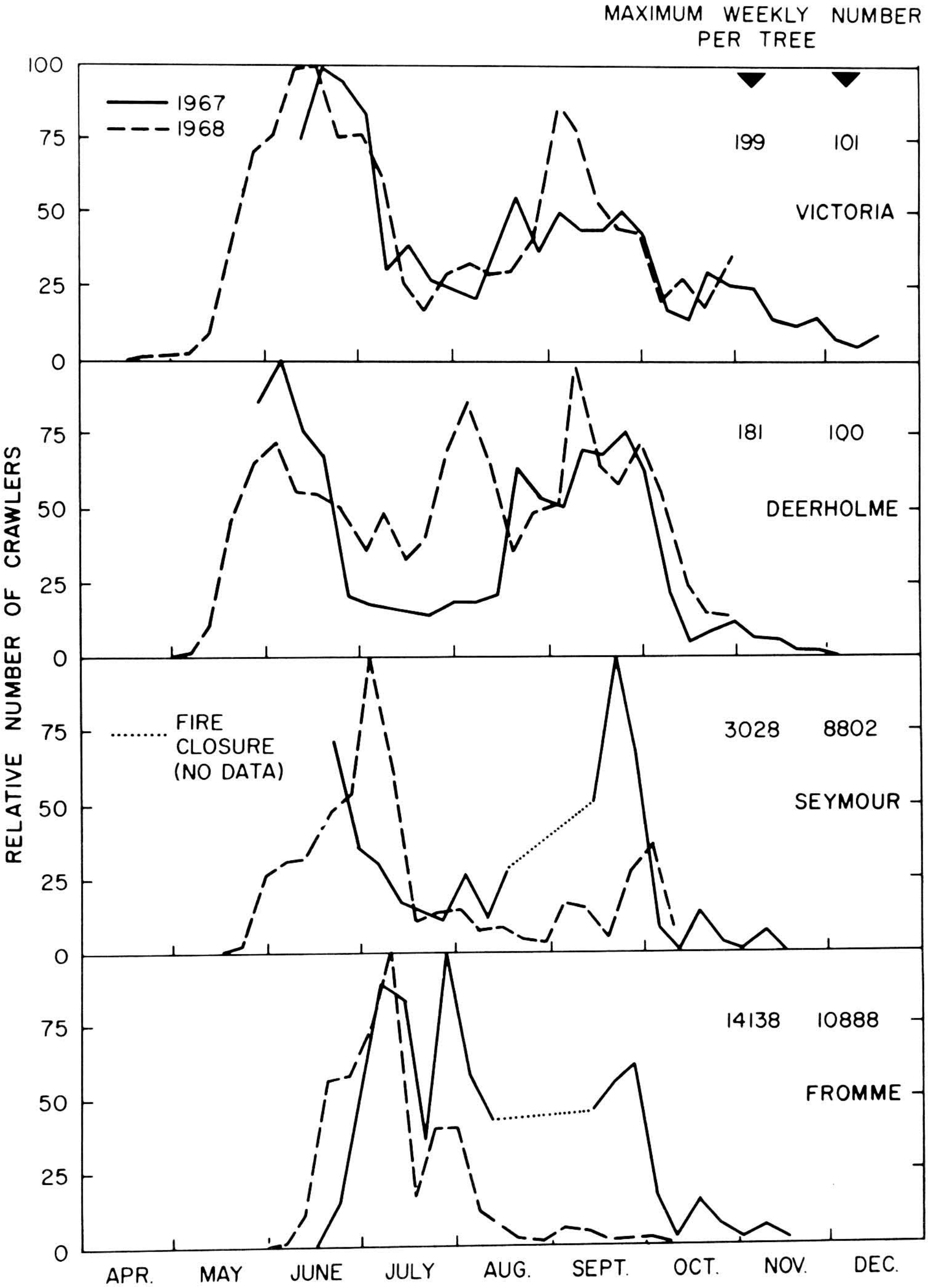

Fig. 4. Crawler drop relative to maximum weekly number (expressed as 100) at four locations, 1967 and 1968.

Greenbank (1970) indicated that 650 degree-days above 42 F were required for completion of the overwintering generation and an additional 1550 were required for completion of a second generation in New Brunswick. The dates on which these requirements were met at each location in each year (Table II) indicate that at least two

TABLE II. Dates on which heat accumulations of 650 and 2200 degree-days above 42°F were attained at four locations in 1967 and 1968.

Location	Degree-days			
	650		2200	
	1967	1968	1967	1968
Victoria	June 7	May 23	August 20	August 15
Deerholme	June 12	June 11	August 25	September 10
Seymour	June 17	June 20	August 24	September 7
Fromme	July 2	July 10	October 9	(Oct. 7 only 1590)

generations might be expected at all locations except Mount Fromme in 1968, and that development would be later on the mainland than on Vancouver Island. Although heat accumulation requirements were met earlier at Victoria than at Deerholme, the bole examinations and crawler drop indicated that development of the overwintering generation occurred at least as rapidly at Deerholme as at Victoria. Although mean temperatures were usually slightly lower at Deerholme than at Victoria, maximum temperatures were higher, suggesting that more efficient development took place under conditions occurring at Deerholme.

The crawler drop was affected to some extent by weather conditions, as indicated by the means of the daily maximum temperatures (mean maximum temperature) during the periods of crawler drop (e.g. Seymour Valley, 1968, Fig. 5). Higher temperatures cause greater activity of the crawlers (Atkins and Hall, 1969) and therefore increase the chance of their dropping onto cards. Initial peak crawler drop was possibly delayed at Seymour in 1968 by early June weather conditions.

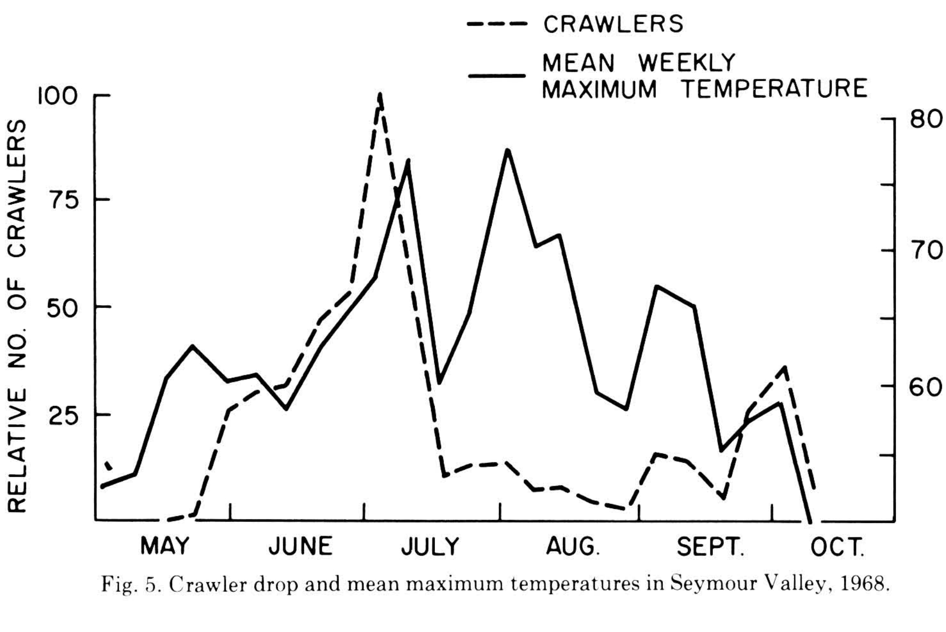

Fig. 5. Crawler drop and mean maximum temperatures in Seymour Valley, 1968.

Variation in crawler drop was also introduced by differences in trees. The initial peak crawler drop on different trees at the same location was up to two weeks apart, and later peaks up to five weeks apart. The pattern of crawler drop on one tree at Deerholme (Fig. 6) was greatly different from the pattern on other trees in 1967 and was omitted from the data for Figure 4. Although the initial peak occurred at the same time as on other trees, the second peak occurred only five weeks later, whereas at least eight weeks elapsed between similar peaks on other trees at all locations. The pattern of drop was similar on each cardinal direction and no differences in location of this tree in comparison with other trees at Deerholme were apparent. Some individual host difference may have promoted rapid development of the summer generation on this tree. In 1968, such extreme differences between this tree and others were not apparent, although peak populations of crawlers did differ in relative magnitude. Unfortunately, the development of the aphid on the bole of this tree was not observed.

Comparison of monthly mean temperatures, 1955 through 1969, at Victoria Gonzales and Vancouver Airport weather stations indicated that neither 1967 nor 1968 had extreme weather conditions except that February-March 1968 was one of the warmest of the 15 years. Thus 1967 and 1968 were fairly representative years. However, the warmer spring weather in 1968 was reflected by the earlier appearance of adults on the bole in the spring of that year (Fig. 3). August and September weather conditions, being cooler in 1968 than in 1969, probably delayed development of many neosistentes, and accounted for the earlier settling of those that eventually overwintered (Fig. 3).

In general, two generations occurred each year, although crawler drop records for Mount Fromme exhibited little evidence of a second generation in 1968. However, bole examinations indicated that a portion of the population completed a second generation while the rest remained in the neosistens stage and eventually overwintered. Bole observations could not separate additional generations

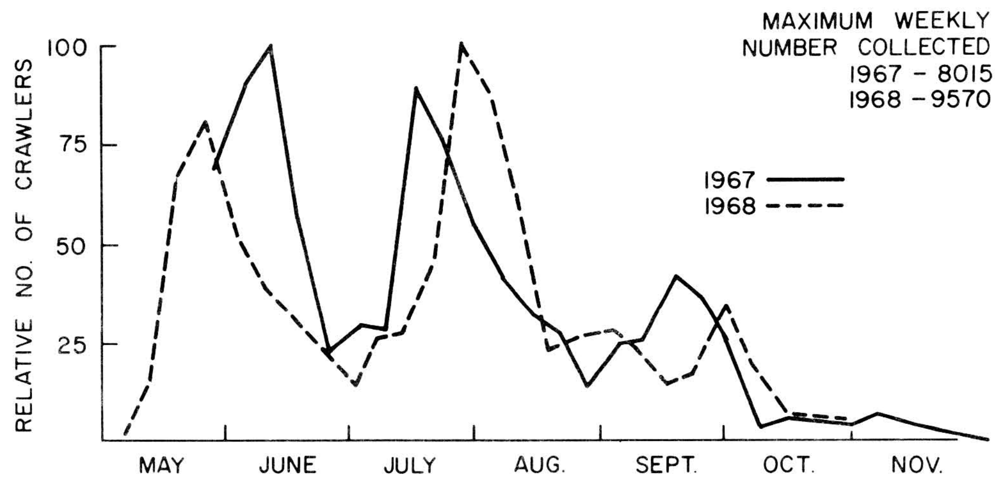

Fig. 6. Atypical crawler drop from the bole of one tree, Deerholme, 1967 and 1968.

occurring during the summer, since the parents of newly settled neosistentes could not be determined. However, evidence indicates that a third generation occurred on Vancouver Island. The crawler drop for both Victoria and Deerholme showed at least two distinct peaks, and crawlers were present thoughout November in 1967 and were still numerous in October, 1968, when observations ceased. Furthermore, the average duration of various stages (Table I) indicated that third generation adults could appear by mid-September at both Victoria and Deerholme and heat accumulation (Table II) at Victoria was sufficient by late August in both years for completion of a second generation, leaving the remainder of the season for at least a partial third generation.

The effect of partial generations on populations is open to conjecture. That portion of the population unable to attain the normal overwintering neosistens stage could be expected to suffer high mortality, expecially under severe climatic conditions. Greenbank (1970) provides an example in which 6% of the population formed a partial third generation and increased the overwintering population by 25%.

The different host species, grand and amabilis fir, may have contributed to differences between the mainland and Vancouver Island. However, weather conditions appeared to be the dominating factor.

Dispersal of the insect is believed to be chiefly by wind (Balch, 1952), but it may be spread by man (Atkins and Woods, 1968). Thus the main hazard of dispersal exists when the crawlers are present, from late April through November, although peak crawler populations occur at various times. At high elevations, the major hazard period is reduced to June through October.

The results of the studies reported here provide a guide to the times of year when various stages of the insect are present, and confirm that heat accumulation data can be used as a general guide to the number of generations. However, variations are such that when precise knowledge is required, sampling of the populations would be necessary.

Acknowledgements

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