

Suction Trapping of Selected Small Grain Aphids in Colorado, 1988-1998

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Aphids are serious pests of small grains worldwide because of direct feeding damage and the ability to transmit plant pathogens. In Colorado, the major cereal aphid pests are the Russian wheat aphid, *Diuraphis noxia* (Mordvilko), greenbug, *Schizaphis graminum* (Rodani), and bird-cherry oat aphid, *Rhopalosiphum padi* (L.). The Russian wheat aphid, introduced into the United States in 1986, causes chlorotic leaf streaking, leaf stunting and rolling, and trapped and distorted heads. Losses to Russian wheat aphid have exceeded \$112 million in damage in Colorado (F.B. Peairs, unpublished) and \$500 million in the USA since its introduction (Morrison and Peairs, 1998). The greenbug and bird cherry-oat aphid cause considerable direct damage to plant growth and yield in both winter wheat and barley (Kieckhefer & Kantack, 1988, Ortman and Painter 1960, Mallott and Davy 1978) and spring wheat and barley (Kieckhefer & Kantack 1980, Voss et. al. 1997). They are also vectors of barley yellow dwarf virus (Gildow 1984, Blackman et al. 1987), which also causes significant damage to the world's small grain crops (Burnett 1990). The three aphid species discussed in this publication have different life histories which explain, in part, the varying patterns of suction trap captures.

Russian wheat aphids feed only on grasses, with cool season grasses that are botanically related to wheat being preferred hosts (Hammon et. al.1997, Kindler and Springer 1989). In eastern Europe and Asia, Russian wheat aphids reproduce asexually during the spring and summer, followed by a sexual generation in the fall. They overwinter either as eggs or living aphids, depending on local

climactic conditions. Eggs are much less vulnerable to climactic extremes than living aphids, so Russian wheat aphid populations are more stable from year to year in areas where there is no sexual reproduction. Males have never been found in North America so all reproduction is assumed to be asexual. Russian wheat aphids spend the winter as living aphids, feeding on host plants when climactic conditions permit (Hammon and Peairs, 1992). When winters are very cold or there is extended snow cover, Russian wheat aphid populations decrease or winter kill (Armstrong and Peairs 1996, Butts and Schaalje 1997). Winter mortality can occur over a large region or only within isolated portions of an area. When winter mortality of aphids occurs over a large area, the region can be reinfested by flights of alatae (winged aphids) from another area. Russian wheat aphid populations increase in the spring as they reproduce on wheat and barley. Local movement occurs as these aphids move within and between fields. This is evident in areas where spring grains are produced, as these fields may be infested by alatae soon after plants emerge. As the grain crop matures, many alatae are produced which migrate to oversummering host plants. Fall migration occurs as aphids migrate from oversummering host plants into the newly emerged fall planted small grain crop.

Bird cherry-oat aphids have a variety of life cycle phenotypes. Some have an obligate heteroecious (host-alternating) holocyclic (with a sexual stage) life history, while others are mostly holocyclic with a residual anholocyclic (asexual) population. Some clones are permanently anholocyclic. In the heteroecious forms, alate aphids migrate to chokecherry plants in the fall,

where overwintering eggs are produced. Eggs are laid after mating of the oviparae (egg producing females) with migrant males. Eggs are more resistant to cold and dessication than living aphids. The eggs hatch in the spring. These aphids reproduce asexually, and after one or more generations on chokecherry, alatae are produced that migrate to wheat or other grasses, where many generations of both alatae and apterae (wingless aphids) are produced during the summer. In the late summer, many bird cherry-oat aphids infest corn and other grassy hosts, where they sometimes become abundant. Anholocyclic populations of bird cherry-oat aphids on wheat may survive the winter, feeding near the base of plants and reproducing asexually if environmental conditions are not too severe.

Greenbug also has a holocyclic life history in parts of their range, but sexual forms are rare in Colorado. The life history of holocyclic greenbug populations differ from that of bird cherry-oat aphid in that the egg stage is spent on the same grass species that the asexual summer and fall generations feed on (monoecious holocyclic). Their life history is similar to that of Russian wheat aphid in that only grasses are used as host plants. The host range of greenbug is different than that of Russian wheat aphid, as it is a serious pest of warm season grasses such as corn, sorghum and millet in addition to wheat. Greenbugs may survive the winter by feeding on host plants and reproducing asexually if environmental conditions are not too severe.

Monitoring of aphid populations is important to document the extent and severity of infestations in a particular area and aid in predicting future infestations. Suction traps have been used to monitor and forecast peak migrations of various aphids. Suction traps

capture alate aphids (Allison and Pike, 1988) which are weak flying insects responsible for dispersal. Alatae are formed in response to various factors, such as overcrowding and decline in host plant suitability. The number of alatae present is determined by the total number of aphids, growth stage of host plants, season, and other factors. Some species, such as bird cherry-oat aphid produce many alatae to move to overwintering hosts, resulting in late season peaks in aphid captures. Other species, such as Russian wheat aphid, always have a few alatae present with the proportion of the population in the alate form increasing in response to environmental stresses and crop maturity.

In Europe, suction traps are used to monitor movement of many aphid species, and to predict outbreaks resulting from immigrating aphids (Turl 1980, Dewar et al 1984). In South Dakota, Kieckhefer et al. (1974) used suction trap data to show aphid immigration was associated with low-level jet winds. Loxdale et al. (1993) reviewed the evidence concerning short and long-range movement of aphids, and concluded that while long-range movement of aphids (>100 km) certainly occurs, it is infrequent. Short-range dispersal (<20 km) is much more important in the population dynamics of aphid outbreaks. Halbert et al. (1998) presented evidence that suction trap captures reflect aphid flight activity within a 30 km radius of the trap. Halbert and Voegtlin (1994) used the capture of host specific aphids to predict the presence of purple loosestrife, a noxious weed. Halbert et al. (1995) used the aphid species assemblage collected in suction traps as an indicator of plant biodiversity in an area.

In 1983 the Western regional suction trapping system began to monitor barley yellow

dwarf virus vector activity in the Pacific Northwest (Pike et al. 1987, Allison and Pike 1988, Quinn et al. 1991). This system now monitors Russian wheat aphid flight patterns to alert growers of Russian wheat aphid infestations. The earliest yearly collections of Russian wheat aphid have generally coincided with detectable populations in spring seeded cereal crops, and have occurred before economic thresholds have been exceeded. Fall collections of Russian wheat aphids have indicated that they have successfully overwintered, and there was a potential for infestation of the fall seeded cereal crop (Halbert et al. 1998). A network of suction traps was set up in small grain producing regions of Colorado in 1988 to monitor populations of Russian wheat aphid and other small grain aphids. This publication presents the results of this trapping at certain locations for the period of 1988-1998. It gives an important historical perspective on small grain aphid abundance and movement during that time period.

METHODS AND MATERIALS

Suction traps constructed to the specifications of Allison and Pike (1988) were placed in the field in the spring of 1988. The traps are 28 ft tall, with an opening diameter of 12 in. An electric fan pulls air through the traps and insects are funneled into a jar containing a 50:50 mixture of ethylene glycol and 95% ethanol, which kills and preserves the catch. Aphids were separated from other insects under a dissecting microscope, and small grain species counted. The traps were run from approximately April 1 to October 31 of each year.

The traps reported on in this publication are located at:

- Akron - USDA Central Great Plains Research Center, 4 mi E of Akron, Washington Co.
- Fort Collins - 7 mi S of Briggsdale (1988-1993), Weld Co.; ARDEC (1994-1998), 5 mi S of Wellington, Larimer Co.
- Fruita - Fruita Research Center, 2 mi NE of Fruita, Mesa Co.
- Walsh - Plainsman Research Center, 0.5 mi W of Walsh, Baca Co..
- Yellow Jacket - Southwestern Colorado Research Center, 1 mi N of Yellow Jacket, Montezuma Co.

The traps were changed weekly at a minimum. Heavy rains, power outages and mechanical failures have caused short term disruptions in data collection at all sites. Single missing data points were estimated by averaging the two data points surrounding the missing data. If more than two consecutive weeks were missing, the points were not graphed. The data are presented in Figures 4-18 as weekly captures. Data points greater than zero are plotted with dot symbols. If no symbol is present, the capture was either zero or missing. If there is no line connecting two points, there are missing data points.

Temperature and precipitation data was obtained from the Colorado Climate Center (<http://ulysses.atmos.colostate.edu>). The station nearest to the suction trap which had a complete data set for 1988-97 was chosen for data. These stations are listed as:

- Akron 4E
- Fort Collins

- Fruita 2E
- Walsh
- Yellow Jacket 2W

Weather data is presented in Figures 2 and 3. Precipitation is presented as monthly total. Daily maximum and minimum temperatures were averaged for the period of 1988-1996.

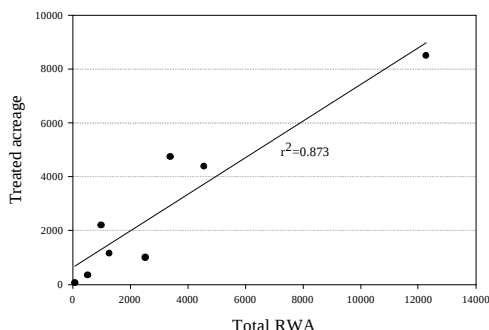


Figure 1. Total Russian wheat aphid captures in eastern Colorado suction traps vs estimated acreage treated with insecticide for 1988-1995.

RESULTS AND DISCUSSION

Meaningful interpretation of the data can be made during three time periods. The first capture gives a relative indication of early season movement. It is related, in part, to the overwintering success of the aphid species and the early season abundance of the species.

The peak capture occurs as the wheat crop matures and aphids migrate from the plants. The number of aphids captured during the peak flight is related to the total number of aphids present in the field and is an indication of the severity of the infestations in an area. The

earliest peak flights are at Walsh, which is at an elevation of about 4000 ft and is where the earliest harvested wheat is located. The latest peak flights are at Yellow Jacket, which is approximately 7000 ft in elevation, and has the latest maturing wheat.

Late season captures of aphids occur during the time period that the fall crop is seeded and are useful in predicting the severity of fall infestation in newly seeded wheat. Typically, no Russian wheat aphids are captured in the late season at Walsh, because they do not overwinter well in the hot, dry period between the harvest of one crop and seeding of the next. Fall infestations were present to varying degrees at Fruita in all years prior to 1995, and this is reflected in low numbers of Russian wheat aphid captured consistently during September and October. Fall Russian wheat aphid infestations were very low from 1995-1998, and late season captures were low. Bird cherry-oat aphid infestations in the fall seeded wheat crop were common in all years at Fruita, which is reflected in consistent late season captures.

The total number of Russian wheat aphids caught during the season is an excellent indication of the severity of the overall infestation (Figure 1). When the total number of aphids is plotted against the estimated acreage that was treated with insecticide, the correlation is very high. Total capture from selected suction traps can be used to document the relative severity of Russian wheat aphid infestations in a given year.

Akron

Russian wheat aphid flight activity began around June 1 and ended near the middle of August in most years. There was near continuous flight activity through mid-September in 1997. A

smaller, second flight occurred in the first week of October and continued through the end of the month in 1989, 1990, 1991 and 1992. The greatest Russian wheat aphid flight was in 1989 when the peak catch was 4,708 aphids during mid July. The smallest Russian wheat aphid flight occurred in 1993, when only seven Russian wheat aphid were captured the entire season.

Weather data seem to indicate that two inches or more precipitation in May will delay initial flights by two to three weeks. Two or more inches of precipitation in May and at least two inches in June will delay the peak aphid flights for one to two weeks (Figs 3 & 4). This is due to the effect of precipitation in decreasing Russian wheat aphid field populations, and delaying the maturity of the wheat crop.

Bird cherry-oat aphids were caught in the suction trap as early as April (1990), however the first captures in all other years were in late May or June (Fig 6). Peaks in June reflect emigration from maturing wheat. Later peaks reflect emigration from corn, sorghum, millet, and other warm season grasses.

Greenbug captures were the most variable of the three species. Peak catches may occur in June (1988 & 1996) through September (1990) (Fig 5). This aphid does not appear to be affected by significant moisture or dry periods. 1996 was the most active year of the greenbug for all years of data collection. Greenbug could be found in the field infesting winter wheat in early spring, indicating that winter survival probably occurred in Northeast Colorado. In 1996 the greenbug reached a peak of 979 alatae caught on 17 June. By comparison, only 24 alatae were caught during the entire flight season of 1993.

Fort Collins

Fort Collins Russian wheat aphid captures commonly occur from mid-May through mid-October (Figure 7). Peak captures generally coincide with maturing wheat, from mid-June through late July. The largest seasonal captures occurred in 1989, 1991, and 1992. These high captures were preceded by low precipitation during the fall and winter months. Few Russian wheat aphids were present in the field or suction traps in 1993, which may have been due to lack of moisture in the late summer of 1992, resulting in few overwintering hosts.

Greenbug captures usually begin around the first of June and end in late October (Figure 8). There are usually two peak captures per season. The first peak corresponds with maturing wheat in early summer and the second peak occurs as the corn crop matures in the fall. The largest greenbug capture was observed in 1996, with a weekly capture of nearly 600 greenbug. Low numbers of greenbug were captured in 1993, corresponding with low Russian wheat aphid captures.

Bird cherry-oat aphid captures were variable throughout the seasons (Figure 9). Captures began during mid-May and continued through late October. Peak flights occur as wheat matures in mid-June and again in mid-August as the aphids search for overwintering hosts.

Fruita

Alate Russian wheat aphids usually can be found in the field for some time before they are caught in the suction trap. The first trap capture in the spring is usually in mid-May, although they were caught in April in 1990, 1995, 1996 and 1998 (Figure 10). There were significant Russian wheat aphid problems in

these years, which indicates that early suction trap captures may be used as an indicator of potential problems in the area. Peak Russian wheat aphid captures at the Fruita suction trap occur as small grain matures in late June and early July. The greatest captures occurred in 1988, 1989 and 1990. Captures since that time have been much lower. Greater precipitation and lower temperatures delayed wheat and barley maturity in 1991 and 1992, which delayed peak Russian wheat aphid flights until mid to late August accordingly. The mix of winter and spring planted small grains in the valleys of western Colorado spreads out the peak captures compared with other areas. Captures in 1993, 1994 and 1995 were very low, but increased in 1996 after Russian wheat aphid was present in large numbers in the Grand Valley's small grain crop. Late season Russian wheat aphid captures, while represented by low numbers, are significant in that they are good predictors of fall infestations. Captures as low as two or three Russian wheat aphids per week during wheat planting season (mid September to late October) can be related to significant fall infestations. Fall infestations were present to varying extent in all years until the fall of 1995. There were very few or no Russian wheat aphid captured late in the season after 1995, which translated to very low fall and spring populations in the field.

Greenbug captures were low in 1988, 1992, 1993, 1994, 1995 (Figure 11). There were two peaks in flights in 1989 and 1990, the first reflecting migration out of maturing small grain, and the second coinciding with maturing corn and grain sorghum. The late peaks in 1989 and 1991 coincided with maturing corn, and the early peaks in 1996 and 1997 coincided with maturing

wheat and barley. The peak greenbug flights in June or July were slightly earlier than the peak Russian wheat aphid flights, possibly reflecting differing responses to small grain maturity.

Bird cherry-oat aphid captures have been erratic in the early part of the season in most years (Figure 12). There was a large capture of bird cherry-oat aphid in 1989, coinciding with small grain maturity. Captures during August and September have been in low numbers, but consistent in all years, reflecting their movement to and from corn. These aphids were present in exceptionally high numbers in corn during the fall of 1996, and suction trap captures reflect this. Bird cherry-oat aphids are present in varying numbers in the fall planted small grain crop in the Grand Valley, and suction trap captures are good documentation of fall flights.

Walsh

Russian wheat aphids can readily be found in wheat fields in southeast Colorado much earlier than they are captured in the suction trap. For this reason, Russian wheat aphid suction trap captures are not effective tools to predict the need for scouting and treatment of Russian wheat aphid in this area. First Russian wheat aphid captures in spring typically occur from mid-April to the first week in May (Fig 13). As seen in Akron, at least two inches of precipitation in March and April will cause a delay in the initiation of Russian wheat aphid captures. Peak catches occur from June 1 to mid-June and correspond with the maturing small grain crop. The highest Russian wheat aphid captures occurred in 1988, 1990, 1994 and 1997. Russian wheat aphid captures were lowest in 1989, 1993, 1995, 1996 and 1998. Captures in 1989, 1993, and 1995 likely reflect the colder than average

temperatures over the winter into early spring and low moisture conditions. In 1996 there was severe drought in southeast Colorado which, coupled with an early spring freeze, affected wheat production over a wide range of southeast Colorado. No Russian wheat aphid captures have occurred in the fall at Walsh since 1994 and Russian wheat aphid are difficult to detect in wheat fields from emergence to regrowth of wheat in most years.

Bird-cherry oat aphid captures begin in early April through mid-May in most years (Fig 15). The exception occurred in 1996 when the wheat crop failed over a wide area of southeast Colorado and first captures began in mid-June. Peak captures tend to occur in June as the wheat crop matures and again in the period of mid-August through mid-September as the corn and sorghum mature and emigration to fall-planted wheat occurs. Bird cherry-oat aphid captures continue throughout the summer into late fall.

Greenbug are typically the first alatae captured in spring from the Walsh suction trap (Fig 14) with captures beginning in early April in most years. Peak captures of greenbug occur in mid-August to mid-September. This period corresponds to maturing sorghum and may represent some emigration to surrounding wheat fields. Greenbug are consistently caught in low numbers from May through late fall and can be found in wheat and sorghum fields throughout southeast Colorado.

Yellow Jacket

Initial and peak suction trap captures of Russian wheat aphid at Yellow Jacket are typically later than at other locations within Colorado (Figure 16). Captures before the beginning of June are rare, and peak captures

have occurred as early as July 1 (1994, 1997), but are usually delayed until mid-August. This is due to the high elevation (~7000 ft) in the area, which leads to later maturity of the dryland wheat crop. An increase in acreage of irrigated spring wheat in 1997 is reflected in a second peak in Russian wheat aphid captures. The years in which Russian wheat aphids were caught before June 1 are those years that it successfully overwintered in the area. The most damaging Russian wheat aphid infestation during the trapping period occurred in 1996. The lack of snow cover, coupled with above normal winter temperatures allowed Russian wheat aphids to overwinter in high numbers in many wheat fields. The total number of Russian wheat aphids captured in that year was among the lowest recorded. This may be due to the large numbers of predators that eliminated many of the Russian wheat aphid in drought stressed wheat fields. The fall planted wheat crop is usually infested to some extent in the region, and late season captures reflect this. 1997 and 1998 were the first years that Russian wheat aphids were not captured through September, and fall infestations in the field were the lowest of any year since the trapping began.

Greenbugs are rare in the area around Yellow Jacket, which is reflected in the low suction trap captures (Figure 17).

Captures of Bird cherry-oat aphid begin in mid May until early July, depending on the year (Figure 18). Peak captures are not well defined, but the greatest numbers of bird cherry-oat aphid are caught in late summer. This is reflected in the fact that Bird cherry-oat aphid is, in many years, the most abundant aphid in the fall seeded wheat fields.

SUMMARY

Suction trap data are useful in predicting aphid infestations and as an historical record of aphid infestation. Meaningful interpretation of the data requires that there is an understanding of its significance. Early season captures are more useful in predicting infestations in spring seeded small grains than in fall seeded small grains. Very low numbers of Russian wheat aphids captured in the fall may be significant, while higher numbers of greenbugs captured at the same time may not be nearly as significant. The significance of absolute numbers may vary from region to region, depending upon local cropping systems and climate. Traps are vulnerable to heavy rainfall and windy conditions. These climactic conditions may limit the ability of the traps to pick up aphid flights at times. Suction traps are not an alternative to timely scouting of fields. They should be used in addition to scouting. Some useful ways to use suction trap data are:

- Early season aphid captures are an indication of local movement. If scouting has not begun before aphids are caught in the trap, it should start immediately, especially in spring seeded grains. Very early captures may occur when aphids overwintered in high numbers.
- Peak aphid captures are an excellent record of the overall aphid population in the small grain crop. They also represent the number of aphids that can potentially move to other susceptible crops. The time of the peak capture is correlated with crop maturity, so is an excellent

indicator of the time the crop matures from year to year.

- Fall captures are an excellent indicator of the potential for fall infestation. Significant fall infestations of Russian wheat aphids or bird cherry-oat aphids may occur when only 1 or 2 aphids are captured in a suction trap per week. Fall infestations of either of these aphid species may lead to significant yield loss.

REFERENCES CITED

- Allison, D. and K.S. Pike. 1988. An inexpensive suction trap and its use in aphid monitoring network. *J. Agric. Entomol.* 5:103-107.
- Armstrong, J.S., and F.B. Peairs. 1996. Environmental parameters related to winter mortality of the Russian wheat aphid (Homoptera: Aphididae): basis for predicting mortality. *J. Econ. Entomol.* 89: 1281-1287.
- Blackman, R.L., V.F. Eastop, and P.A. Brown. 1987. The biology and taxonomy of the aphids transmitting barley yellow dwarf virus. *In* Burnett, P.A., ed. 1990. *World Perspectives on Barley Yellow Dwarf*. CIMMYT, Mexico, D.F., Mexico.
- Burnett, P.A., ed. 1990. *World Perspectives on Barley Yellow Dwarf*. CIMMYT, Mexico, D.F., Mexico.
- Butts, R.A. and G.B. Schaalje. 1997. Impact of subzero temperatures on survival, longevity and natality of adult Russian wheat aphid (Homoptera: Aphididae). *Environ. Entomol.* 26:661-667.
- Dewar, A.M., G.M. Tatchell, and L.A.D. Turl. 1984. A comparison of cereal-aphid migrations over Britain in the summers of 1979 and 1982. *Crop Protection*. 3: 379-389.

- Gildow, F.E. 1984. Biology of aphid vectors of barley yellow dwarf virus and the effect of BYDV on aphids. *In*: Burnett, P.A., ed. 1990. World Perspectives on Barley Yellow Dwarf. CIMMYT, Mexico, D.F., Mexico.
- Halbert, S.E. and D.J. Voegtlin. 1994. Suction trap records of *Myzus lythri* (Homoptera: Aphididae) associated with purple loostripe (*Lythrum salicaria*) infestations in Idaho. *Weed Technology* 8:794-796.
- Halbert, S.E., M.D. Jennings, C.B. Cogan, S.S. Quisenberry and J.B. Johnson. 1995. Potential use of suction trap collections of aphids as indicators of plant biodiversity. *In*: Insects in a Changing Environment. Academic Press, London. 491-504.
- Halbert, S., L. Elbertson, M. Feng, T.J. Poprawski, S. Wraight, J.B. Johnson and S.S. Quisenberry. 1998. Suction trap data: Implications for crop protection forecasting. *In*: S.S. Quisenberry & F.B. Peairs ed. Response Model for an Introduced Pest - The Russian Wheat Aphid. Thomas Say Publications, Entomol. Soc. Am. Lanham MD. 412-428
- Hammon, R.W. and F.B. Peairs. 1992. Distribution of overwintering Russian wheat aphid (Homoptera: Aphididae) in furrow-irrigated small grains in western Colorado. *J. Econ Entomol.* 85:2452-2458.
- Hammon, R.W., J.S. Armstrong, W.L. Meyer. C. Walker and F.B. Peairs. 1997. Alternate host plants of Russian wheat aphid in Colorado. *Colo. St. Univ. Ag. Exp. Stn. Tech. Rpt.* 97-2.
- Kieckhefer, R.W. and B.H. Kantack. 1980. Losses in yield in spring wheat in South Dakota caused by cereal aphids. *J. Econ. Entomol.* 73:582-585.
- Kieckhefer, R.W. and B.H. Kantack. 1988. Yield losses in winter grains caused by cereal aphids (Homoptera: Aphididae) in South Dakota. *J. Econ. Entomol.* 81:317-321.
- Kieckhefer, R.W., W.F. Lytle and W. Spuhler. 1974. Spring movement of cereal aphids into South Dakota. *Environ. Entomol.* 3: 347-350.
- Kindler, S.D. and T.L. Springer. 1989. Alternate host plants of the Russian wheat aphid (Homoptera: Aphididae). *J. Econ. Entomol.* 82:1358-1362.
- Loxdale, H.D., J. Hardie, S. Halbert, R. Foott, N.C. Kidd and C.I. Carter. 1993. The relative importance of short- and long-range movement of flying aphids. *Biol. Rev.* 68:291-311.
- Mallott, P.G. and A.J. Davy. 1978. Analysis of effects of the bird cherry-oat aphid on the growth of barley: unrestricted infestation. *New Phytologist*, 80:209-218.
- Morrison, W.P. and F.B. Peairs. 1998. Response model concept and economic impact. *In*: S.S. Quisenberry & F.B. Peairs ed. Response Model for an Introduced Pest - The Russian Wheat Aphid. Thomas Say Publications, Entomol. Soc. Am. Lanham MD. 1-11
- Ortman, E.R. and R.H. Painter. 1960. Quantitative measurements of damage by the greenbug, *Toxoptera graminum*, to four wheat varieties. *J. Econ. Entomol.* 53:798-802.
- Pike, K.S., D.W. Allison, G. Low, G.W. Bishop, S. Halbert, and R. Johnston. 1987. Cereal aphid vectors: a western regional (USA) monitoring system. *In*: Burnett, P.A., ed. 1990. World Perspectives on Barley Yellow Dwarf. CIMMYT, Mexico, D.F., Mexico.
- Quinn, M.A., S.E. Halbert, and L. Williams III. 1991. Spatial and temporal changes in aphid (Homoptera: Aphididae) species assemblages collected with suction traps in Idaho. *J. Econ. Entomol.* 84:1710-1716.

Turl, L.A.D. 1980. An approach to forecasting the incidence of potato and cereal aphids in Scotland. EPPO Bull. 10: 135-141.

Voss, T.S., R.W. Kieckhefer, B.W. Fuller, M.J. Mcleod and D.A. Beck. 1997, Yield losses in maturing spring wheat caused by cereal aphids (Homoptera: Aphididae) under laboratory conditions. J. Econ. Entomol. 90:1346-1350.

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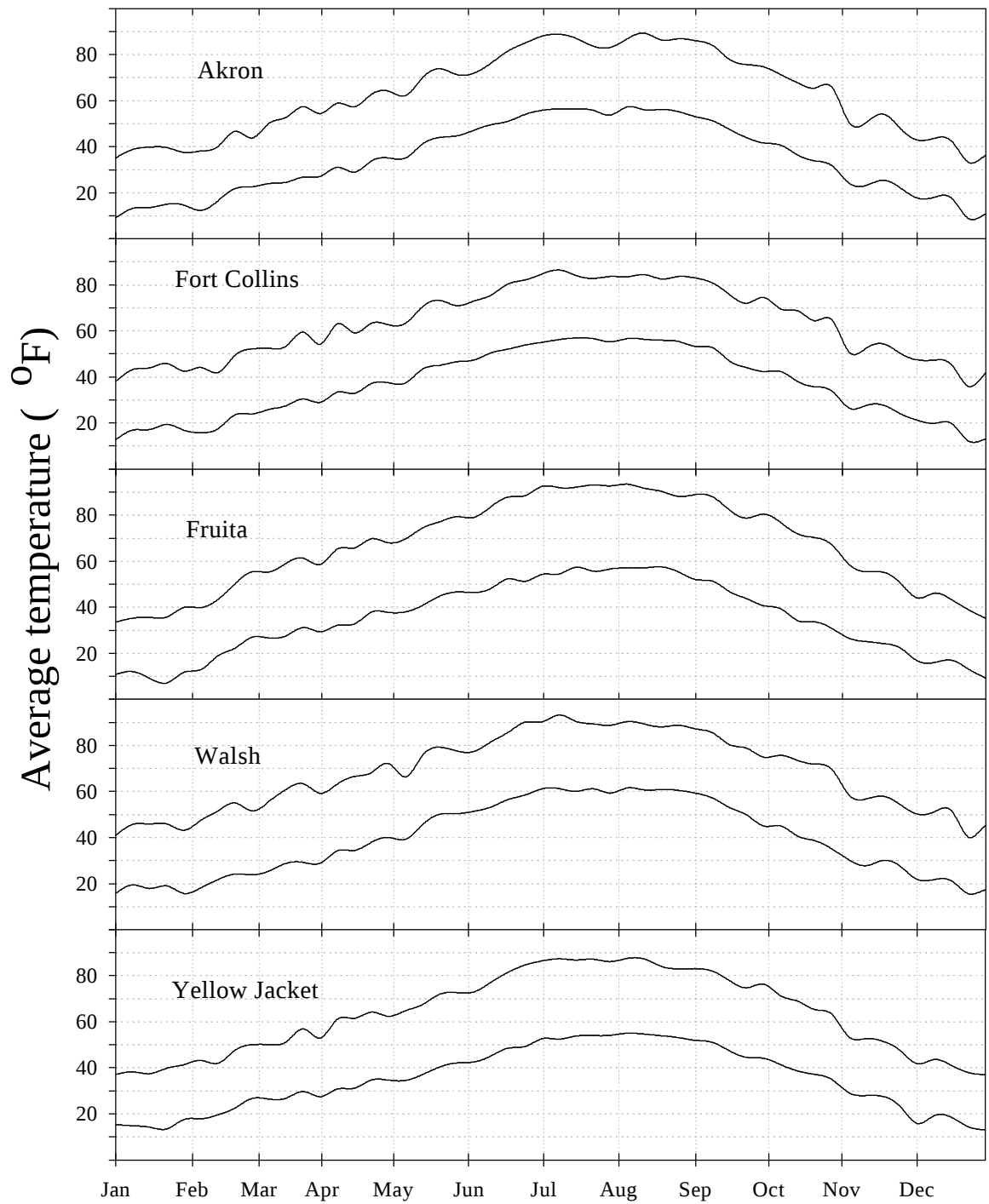


Figure 2. Average daily maximum and minimum temperatures for weather stations in the vicinity of suction traps, 1988-1998.

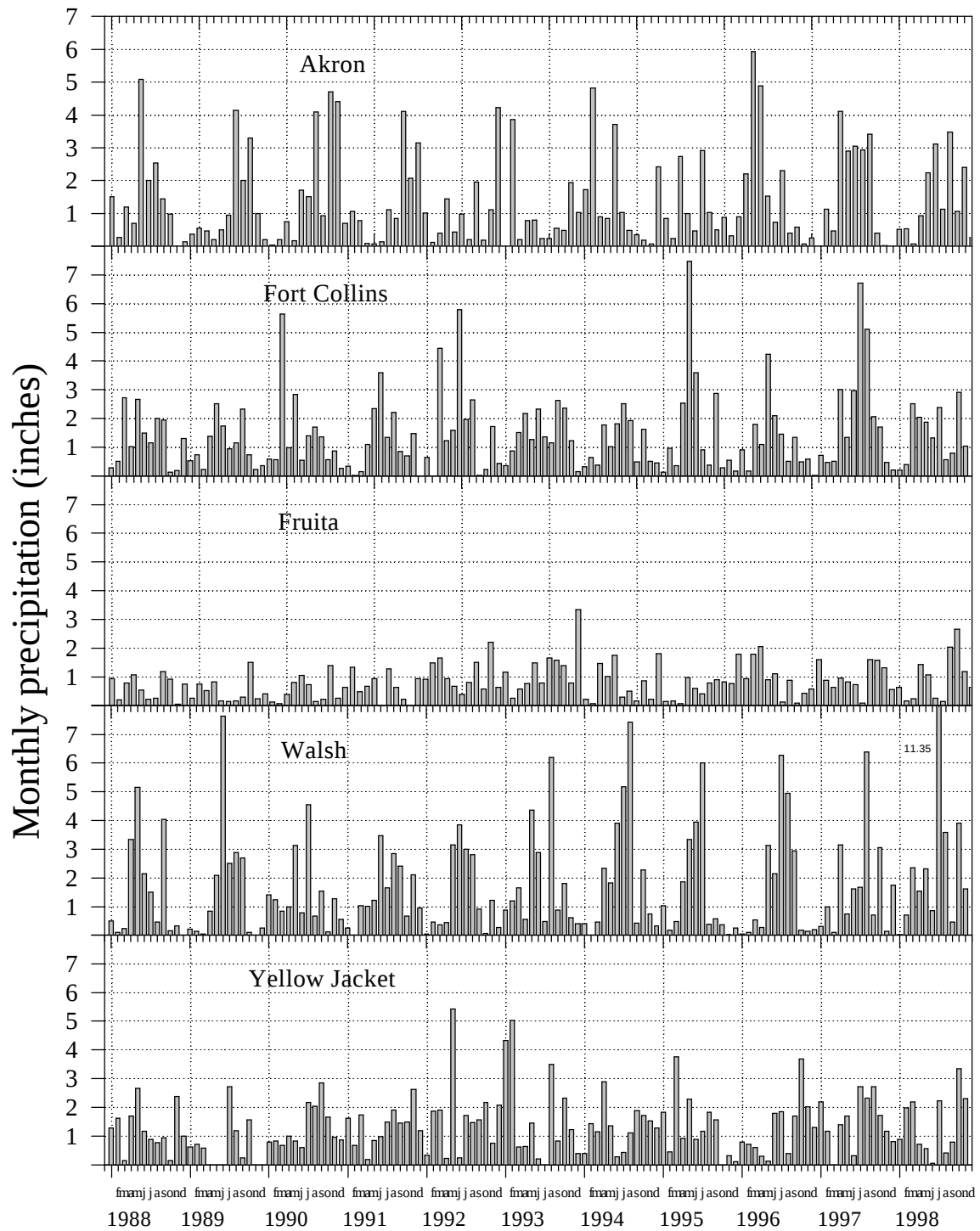


Figure 3. Monthly precipitation from weather stations in the vicinity of suction traps, January 1988 - November 1998.

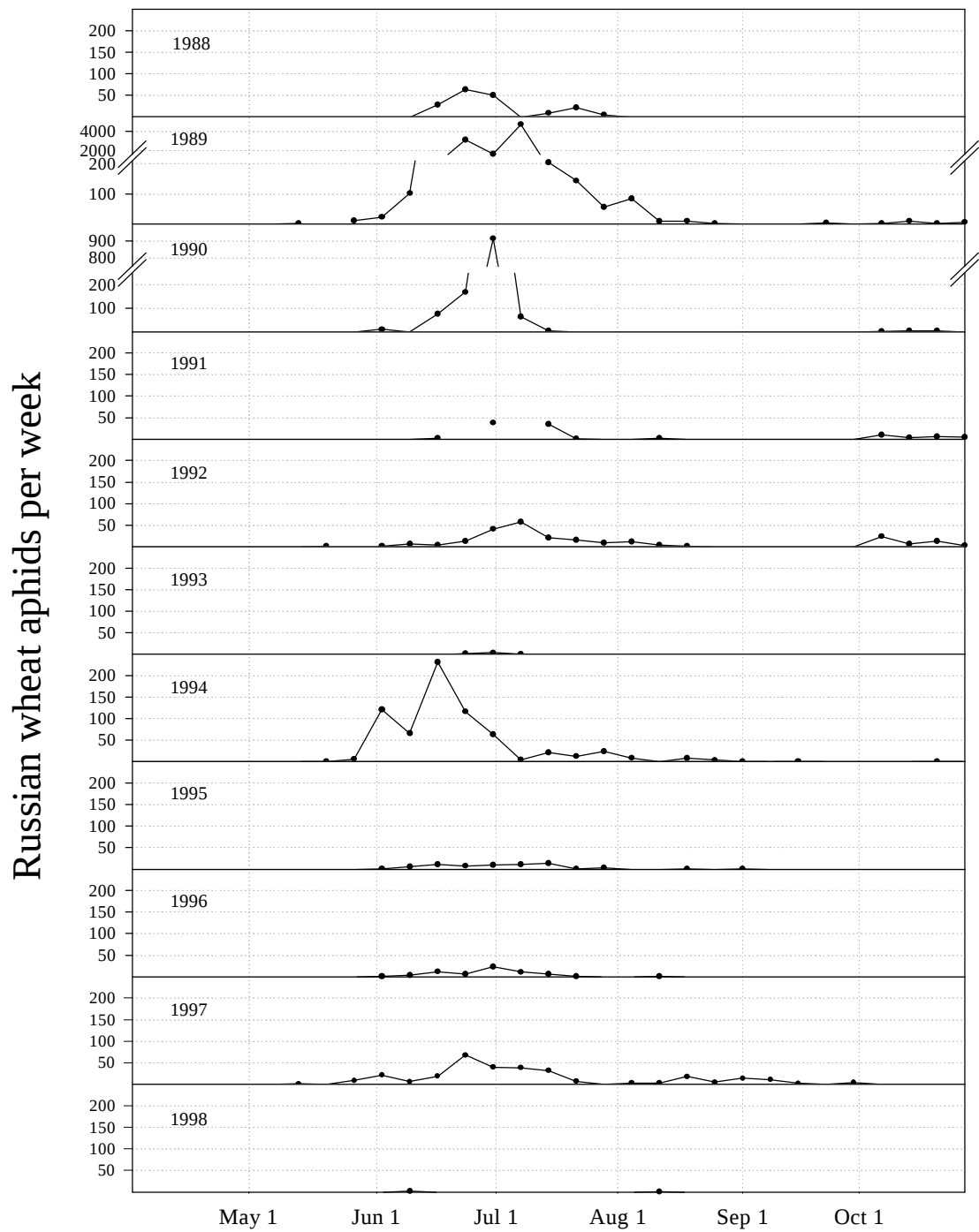


Figure 4. Russian wheat aphid captures, Akron.

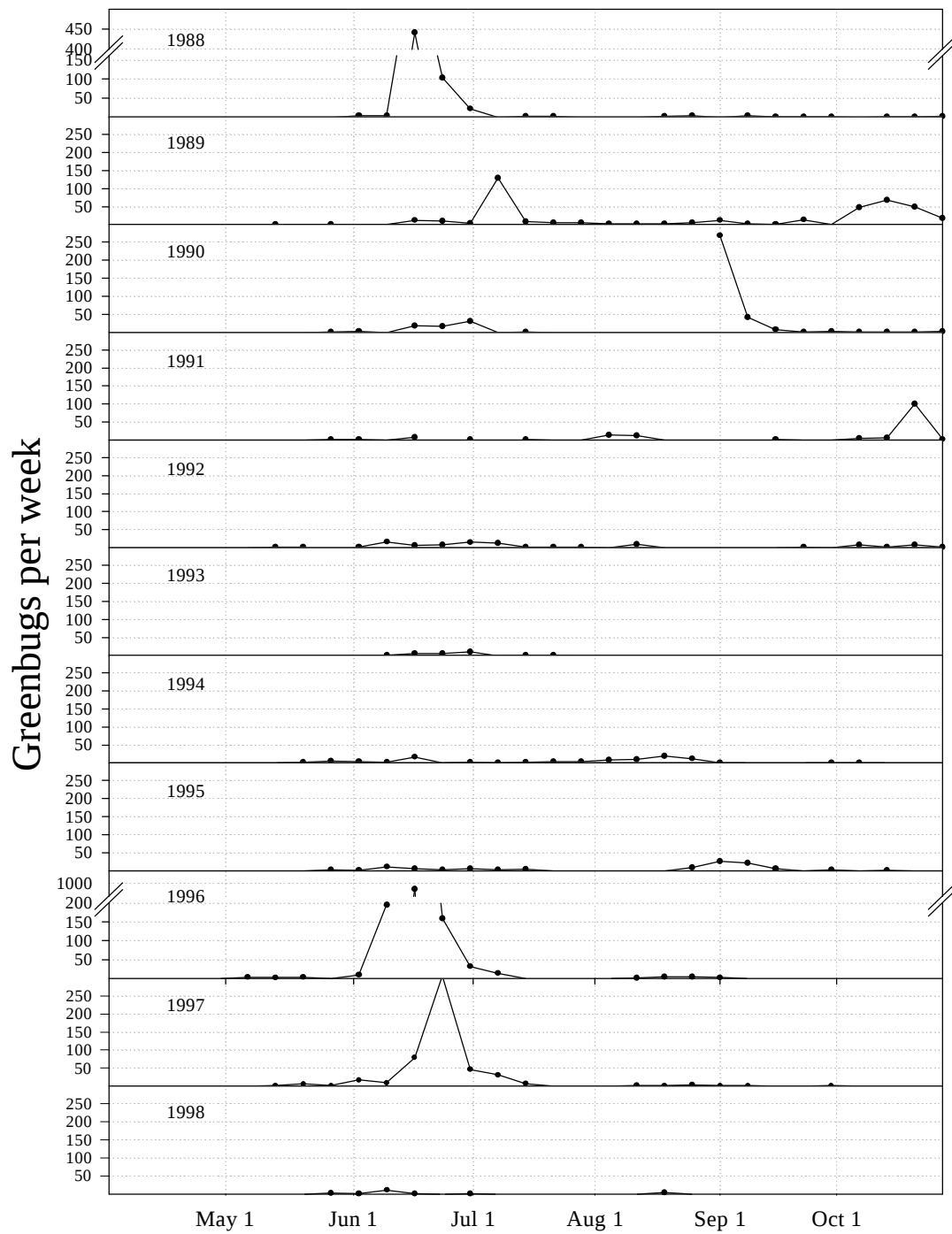


Figure 5. Greenbug captures, Akron.

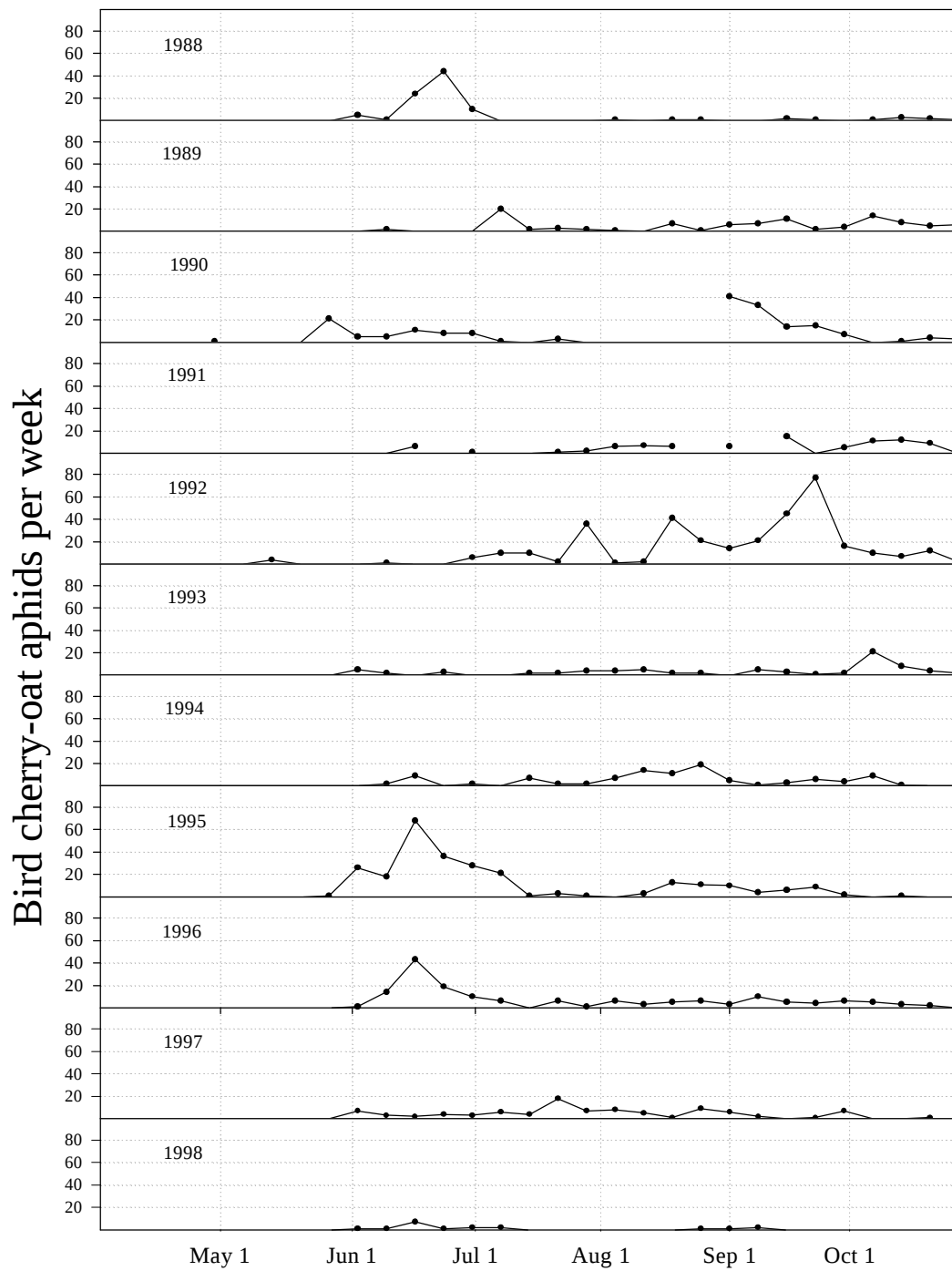


Figure 6. Bird cherry-oat aphid captures, Akron.

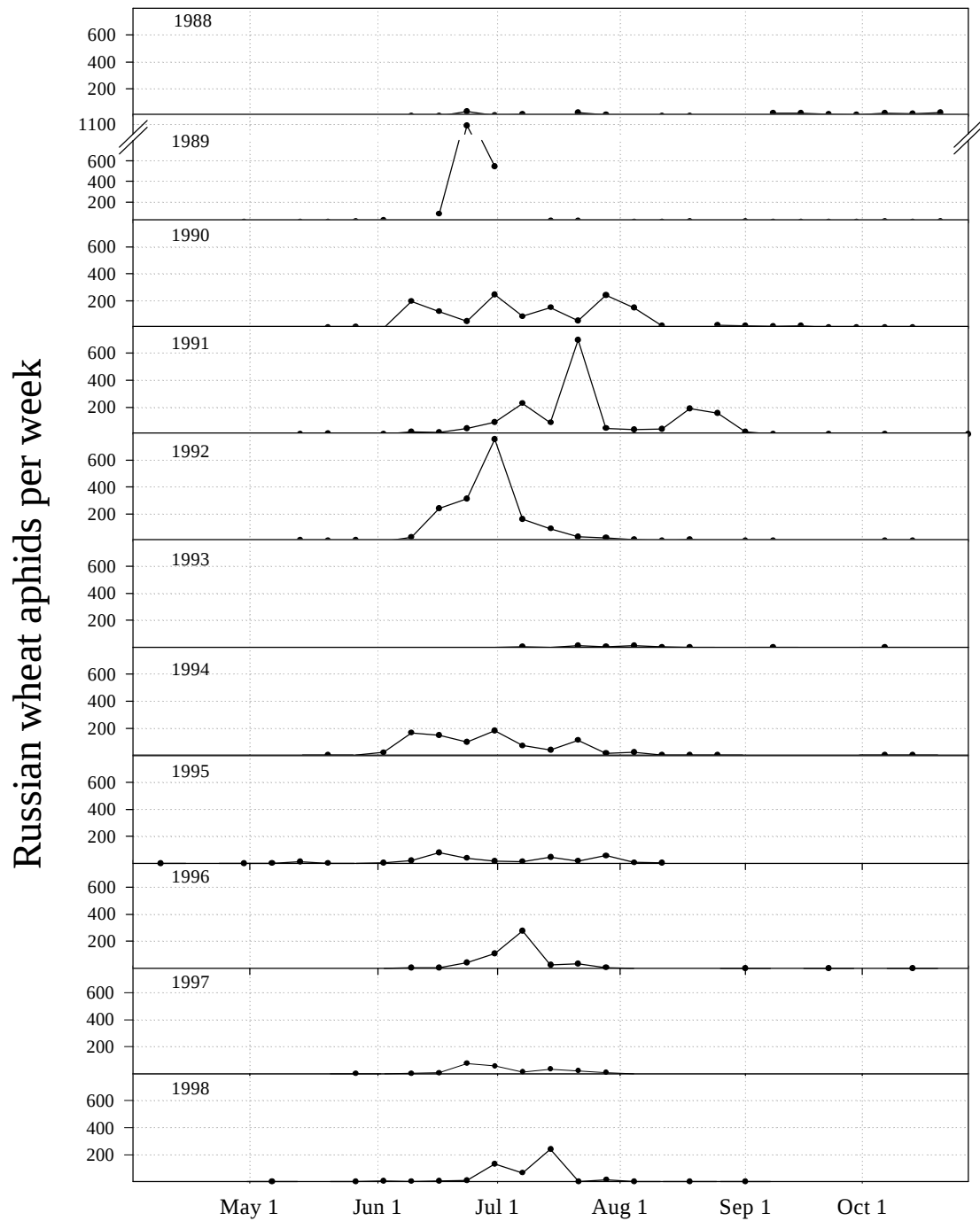


Figure 7. Russian wheat aphid captures, Fort Collins.

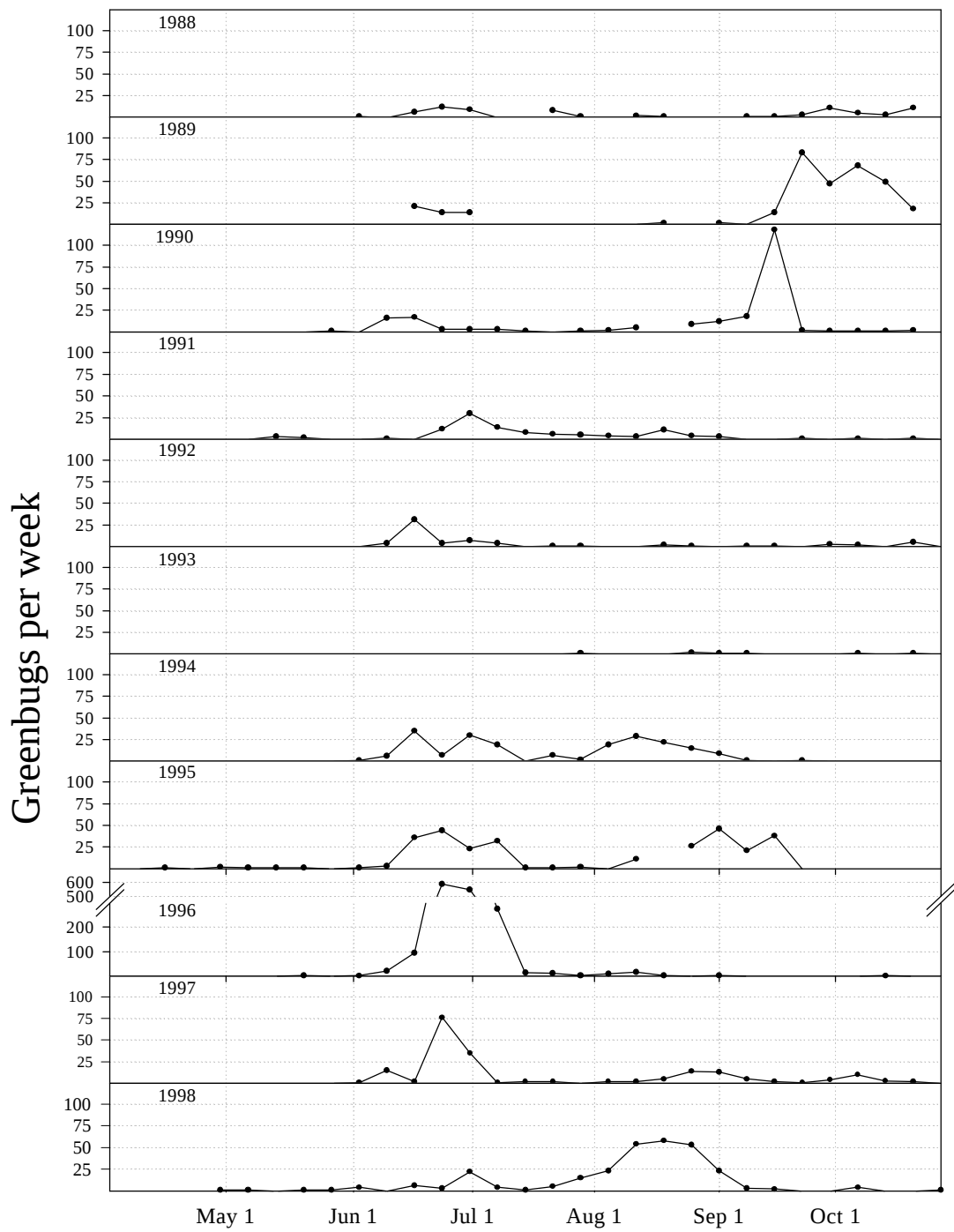


Figure 8. Greenbug captures, Fort Collins.

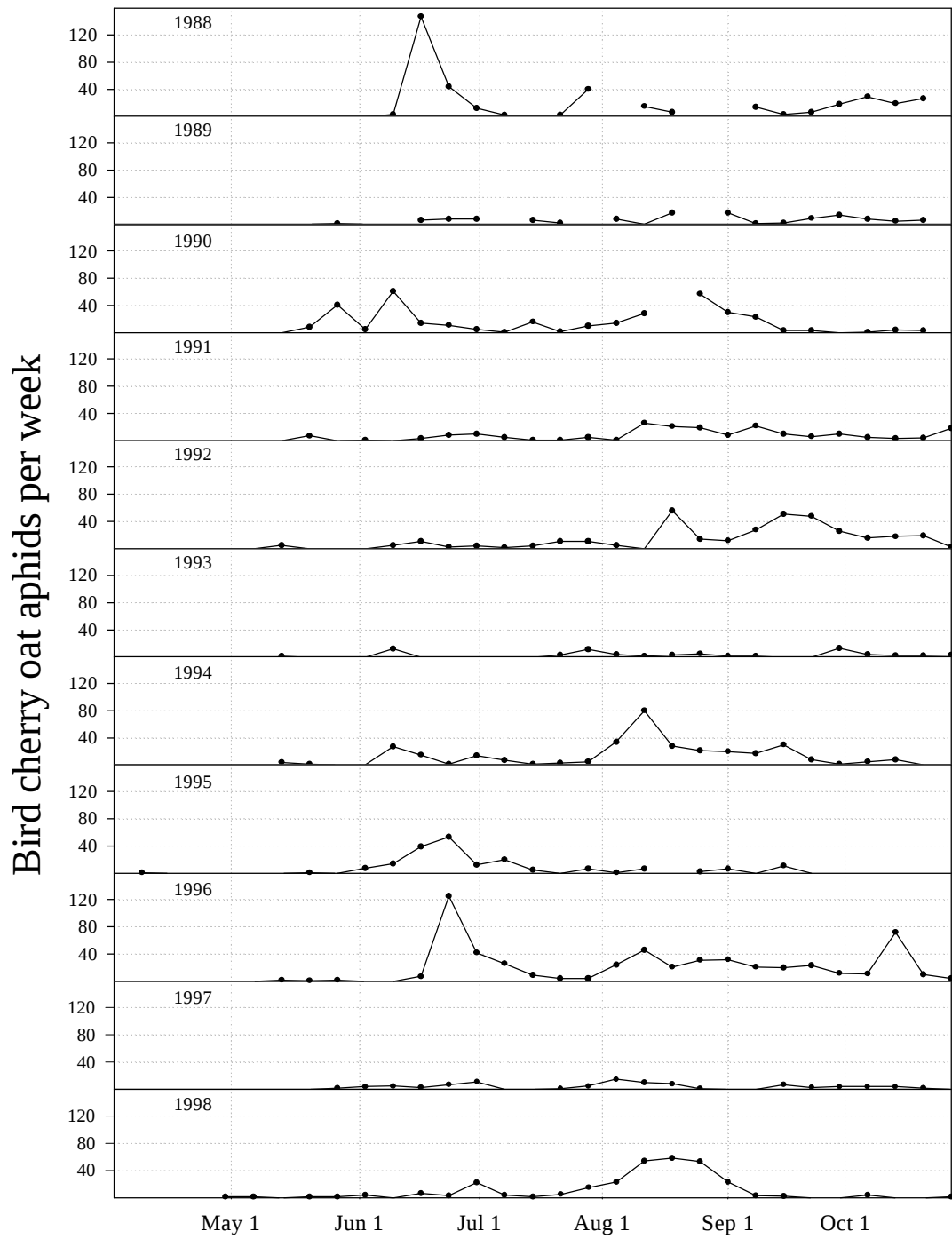


Figure 9. Bird cherry-oat aphid captures, Fort Collins.

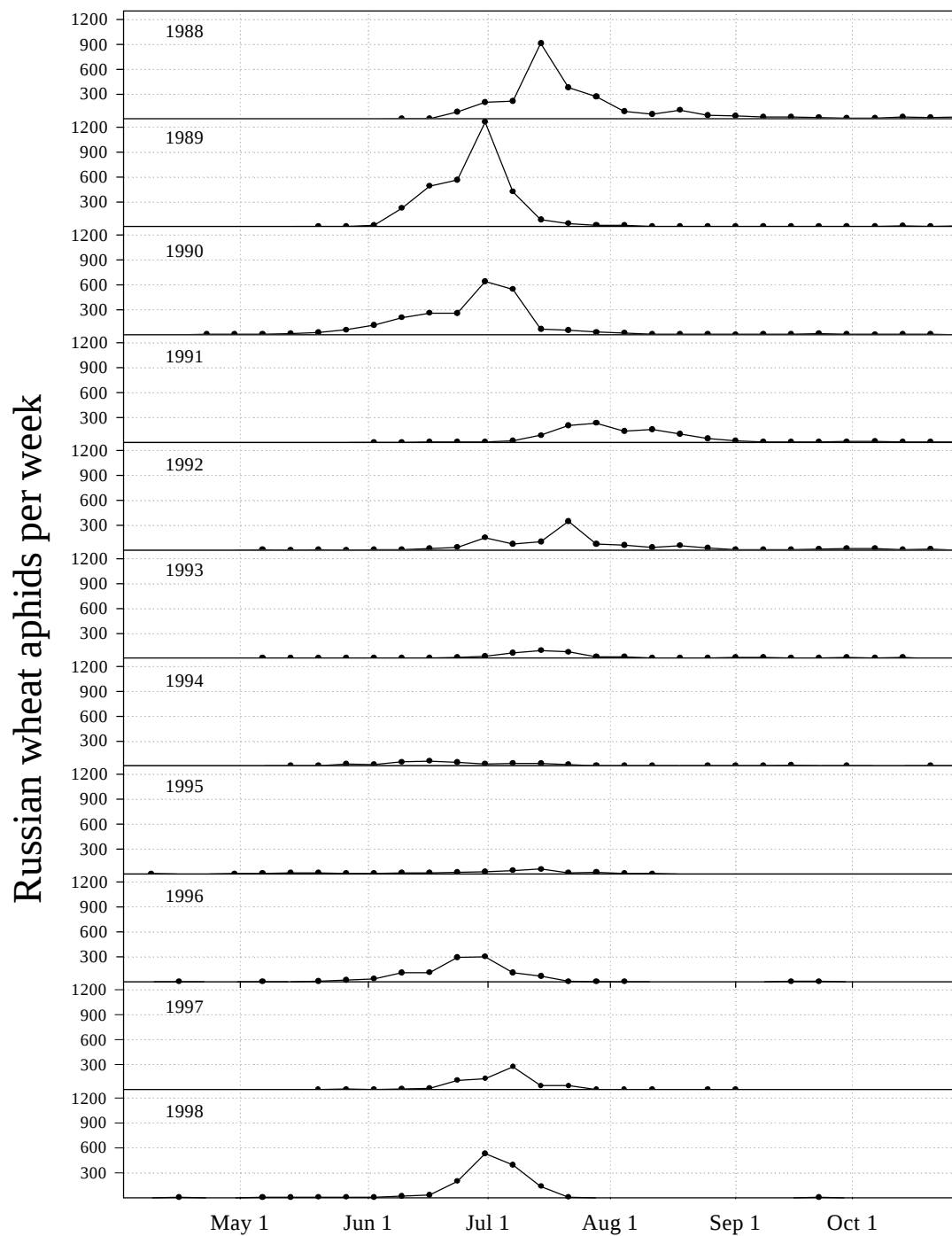


Figure 10. Russian wheat aphid captures, Fruita.

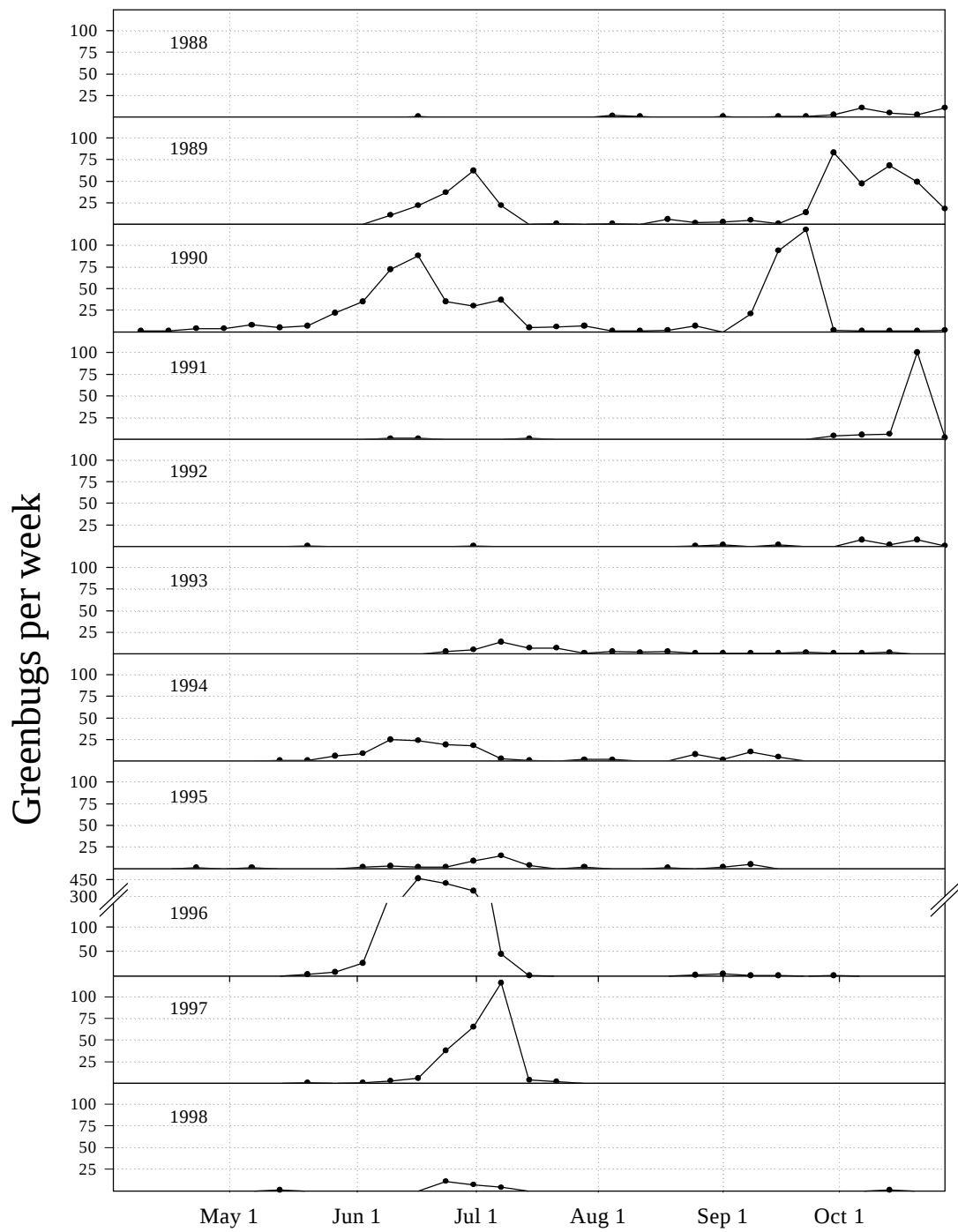


Figure 11. Greenbug captures, Fruita.

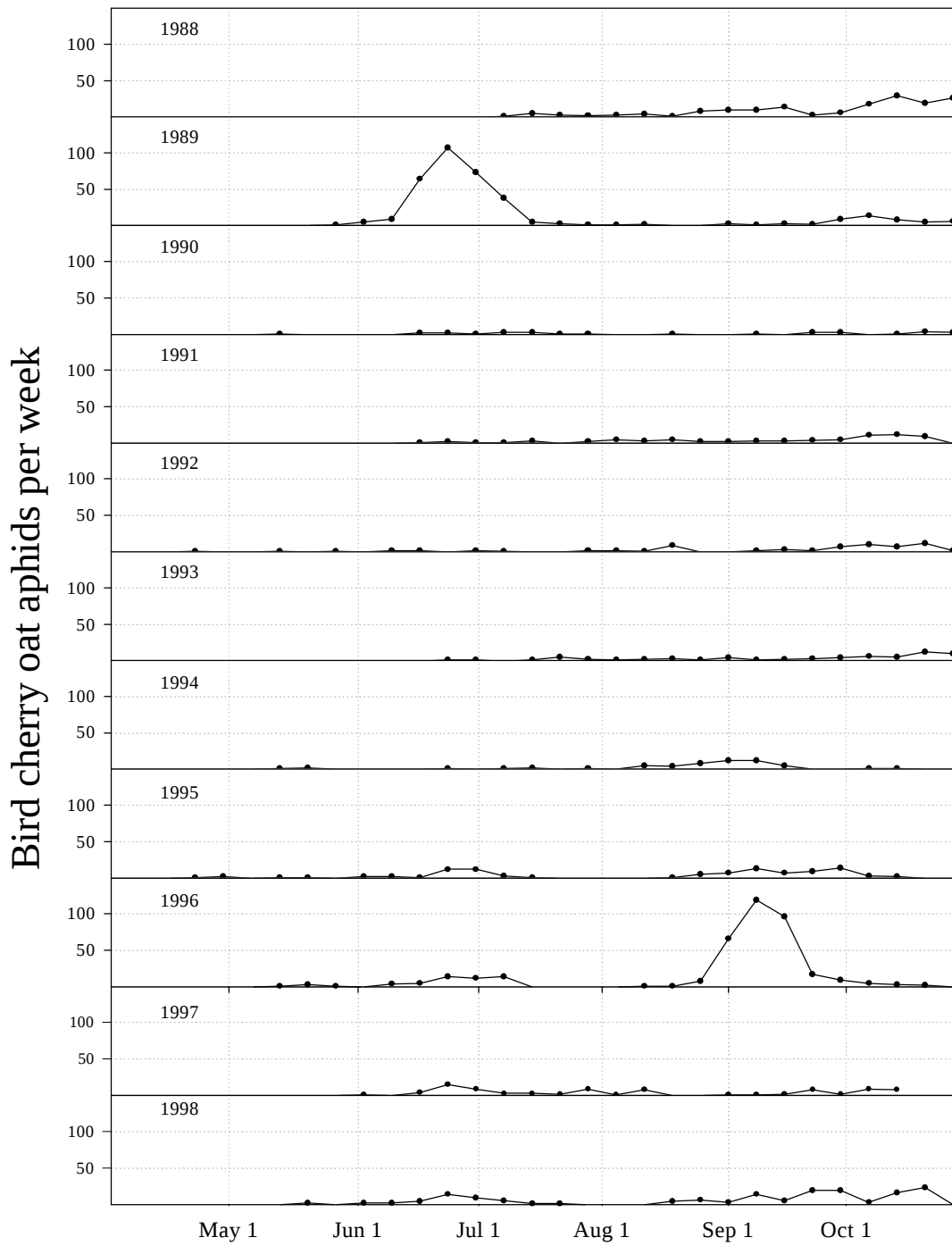


Figure 12. Bird cherry-oat aphid captures, Fruita.

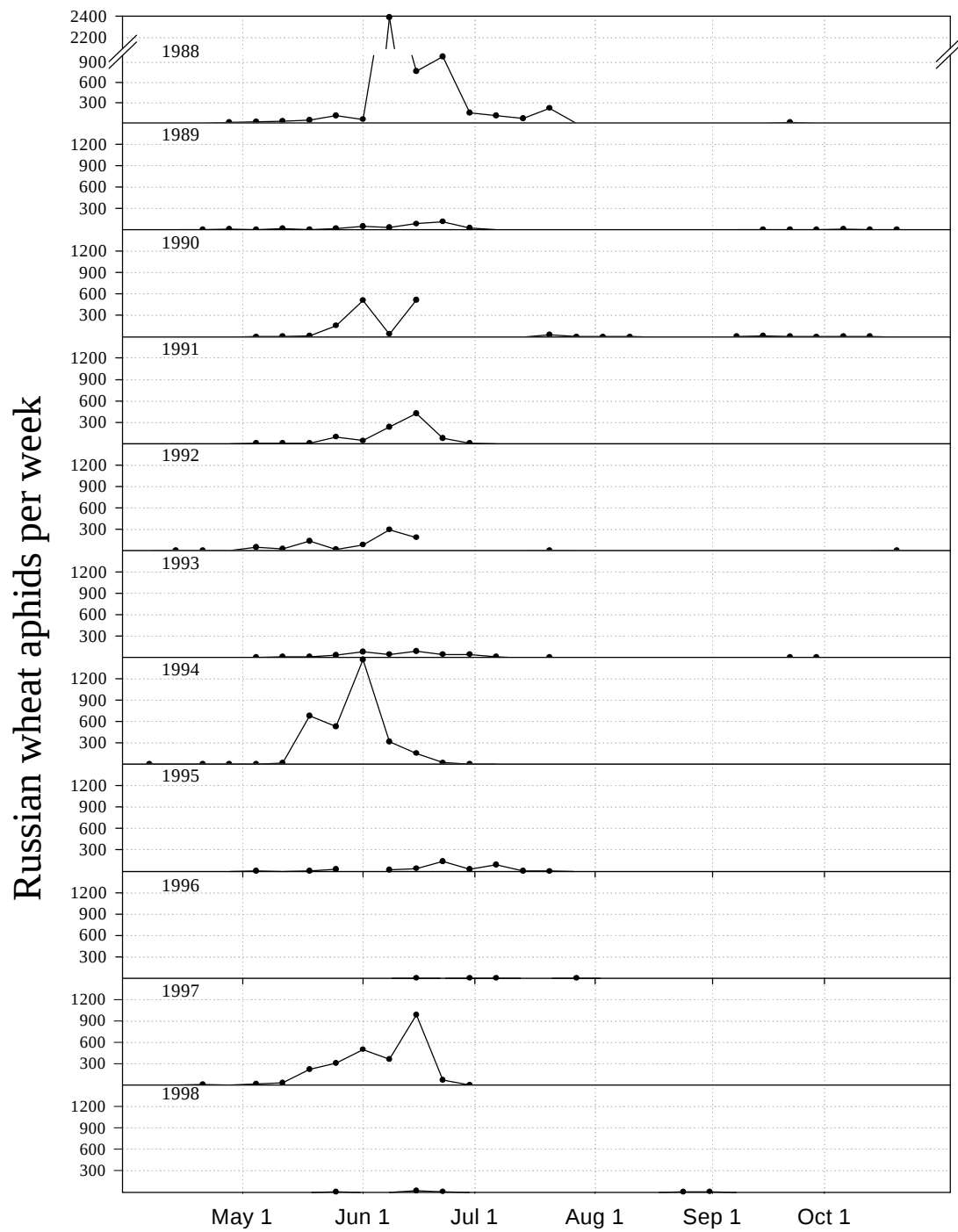


Figure 13. Russian wheat aphid captures, Walsh.

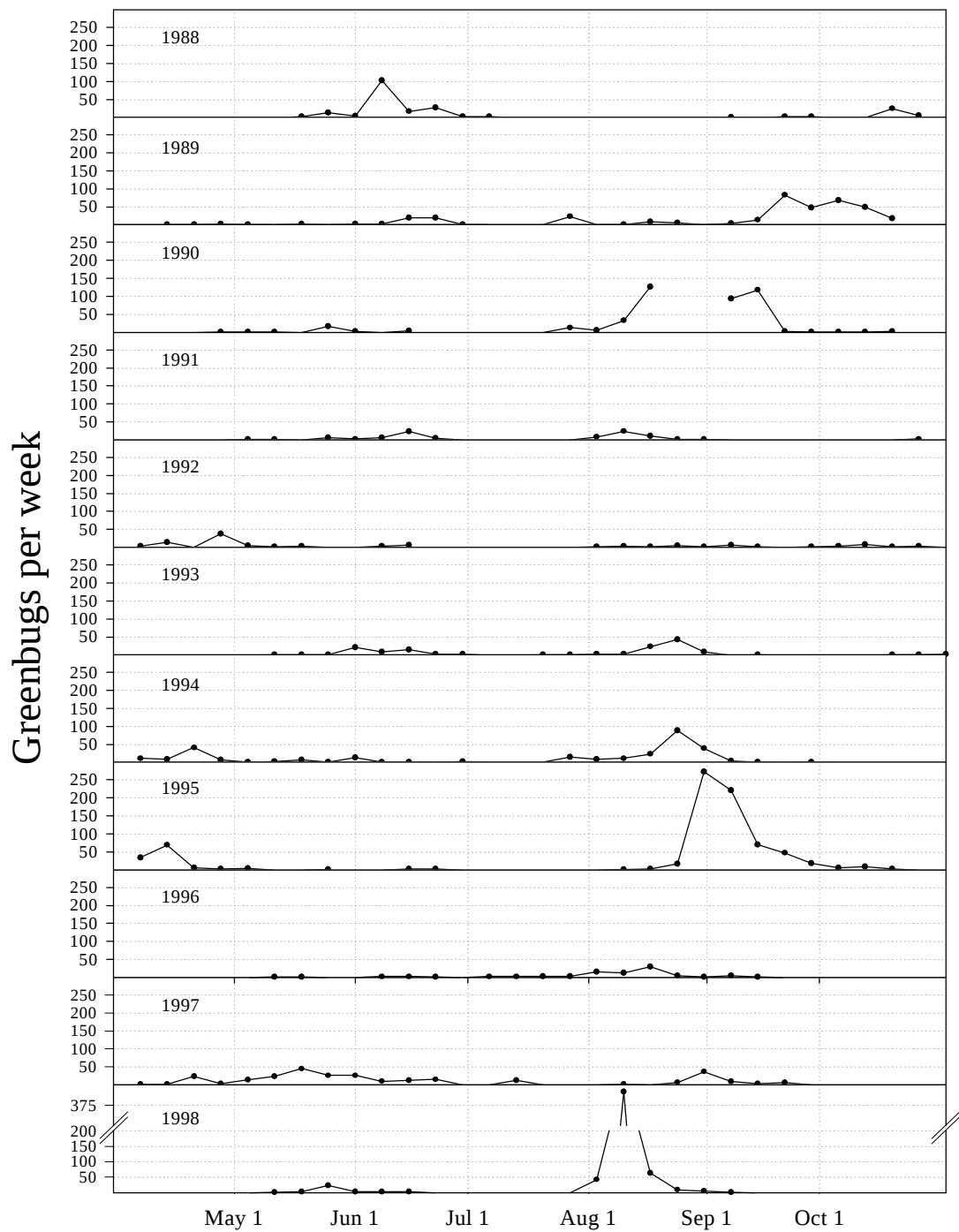


Figure 14. Greenbug captures, Walsh

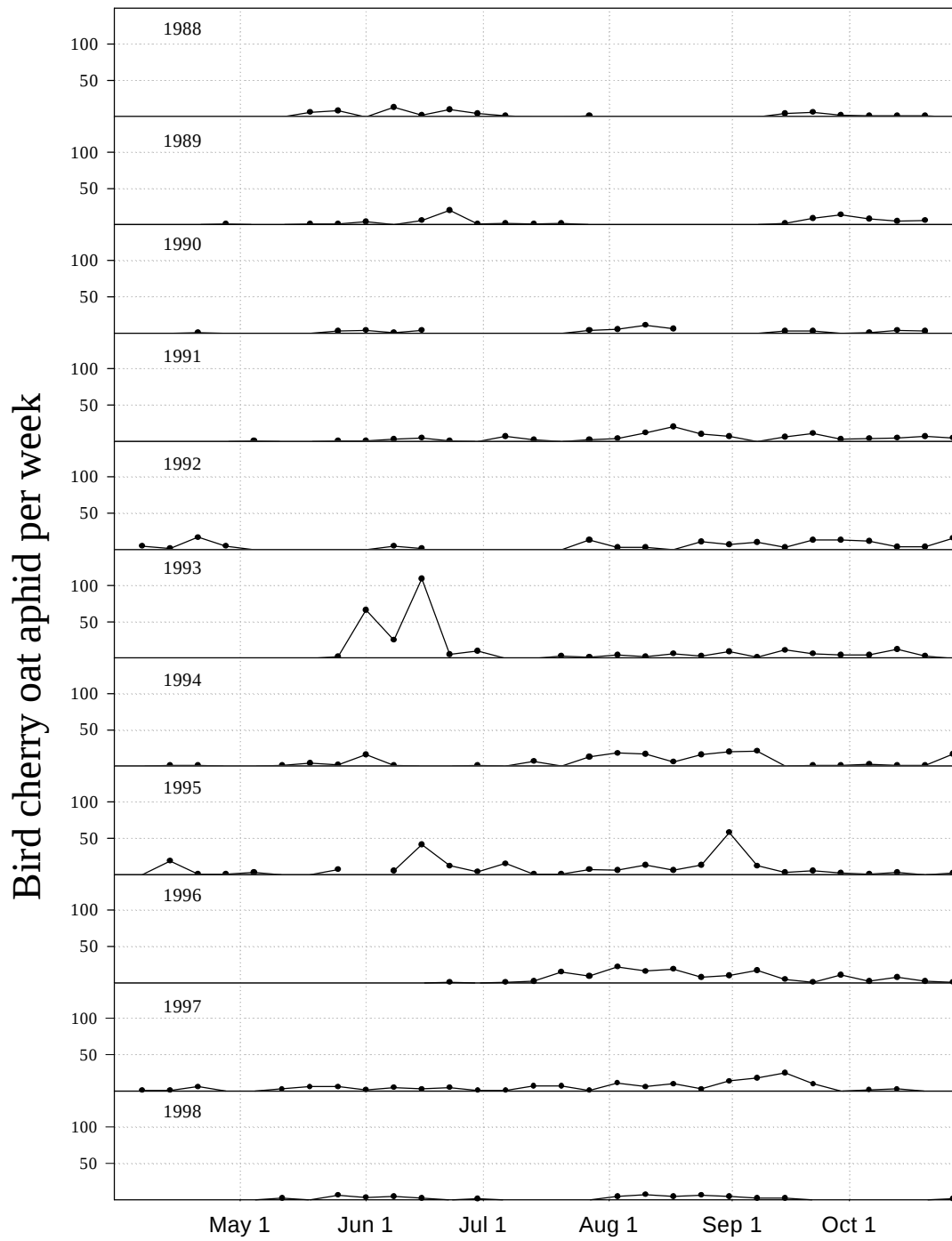


Figure 15. Bird cherry-oat aphid captures, Walsh.

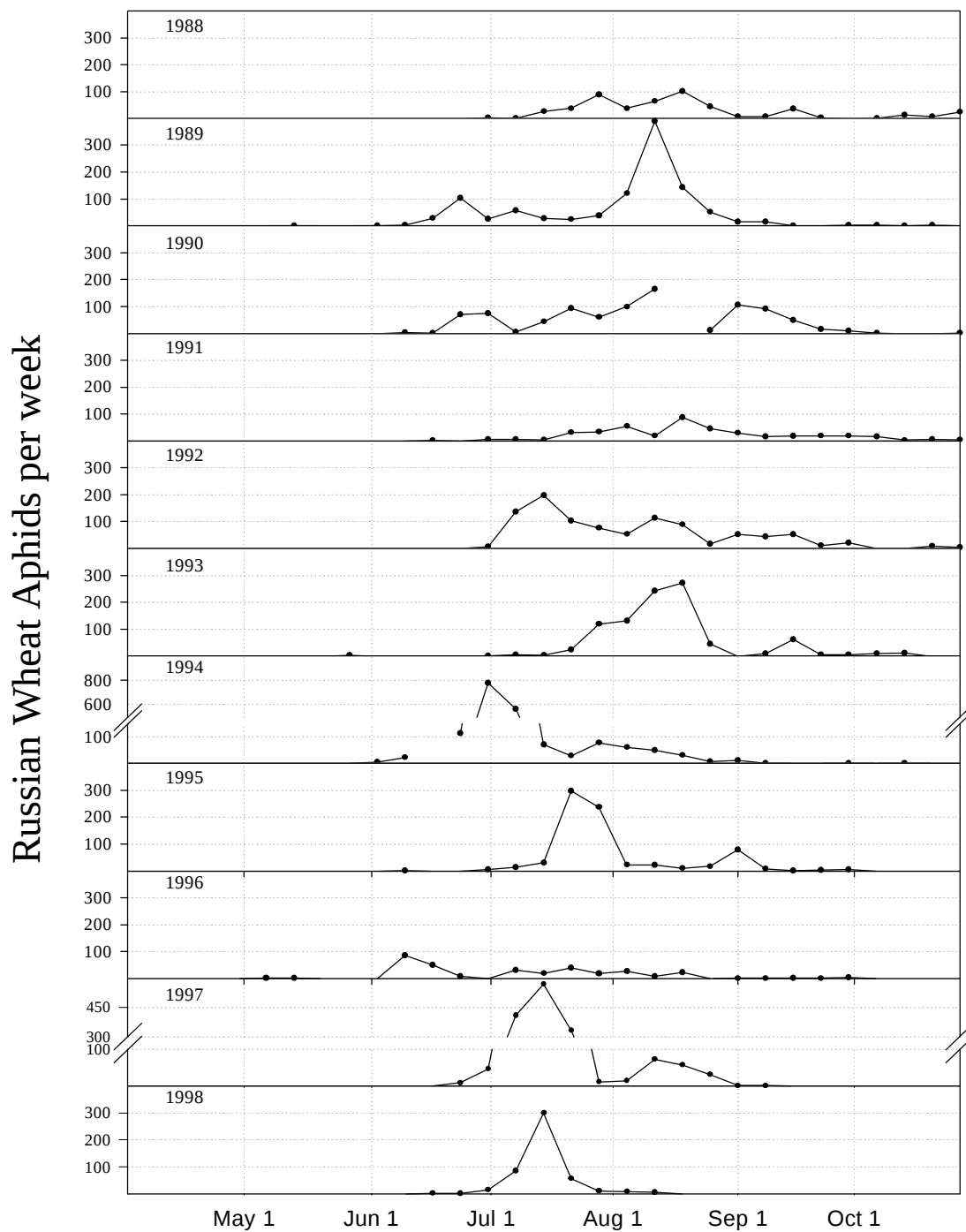


Figure 16. Russian wheat aphid captures, Yellow Jacket.

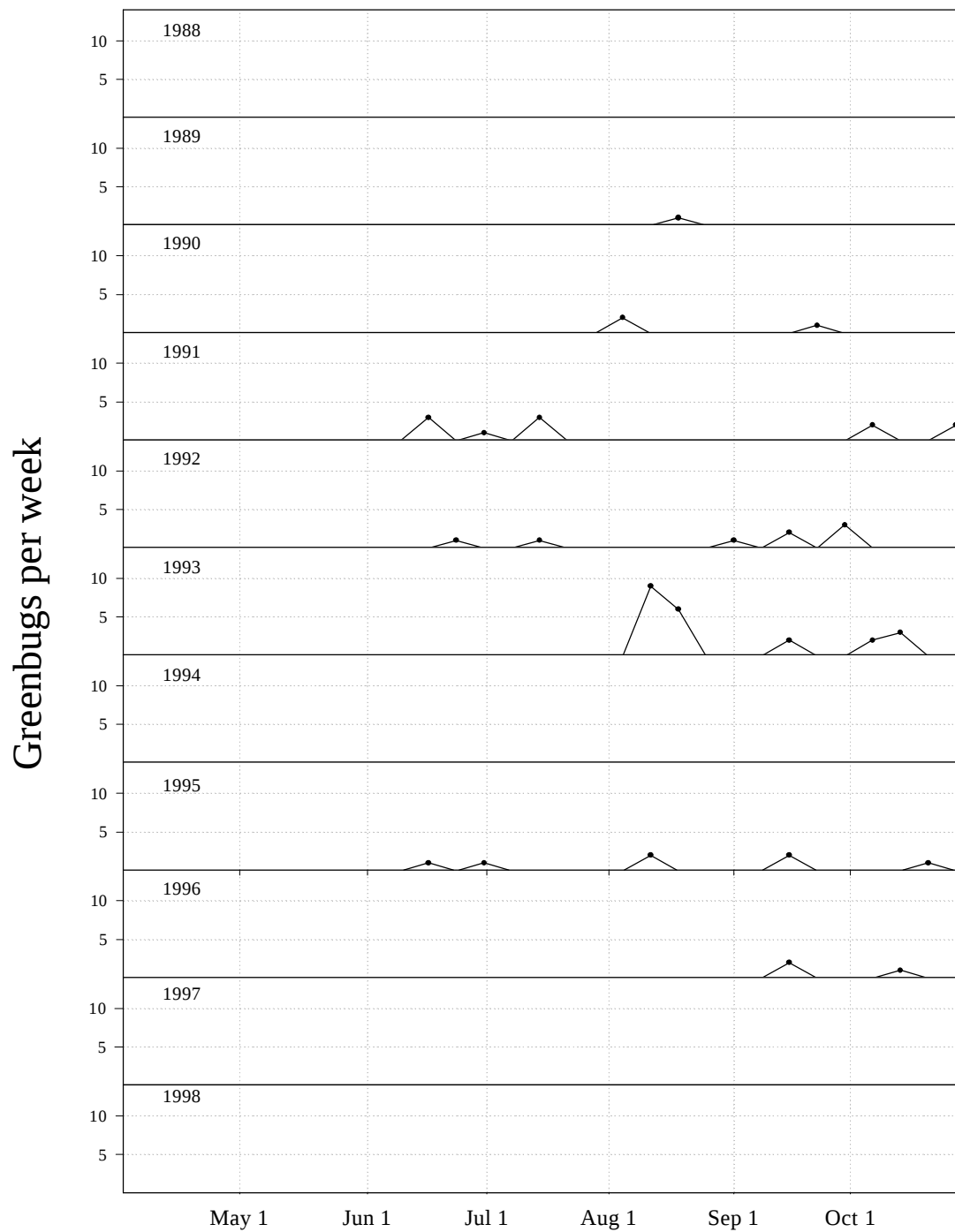


Figure 17. Greenbug captures, Yellow Jacket.

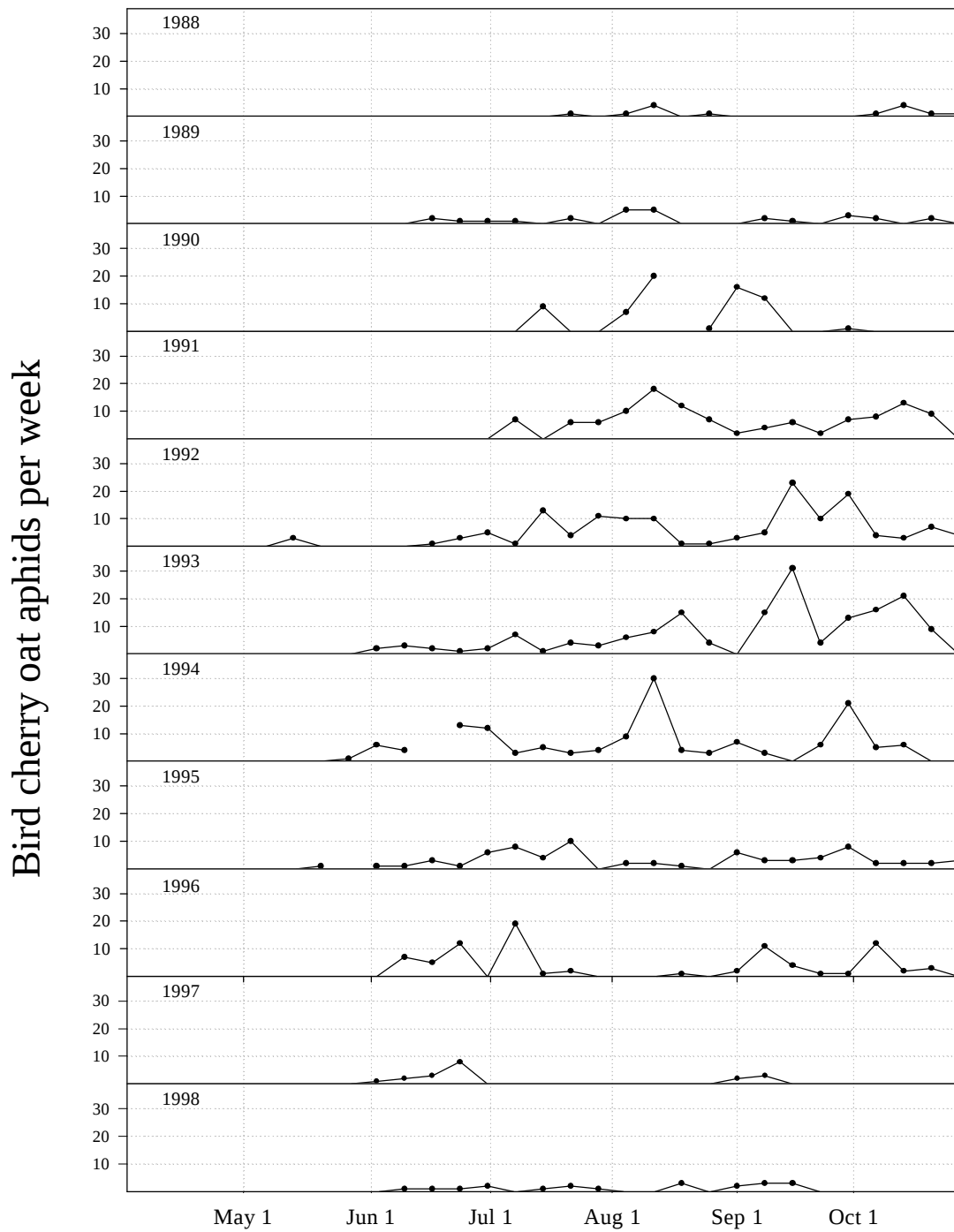


Figure 18. Bird cherry oat aphid captures, Yellow Jacket.

