80-ZA2

ANNUAL REPORT

WEATHER INSTRUMENTS, WEATHER PATTERNS, and DATA PROCESSING OF FIELD DATA PERTAINING TO PEST MANAGEMENT IN ALMONDS

Project No. 80-ZA2
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prepared for the

Almond Board of California

by

Dr. Rolland K. Hauser

Technical Director
NOWCASTING, Inc.
101 Salem Street, Suite 4
Chico, CA 95926
(916) 895-5082

and

Professor of Physical Science
California State University, Chico

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CONTENTS

1. Introduction. The research work reported on here was undertaken during 1981 and falls into three related topics:

- the evaluation and installation of automatic weather equipment suitable for use in almond orchards
- the spatial and temporal detail available in daily climatological information against which to display and interpret the details of current weather events
- data-processing techniques for use in examining raw field observations of navel orangeworm populations for temporal and spatial patterns which may be related to weather events and to differences of microclimate

This report is organized into three sections which correspond to the topics listed above. Each section addresses the objectives, procedures, and results and provides an interpretive summary, discussion, and publication list.

It must be stated at the outset that this report should be viewed as a report of work still in progress. While in each of the topic areas, progress has been steady, unanticipated and unavoidable delays occurred during the fall of 1981 which have somewhat slowed the pace of our work on topics two and three.

2. Automatic, Remote Weather Stations.

a. Interpretative Summary. Automatic weather station equipment suitable for use in orchard environments is available from a number of vendors. Not all such equipment can produce data which can be shared rapidly and cooperatively

*** M C I D A S *** GPUID: CSU PROGRAM: SVCADI TERMINAL: 022 PROJECT: 6999

DDHHMM	STN	T	TD	WIND	PRES	LO	MID	HI	VIS	WX
182100	AMO	15	6	2706	333.3	0	0	0	0.0	
182100	ABE	16	4	3410	333.3	0	0	0	0.0	
182100	CPY	14	5	3315	333.3	0	0	0	0.0	
182100	CDA	15	6	3316	333.3	0	0	0	0.0	
182100	RDD	14	3	3312	1024.9	0	0	3	25	
182100	CEC	18	13	2705	1027.0	0	1	3	3	
182100	SIY	7	0	0000	1027.3	1	0	0	25	
182100	ACV	14	5	2705	1026.3	0	0	3	20	
182100	MHS	8	-3	2205	1026.3	0	0	3	15	
182100	RBL	16	3	3310	1024.9	0	0	3	25	
182100	MYV	16	8	3215	1023.6	0	0	2	25	
182100	UKI	12	4	0000	1024.6	0	0	2	25	
182100	SMF	16	5	3215	1023.9	0	0	2	25	
182100	SAC	18	8	3315	1023.9	0	0	2	25	
182100	BLU	9	-4	0602	1023.3	0	0	2	25	
182100	SCK	15	7	3109	1023.9	0	0	2	25	
182100	OAK	18	5	0310	1023.9	0	0	1	25	
182100	SFO	14	7	3506	1023.9	0	1	1	25	
182100	SJC	18	6	3510	1023.9	0	0	1	20	
182100	MRY	17	5	0307	1022.6	0	0	1	25	
182100	SNS	17	6	0000	1022.2	0	0	1	25	
182100	FAT	12	9	2705	1023.3	1	0	2	4	
182100	BIH	14	-8	3205	1023.6	0	0	3	25	
182100	PRB	18	4	0612	1021.6	0	0	1	25	
182100	SMX	23	1	3610	1017.5	0	0	1	25	
182100	BFL	16	6	2405	1022.6	0	0	2	15	
182100	SBA	19	7	2410	1017.8	0	0	0	25	
182100	SDB	12	-7	0523	1019.2	0	0	0	25	
182100	DAG	19	-6	0000	1020.9	0	0	0	25	
182100	BUR	27	8	1105	1017.2	0	0	1	25	
182100	LAX	24	6	3405	1016.1	0	0	0	7	
182100	ONT	23	6	2105	1016.8	0	0	0	7	
182100	BUO	21	-8	0618G25	333.3	0	0	0	25	
182100	EED	23	-7	3618G27	1017.8	0	0	1	25	
182100	BLH	26	-3	3510	1017.2	0	0	0	25	
182100	STS	16	5	3205	1023.9	0	0	2	25	
182100	FUL	24	-62	3008	1015.5	0	0	0	7	
182100	SNA	20	13	1812	1015.5	0	0	0	6	
182100	SAN	21	14	3115	1015.5	0	0	0	12	

DDHHMM	STN	T	TD	WIND	PRES	LO	MID	HI	VIS	WX
182100	TVL	6	-5	3603	1026.[illegible]	0	0	3	25	
182100	WJF	17	-7	0515G20	1020.9	0	0	1	25	
182100	RAP	15	6	3309	1023.9	0	0	2	25	
182100	EDW	18	-6	0403	1021.6	0	0	1	25	
182100	MCC	15	5	3307	1023.6	0	0	2	25	
182100	MHR	14	5	3408	1023.6	0	0	2	25	
182100	NGZ	16	9	3208	1023.6	0	0	1	20	
182100	NID	19	-7	1703	1020.9	0	0	1	25	
182100	NKX	21	12	3010	1016.5	0	0	0	7	
182100	NLC	16	8	3212	1022.6	1	0	1	10	
182100	NPS	18	13	2917	1015.5	0	0	0	7	
182100	NSI	19	10	3309	1017.5	0	0	0	25	
182100	NTD	21	7	2912	1016.5	0	0	1	7	
182100	NUC	19	13	3504	1015.8	0	0	1	[illegible]	
182100	NUQ	16	4	0312	1023.[illegible]	0	0	1	25	
182100	NZJ	22	15	2704	1015.5	0	0	0	7	
182100	NZY	20	13	3114	1015.1	0	0	0	10	
182100	OAR	17	7	0510	1022.6	0	0	1	20	
182100	RIV	24	-2	3608G14	1016.8	[illegible]	[illegible]	[illegible]	[illegible]	
182100	SED	26	[illegible]	2603	1017.2	0	0	1	25	
182100	SUU	17	3	34[illegible]	1023.6	0	0	2	25	
182100	VBG	18	7	3214	1018.2	0	0	1	15	
182100	VCV	17	-6	0208	1021.9	0	0	1	25	
182100	DXN	14	7	2313	333.3	0	0	0	0.0	
182100	FIC	14	7	3211	333.3	0	0	0	0.0	
182100	CIC	16	9	2810	1023.9	0	0	1	25	
182100	MOD	15	-62	3310	1023.[illegible]	0	0	1	25	
182100	LYM	-1	-7	1502	1024.6	3	0	0	12	
182100	BGC	14	6	3316	333.3	0	0	0	0.0	
182100	SPC	-6	-10	2723	1025.0	1	0	0	15	
182100	BMD	-7	-11	0405	1029.0	3	0	0	1[illegible]	
182100	KRK	15	6	3110	333.3	0	0	0	0.0	
182100	MAX	15	2	2113	333.3	0	0	0	0.0	

among different parties with differing needs for agricultural weather information. Similarly, not all such equipment can produce data suitable for merging with other available weather information, for comparison with long-term climatological records, or for use in applying specialized research results.

In order to reduce the potential for problems of data incompatibility and to promote the near real-time use of detailed weather information, units manufactured by Campbell Scientific, Inc., have been selected and deployed for detailed test and evaluation in almond growing regions in the Great Central Valley. Growers are invited to inspect one or more of these locations. The resulting data and displays based thereon can be accessed from any point in California which is equipped with data-terminal equipment or with suitably configured microcomputers. To make arrangements to do so contact the author.

The resulting weather system, focused on the weather support to agriculture and developed partially as a result of research performed for the Almond Board of California, stands ready to serve cooperatively should the current trend toward increasing budgetary pressures on traditional services continue. Much effort has been extended to identify other pertinent sources of weather information in order to cooperate with these efforts, rather than to duplicate them, and to urge standardization of output insofar as possible. The results of these efforts have been mixed.

An unusual type of remote-sensing weather instrument, acoustic echo sounders, with the potential for application to frost protection problems has been deployed in field-crop situation using funds from other sources. Output from this device is available for study by interested parties in the almond industry.

b. Procedure. The selection and testing of automatic weather station equipment suitable for use in almond orchards was a significant activity from February through November 1981. A committee of growers provided input concerning desirable and necessary features of orchard weather systems suitable to weather applications of the broadest possible nature in support of their operational activities. The results of their input have been put into simple tables which have been published elsewhere (Hauser, 1981) and are included in Section 2.c (below) for convenience.

Acting on this preparatory work, project staff evaluated automatic weather station equipment from nine different vendors. The following sources of automatic weather station equipment were evaluated:

- Sierra-Misco, Inc.
  1825 Eastshore Highway
  Berkeley, CA 94710
- Climatronics Corporation
  1721 Eastern Avenue
  Sacramento, CA 95825
- Teledyne Geotech
  Box 28277
  Dallas, TX 75228
- Campbell Scientific, Inc.
  P. O. Box 551
  Logan, UT 84321
- Atmospheric Research & Technology
  6040 Verner Avenue
  Sacramento, CA 95814
- Helion, Inc.
  Box 445
  Brownsville, CA 95919
- Meteorology Research, Inc.
  464 West Woodbury Road
  Altadena, CA 91001
- HANDAR Company
  3327 Kifer Road
  Santa Clara, CA 95051
- LaBarge Electronics
  P. O. Box 926
  Tulsa, OK 74101
- Heath/Zenith
  Benton Harbor, MI 49022

Units from Campbell Scientific, Inc., were selected based on several findings. Field and central-office equipment did not require mounting in an electronic equipment rack. Sensor input channels were numerous and could be used flexibly. The micrologger unit (electronic microprocessor) permitted field programming and read-out, operated on either line voltage or batteries, was based on flexible computer programs in a Read Only Memory chip, could produce multiple output-data tables both for three different sampling or averaging times and for different combinations of weather elements, and could support either dial-up or leased-line telephone acquisition of weather data either by data-terminal or microcomputer equipment. The telephone modem and interface were relatively inexpensive, yet convenient to use. Hundreds of units were in use around the country and field performance and maintenance histories could be determined. Short delivery dates could be met. Finally, this vendor was among the least expensive. See Section 2.c for a list of automatic weather station equipment selected.

While not foreseen at the time Project No. 80-ZA2 was funded, acoustic echo sounders from three different vendors were also evaluated by project staff:

- Aerovironment, Inc.
  145 North Vista Avenue
  Pasadena, CA 91107

- Mesomet, Inc.
  190 N. State Street
  Chicago, IL 60601

- Radian Corporation
  8500 Shoal Creek
  Austin, TX 78758

Units from Radian Corporation were selected based on examination of technical documents, sample output, and visits to field installations. Field and central office equipment did not require mounting in electronic equipment racks. The range and sensitivity of measurement were well-suited to determining frost ceilings and could be altered either in the field or remotely by telephone line. The field unit was convenient to set up. The signal processor could deliver identical output to multiple ports for remote display and for field service and could support either dial-up or leased-line telephone acquisition of data by data-terminal equipment. The displays were convenient to use both in real-time and for comparative purposes. Short delivery dates could be met. See Section 2.c for a list of acoustic echo sounder equipment selected. The price from this vendor was the middle price.

Site selection for the placement of test units in almond orchards drew on several sources of data and advice:

- Meteorological analyses at the partial-state and regional levels prepared using the computing equipment and programs of NOWCASTING, Inc.
- Members of the Production Research Committee of the Almond Board of California.
- Selected almond growers.
- Selected County Agricultural Commissioners, Cooperative Extension Farm Advisors, and their staff members.
- National Weather Service agricultural meteorology personnel.

Main criteria for site selection included the filling in of known gaps in available hourly weather information; definition of known or anticipated light-wind circulation features and topographical influences; availability of telephone communications; security from vandalism; and freedom of the site from the biasing influences arising from building or tree interactions with important wind-flow directions or with the nighttime drainage flows of cold air.

The location of the sites is shown in Figure 2.1. They are listed in Table 2.1 for convenient reference. The information from automatic weather station equipment purchased as a result of initial development funding support by the Almond Industry Trust Fund was supplemented by information from identical equipment at seven other sites. Five of the seven supplemental sites were purchased by the Rice Research Board. Of these, the site at Wheatland (WEE) is located adjacent to an older orchard and near, but on higher ground than, a long-time Fruit-Frost

Network Station. The two remaining sites were purchased by private parties. Each of the sites shown in Table 2.2 was selected to best augment the data available to the stations shown in Table 2.1. Equipment for two more sites, purchased as a result of 1981 development funding support by the Almond Industry Trust Fund, are being installed near McFarland and Chowchilla in the San Joaquin Valley.

Table 2.1

Almond Industry Equipment Test and Evaluation Stations

Station ID No.	Station Identifier	Latitude Longitude	Organization	Contact
2003	CPY*	39.83N 122.17W	American Almond Orchards P. O. Box 606 Hamilton City, CA 95951	Ken Kaplan
2005	ABK*	39.07N 122.14W	Harper Ranch 31 Ashley Drive Colusa, CA 95932	Robert Harper
2007	CDA**	39.45N 122.13W	Hansen Farms Route 1, Box 901 Princeton, CA 95970	Keith Hansen
2008	PLG**	38.71N 121.57W	TENCO Tractor P. O. Box X Sacramento, CA 95813	Art Bristow

* Installed in young orchards.

** These locations are the sites of the two acoustic echo sounders. They are equipped with automatic weather station equipment purchased by the Rice Research Board.

Table 2.2

Supplemental Stations Providing Support to the Test and Evaluation Program

Station ID No.	Station Identifier	Latitude Longitude	Organization	Contact
2002	BGG	39.45N 121.73W	Rice Experiment Station P. O.Box 306 Biggs, CA 95917	Mort Morris
2004	WEE***	39.03N 121.42W	Waltz Ranch c/o 215 5th Street Marysville, CA 95901	Doug Waltz
2006	DXN	38.40N 121.71W	Valley Grain Marketing P. O. Box 907 Dixon, CA 95620	Jim Jones
2001	AMO*	39.62N 121.83W	Almont Orchards 3108 Burdick Road Chico, CA 95926	Fred Montgomery
2010	MAX**	39.18N 122.15W	City Fire Station Maxwell, CA 95955	Marion Brown
2009	KRK	38.90N 121.83W	Reclamation District #1500 P. O. Box 96 Robbins, CA 95676	Gordon Bailey
----	BTS****	39.22N 121.83W	TOR Broadcasting Corp. Box 731 Colusa, CA 95932	Lee Otterson

* Purchased by Almont Orchards and installed in a producing orchard location.

** Purchased by West Side Growers Association.

*** Installed adjacent to an older orchard.

**** The field spares equipment was sited on the Sutter Buttes and has no number because it is operated via microwave in real time, rather than polled automatically via telephone by the Apple data grabber.

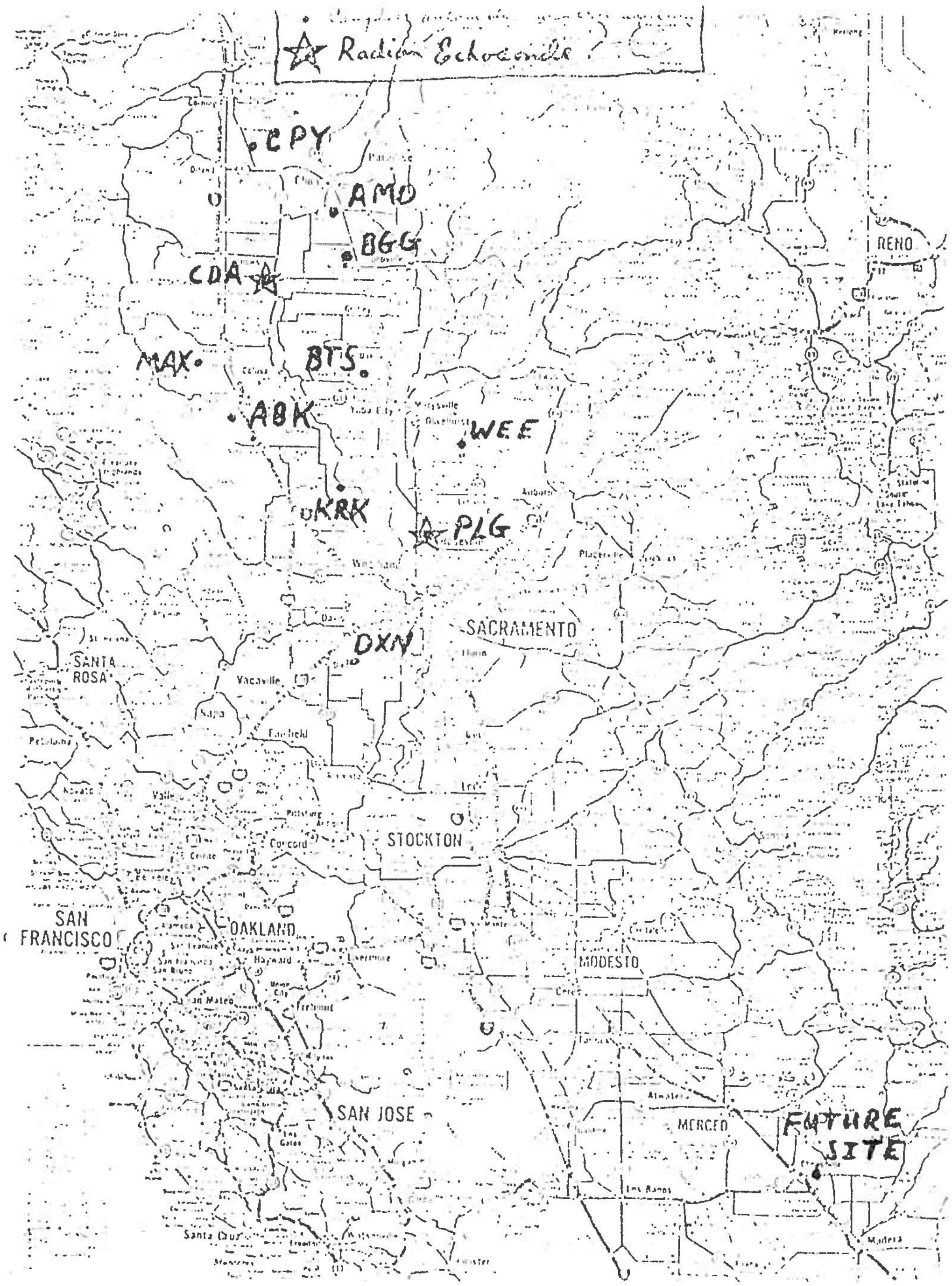


Figure 1

Almond Board of California
and
NOWCASTING, Inc.

In addition to the eleven sites operated by NOWCASTING, Inc., the test and evaluation program made routine use of standard weather information from ten locations listed in Table 2.3.

Table 2.3

Sources of Standard Weather Observations

Station Identifier	Latitude/ Longitude	Name	Intermittent Station
SUU	38.27N/121.93W	Travis Air Force Base	
SAC	38.51N/121.50W	Sacramento Executive Airport	
MHR	38.57N/121.30W	Mather Air Force Base	
MCC	38.67N/121.40W	McClelland Air Force Base	
SMF	38.70N/121.60W	Sacramento Metropolitan Airport	X
MYV	39.10N/121.56W	Yuba County Airport	
BAB	39.13N/121.43W	Beale Air Force Base	
CIC	39.70N/121.90W	Chico Municipal Airport	X
RBL	40.15N/122.25W	Bidwell Field, Red Bluff	
RDD	40.15N/122.30W	Redding Municipal Airport	X

Occasional use was made of information from the automatic stations operated by the California Department of Forestry listed in Table 2.4.

Table 2.4

Automatic Weather Stations near the Sacramento Valley
Operated by the California Department of Forestry

Station Identifier	Latitude/ Longitude	Name
WTM	40.62N/121.90W	Whitmore
BKR	40.29N/122.48W	Baker
CST	39.90N/121.69W	Cohasset
TCK	39.85N/122.60W	Thomes Creek
BGO	39.38N/121.60W	Bangor
DRS	39.32N/121.09W	Dorris Ranch
SRC	38.79N/121.20W	Sierra College
MTZ	38.70N/120.89W	Mount Zion

Table 2.5

Intermittent Touch-Tone Information
in the Great Central Valley

Reporting to NOWCASTING -- Chico, CA

Station Identifier	Latitude/ Longitude	Name
BAG	39.[illegible] 21.57W	Butte County Ag Commissioner
LBC	39.48N/121.98W	Lassen Land-Butte City
LCN	39.48N/121.98W	Lassen Land-Cana
LCB	39.84N/122.06W	Lassen Land-Cana River Bottom
CSF	39.69N/121.83W	Chico State Farm
DFD	38.45N/121.82W	Dixon Fire Department
GMW	38.37N/121.62W	Greg Merwin, Clarksburg
GMR	39.01N/122.07W	Greg Ramos, Arbuckle
HGN	39.49 N/121.49W	Hennigan Farms
NGN	39.69N/121.90W	Nottleman Hegan Lane
NUT	38.38N/121.96W	Nut Tree Airport
LOF	39.63N/121.96W	Lassen Land-Ord Ferry
PHS	39.39N/122.02W	Princeton High School
LPR	40.10N/122.17W	Lassen Land-Proberta
REP	39.89N/122.50W	John Repanich, Corning
STA	39.13N/121.60W	Sutter County Ag Commissioner
TRY	39.88N/122.53W	Terry Henry, Paskenta
DWZ	39.03N/121.42W	Doug Waltz, Wheatland

Reporting to National Weather Service/USDA -- Suitland MD

ARN	35.20N/118.77W	Arvin 3E
ATT	37.35N/120.67W	Atwater
BLK	35.58N/120.98W	Blackwell

BWV	39.25N/121.30W	Browns Valley
CAB	37.72N/121.42W	Carbona
COC	36.10N/119.57W	Corcoran
ORO	33.88N/117.55W	Corona
DAV	38.53N/121.77W	Davis
ECL	37.77N/120.97W	Escalon
PON	36.33N/120.10W	5-Points
HAN	36.30N/119.65W	Hanford
HEM	33.77N/116.95W	Hemet
LDC	36.37N/119.02W	Lindcove
LDX	36.20N/119.08W	Lindsay
LOB	37.05N/120.87W	Los Banos
MUR	38.13N/120.47W	Murphys
ORN	39.75N/122.20W	Orland
OVD	39.52N/121.48W	Oroville Dam
PAR	36.58N/119.50W	Parlier
PAT	37.47N/121.12W	Patterson
TRA	36.63N/120.37W	Tranquility
WAT	37.63N/120.75W	Waterford
WIL	39.52N/122.30W	Willows 6W
WOR	36.03N/118.92W	Worth
YUB	39.08N/121.36W	Yuba City

Additional wind-aloft information up to 5,000 feet was available from two pilot-balloon launching sites: the University Farm owned by California State University, Chico; and TENCO Tractor, Pleasant Grove. Finally, the Air Resources Board Meteorology Section obtained telemetered surface winds from their Air Quality Monitoring Stations at Bethel Island, Chico, Colusa, Sunrise, Willows, Woodland and Yuba City. However, for technical reasons these latter observations were not available for use during the 1981/82 test and evaluation program.

Most of this discussion has presented the spatial coverage of weather information during the test and evaluation program. However, the coverage through time is an important topic to mention in connection with Tables 2.3 through 2.5. The stations marked "Intermittent" in Table 2.3 do not report 24 hours per day, sometimes substantially so. All the stations in Table 2.4 report once every three hours. The information from the stations in Table 2.5 is irregular and normally is reported only once per day. As a result, the amount of weather information available in the nighttime and pre-dawn hours which are critical hours for fruit-frost decisions and for minimum temperature determination, depends crucially on the automatic stations in Table 2.1 and 2.2. Without them, the test and evaluation program could not have been mounted.

The most time consuming part of the automatic weather station site-selection process involved visiting each candidate site with a telephone company engineer to clarify our communications requirements and to determine whether sufficient line capacity was available. Usually at least two visits were necessary before all questions were satisfactorily answered. The installations at Dixon (DXN), Wheatland (WEE), Arbuckle (ABK), Maxwell (MAX), Codora (CDA), Durham (AMO), and Capay (CPY) went in without too much extra effort. The installations at Pleasant Grove (PLG), Kirkville (KRK), and Biggs (BGG) took more staff time. The site on the Buttes still is not in its final configuration. We are making a third attempt to find an anemometer and wind vane mounting configuration which can both use existing antennae supports and withstand strong winds and rain.

The equipment delivered by vendors was checked out both in-house before installation and remotely after installation. On initial check out, two wind-speed sensors proved to have faulty reed switches. One of the processors for the automatic weather stations (initially installed at Wheatland) developed an intermittent malfunction when placed in the field. This processor has been returned to the vendor for the third time with a request for replacement.

One of the acoustic echo sounders, on check out, proved to have a faulty set of processor boards and all were initially supplied with programs in Read Only Memory suitable for writing output to disk storage rather than to serial ports for delivery to modems. These initial problems were corrected by the vendor in a very expeditious fashion. During the test and evaluation program a second problem with the programs was detected: negative mean vertical velocities between 0 and 0.99 m sec^{-1} were erroneously displayed as positive numbers. This relatively minor problem, too, has been corrected by the vendor.

Remote check procedures which were necessary to ensure operational data integrity from the automatic weather stations required the creation of computer programs to automatically acquire information from the field units, to process this information for transfer to the main NOWCASTING computing machinery, and to actually accomplish the transfer. This data-acquisition software is a substantial outcome of the test and evaluation program, and has prompted inquiries from Cooperative Extension workers in several Western states. As a result of immediately merging the automatic station data into the standard data sets for near real-time analysis, a thirty degree error in mounting two wind-direction sensors was discovered and corrected. The major difficulty discovered as a result of remote check-out did not appear until the air became dry enough to create temperature and relative humidity combinations appropriate to negative dew-point temperatures on the Celsius scale. This algorithm has been corrected.

During the first two or three weeks of the test and evaluation program, each site was visited weekly to perform visual checks of the wind-speed and direction sensors and to check the temperature and relative humidity sensors against a sling psychrometer. No major mis-calibration error or bias of an instrument sensor has been discovered to date. In spite of the fact that the recommended practice is to replace the relative humidity sensors yearly, no observable problem has yet surfaced for this least durable sensor. With one exception all stations are still operating on their original battery packs.

In the case of the acoustic echo sounders, there is no separate set of instruments which can be taken to the field to check on the integrity of the electrical and mechanical devices. Therefore, each sounder was set up outside the NOWCASTING office and operated remotely via telephone line prior to field installation. Then early in the fall, visual sitings were taken to check sounder output of mixing height against the upward penetration of smoke plumes and against the visible top of the low-level haze layer. Once winter arrived the top of the fog and the sudden onset of strong north winds provided useful check points for instrument accuracy.

Installation was a major enterprise. The automatic weather station installations required a team of two people and the sounders a team of three people. Initially, the wind speed and direction sensors were mounted on concrete-based steel towers which we installed. Later we turned to the use of "utility-type" poles as the cheaper and quicker method of sensor support. Telephone lines to the site in most cases were installed underground, which caused some delay in hard-pan soils. In two cases we were able to use an existing tower or pole. It was learned late in the installation period that the rural interests involved often can expedite the installation of poles and telephone lines in rural areas, overcoming inertia sometimes encountered in central offices located in urban areas.

Coordination of telephone line identification, installation, and connection was time-consuming, frustrating and, at times, seemed impossible. This was especially true of the leased lines to the echo sounders. Receipt of the data did not begin until late September. All in all, however, it was a big and complicated job and the telephone companies involved went out of their way to get everything finally in order.

Mounting the wind speed and direction sensor and servicing them required climbing equipment and safety gear. Working with the electronic equipment required field troubleshooting skills. Placing towers on concrete blocks required some physical labor.

All installations have the wind speed and direction sensors mounted at about 10 m above the ground in order to observe air motion in light wind, observe the wind direction free of some of the largest effects of friction, and to enhance the comparability of the site to standard sources of hourly weather data. For use in connection with the data to be obtained for irrigation purposes under the proposed California Irrigation Management and Information System, there would be some advantage to having the wind speed for these stations obtained at a height of six feet above the ground and to having the temperature and humidity sensors exposed over a surface of irrigated grass. If this is thought desirable by the almond industry, we would suggest two steps: the wind sensors remain at 10 m, but the data acquisition programs simply apply the mathematical relationships used in the study of wind energy to obtain estimates of wind speed at 2 m; and that irrigated grass plots be installed where possible.

The weather equipment evaluation and test program was a major research activity during 1981. Related computer programming tasks were a major activity during July, August, and the first half of September.

c. Results. The equipment selected for orchard deployment is listed below. In addition to these items, a modestly priced Heath/Zenith Unit, capable of creating outputs that can be accessed via popular home/business microcomputers, was purchased. However, after examination it was deemed too fragile for field deployment.

The area of automatic weather equipment suitable for use in agricultural settings is one that is still undergoing rapid development. We intend to stay abreast of changes and to remain a reliable source of related information for the almond industry.

Campbell Scientific
Automatic Weather Station

Description

CR21 Micrologger
DC103A Answer Modem
024A Met-One Wind Direction Sensor w/35' leads
014A Met-One Wind Speed Sensor w/35' leads
041 Sensor Shelter w/mounts
201 Temp & RH Probe
RG2501 Sierra Tipping Bucket Raingage
LI-COR Silicon Pyronometer LI2005 w/35' lead
LI2003S Pyrnometer Mounting Base
021 CR21 Enclosure w/shield & mounts
Communication Shelters
Rhon Weather Tower, 30'
Spiked Poles

Radian Corporation
Acoustic Echo Sounder

Description

Echosonde III Control Chassis including DART III Processor, 8K ROM and 64K bytes RAM

Acoustic Enclosure with Parabolic Reflector Antenna Assembly, Transducer and 1000-foot Interconnecting Cables

Digital Dot-Matrix Display Units (TI-Omni 825, modified)

Monostatic Remote Driver/Preamplifier

Master Cable (1,000 feet)

Transducer/Driver Assembly

Voice Coil/Diaphragm

VA317P-MX-3 Answer-Only Bell 103/113 Compatible Modems

Tables 2.7 through 2.9 are the outcome of grower input concerning the type of real-time weather display which they would like to explore as a means of influencing their short-term management decisions.

An example of a grower-assisted sensor specification is shown in Table 2.6. We must emphasize the importance of working with the agriculturalist and the applied biologist at the level of detail illustrated in Table 2.6.

Table 2.6

Measurement Characteristics for Wind Velocity

Name	Form	Units	Tolerance	Range	Polling Sample Frequency	Interrupt Alert Threshold
Speed	Scalar magnitude	Miles per hour	$\pm$ 0.5; $S \leq 10$ $\pm$ 1.0; $10 \leq S \leq 40$ $\pm$ 2.5; $S > 40$	1.5-60	½ hourly, of last 5-minute average	Settable threshold for increase or decrease in wind speed
Direction	Angle	Compass octants (1/8ths)	$\pm$ 1/16 of the compass circle	Eight compass points	½ hourly, of last 5-minute vector average	Vane movement after calm and no wind speed

Table 2.7

User-Defined Display Priorities: 1 = High; 4 = Low

Variable	Type of Display	Local	Regional	Partial State	State	Western USA
Wind Speed	Plotted Values	2	1	1	3	4
	Contours	1	1	3	1	3
Wind Direction	Plotted Values	2	1	1	3	4
	Stream-lines	2	1	1	3	4
Wind Velocity	Speed Contours and short arrows	2	1	1	3	4
Temperature	Plotted Values	1	1	2	3	4
	Contours	2	1	2	3	4
Dew-Point Temperature	Plotted Values	2	1	3	3	4
	Contours	2	1	2	3	4
Text	Suggestions which will direct users to key user-initiated displays	1	1	2	4	4
Rainfall	Plotted Symbols for occurrence now	1	1	2	3	4
	Plotted 6-hr accumulations	1	1	2	3	4
	Plotted 24-hr accumulations	1	1	2	3	4
	Plotted Rain Probabilities	2	2	2	3	4
	Plotted intensities occurring now (3-levels)	1	1	2	3	4
	Outlined area of scattered showers	1	1	2	3	4
Text	Short-Term outlooks	1	1	4	4	4
Derived Weather Variables	Degree Days, 24-hr, 3-day, 5-day, 10-day, 30-day, seasonal	1	1	2	2	3
	Many Others	--not yet prioritized--				

Table 2.8
Apple Test-User Display Schedule

Display	Local Map	Data Available	Regional Map	Data Available
Wind Speed/Direction Plotted Values	X	6/15/81	X	6/15/81
Wind Speed Contours	X	5/15/81	X	5/15/81
Wind Streamlines	X	8/31/81	X	8/31/81
Wind Composite Contours & Short Arrows	X	6/15/81	X	6/15/81
Air Temperatures Plotted Values	X	6/15/81	X	6/15/81
Air Temperatures Contours	X	5/15/81	X	5/15/81
Dew-Point Temperatures Plotted Values	X	6/15/81	X	6/15/61
Dew-Point Contours	X	5/15/81	X	5/15/81
Text-Comments			X	6/15/81

Table 2.9
Apple Test-User Hardware Requirements

48K Bytes of program memory

Two Apple Disk II floppy disk units with DOS 3.3 controller.

A standard color television (12" to 15" screen size recommended) or a color monitor that can be attached to the Apple's video output jack.

If you are using a standard color television, a Sup'R'Mod II TV interface unit (or equivalent) is required.

An Apple Serial Interface Card

An accoustically-coupled, Bell 103 compatible modem.

Proper cabling to connect the Apple to the modem (pins 2 and 3 of the DB-25 connector must be reversed).

A standard telephone, or

Items 5-8 may be eliminated by the use of a D.C. Hayes Micro-model II and the availability of a female RJii modular telephone connection.

3. <u>Daily Climatological Information</u>.

a. <u>Interpretive Summary</u>. Averages of daily climate information can be prepared and mapped for twenty-three stations in or near the Sacramento Valley. Data for a slightly larger number of stations in the San Joaquin Valley is on order.

To display daily climate information with greater detail, resort must be made to 10-year averages because of changes in the climatological substation network and because of budgetary trends affecting this network during the last decade. Some grower receptivity to receiving current and recent weather information displayed and quantified against such map displays has been demonstrated. The largest departures normally occur during the spring and fall seasons. Some of their effects remain to affect events much later in the growing season.

Degree-day information can be computed in a practical manner using hourly weather observations. Such values can exceed those computed using maximum and minimum temperatures on cloudy or stormy days and are less than the traditional values on sunny days. Work is continuing to learn about the importance of this information.

An archive of hourly surface weather observations and twice daily upper-air observations beginning 1 October 1981 has been established. This archive can be accessed remotely from anywhere in California by contacting the author.

Work begun under the auspices of the Almond Board of California and concerned with the packaging of weather information for use by agribusinessmen will continue through early 1984 and is funded by the W. K. Kellogg Foundation. We would be interested in maintaining contact with any parties who wish to be a part of this continuing effort which will culminate in a Conference on the Packaging of Weather Information for Agriculture to be held in Chico in the Spring of 1984.

b. <u>Procedure</u>. The research effort directed toward the use of daily climatological information as the context against which to display and interpret current weather information has had three major foci:

- the acquisition, processing, and analysis of daily climatological records in the Great Central Valley
- the comparison of hourly weather information to daily data to describe available weather detail
- the creation of an archive easily accessible to California's almond growers.

Each of these foci will be dealt with briefly in the material that follows:

Daily climatological records have been acquired on a reel of computer compatible magnetic tape, for the following 23 climatological substations located in or near the Sacramento Valley:

Station Name	Location	Useable Length of Record 1948-1979, Years
Auburn	38 54N 121 04W	30
Blue Canyon WB AP	39 17N 120 42W	30
Brooks Farnham Ranch	38 46N 122 09W	20
Chico Experiment Station	39 42N 121 47W	20
The University Farm California State Univ.,Chico	39 42N 121 49W	5
Clarksburg	38 25N 121 32W	20
Colusa 2 SSW	39 12N 122 01W	30
Davis Expimental 2 WSW Exp Farm	38 32N 121 46W	30
De Sabla	39 52N 121 37W	30
East Park Reservoir	39 22N 122 31W	30
Grass Valley 2	39 13N 121 04W	10

Orland	39 45N 122 12W	30
Oroville 1 WSW	39 30N 121 34W	10
Paradise	39 45N 121 37W	10
Portola	39 48N 120 28W	30
Red Bluss WB AP	40 09N 122 15W	30
Redding Fire Station #2	40 35N 122 24W	10
Sacramento FAA AP	38 31N 122 30W	30
Shasta Dam	40 43N 122 25W	30
Stony Gorge Reservoir	39 35N 122 32W	30
Vacaville	38 22N 121 57W	30
Winters	38 32N 121 58W	30
Woodland 1WNW	38 41N 121 48W	30

These records are accessible to data-processing programs which operate on the HP 3000 computer operated by the Department of Computer Science at California State University, Chico. The magnetic tape can be made available to other processing facilities.

Similar computer-compatible, daily weather records are on order for those of the following locations in the San Joaquin Valley which have the longest useable history in growing regions:

Name	Location
Lodi	38 07N 121 17W
Stockton Fire Station 4	38 00N 121 19W
Tracy Pumping Plant	37 48N 121 35W
Tracy 2 SSE	37 43N 121 25W
Tracy Carbona	37 42N 121 25W
Modesto	37 39N 121 00W

Modesto 2	37 38N 121 00W
Denair 3 NNE	37 34N 120 47W
Newman 2 NW	37 21N 121 03W
Los Banos Det. Resv.	37 01N 120 56W
Los Banos	37 03N 120 52W
Madera	36 57N 120 02W
Fresno WSO AP	36 46N 119 43W
Coalinga	36 09N 120 21W
Five Points 5 SSW	36 22N 120 09W
Kettleman Sta.	36 04N 120 05W
Corcoran Irrig. Dist.	36 06N 119 34W
Hanford 2 S	36 18N 119 39W
Visalia	36 20N 119 18W
Lindsay	36 12N 119 03W
Lemon Cove	36 23N 119 02W
Orange Cove	36 37N 119 18W
Porterville	36 04N 119 01W
Wasco	35 36N 119 20W
Buttonwillow	35 24N 119 28W
Kern River PH 1	35 28N 118 47W
Bakersfield WSO AP	35 25N 119 03W
Maricopa	35 05N 119 23W
Tejon Rancho	35 02N 118 45W
Panoche Cr.	36 41N 120 35W
Idria	36 25N 120 40W
Blackwells Corner	35 37N 119 52W
Glennville	35 43N 118 42W

Le Grand	37 14N 120 15W
Merced Fire Stn 2	37 18N 120 29W
Manteca	37 47N 121 12W
Walnut Grove	38 14N 121 31W
Knights Ferry 2 SE	37 48N 120 39W
Paso Robles FAA AP	35 40N 120 38W

Working with the first data set has shown that it can be helpful to move from the standard 30-year length of record to 20 years or 10 years in cases when additional detail needed. With the many changes in the nation's climatological network during the last decade, the number of times one must turn to a shorter record than normally desired appears to be increasing.

Tables 2.10 through 2.12 illustrate a case in point. During mid-June 1981 (ending June 22nd), a layer of moist air between 5,000 and 10,000 feet acted as a blanket and produced several nights in almond-growing locations with minimum temperatures in the mid-70's. Each Table shows the 1-day, 3-day, 5-day, 10-day, and 30-day cumulative degree days $((T_{max} + T_{min})/2 - 55F)$ expected according to the available daily climatological record. No upper cut-off temperature was used. Table 2.10 is based on 30 years of records; Table 2.11 on 20 years; and Table 2.12 on 30 years.

Table 2.13 shows, on the other hand, the cumulative degree days on record from five sites that reported to the NOWCASTING Touch-Tone Network. The considerable departure of these values from "normal" was the weather effect being experienced in the field. When quantified and communicated to growers and PCA's <u>while it was being experienced</u>, they responded favorably to receiving information concerning the size and frequency of this weather departure from normal.

Table 2.10

Spatial Resolution of Cumulative Degree Days
Based on 30-year Average of Daily Values

STATION	[illegible]	3-day	5-day	10-day	30-day
Auburn	19.9	55.2	88.0	165.0	404.2
BlueCanyon WB AP	9.8	27.0	42.9	76.7	163.3
Brooks Farnham Ranch	19.9	56.4	92.3	178.3	445.8
Chico Experiment Station					
Clarksburg					
Colusa 1 SSW	21.6	62.1	99.8	194.1	501.3
Davis Experimental Farm 1 WSW	18.9	53.7	85.8	166.4	427.7
De Sabla	14.4	40.8	65.4	121.3	276.5
East Park Reservoir	19.1	55.0	90.6	166.4	410.3
Grass Valley					
Orland	22.6	63.9	104.5	203.5	516.0
Oroville 1 WSW					
Paradise					
Portola	5.7	15.5	24.7	42.0	83.5
Red Bluff WB AP	25.3	73.8	119.4	228.9	571.2
Redding Fire Station #2					
Sacramento FAA AP	18.8	55.5	87.6	170.9	430.8
Shasta Dam	23.0	66.0	109.0	205.1	508.3
Stony Gorge Reservoir	21.0	61.0	90.4	192.5	470.7
Winters	22.2	63.0	101.4	196.8	502.5
Woodland 1 WNW	21.2	60.2	97.4	188.0	476.7
Vacaville	19.4	57.1	90.7	174.8	435.8

Table 2.11

Spatial Resolution of Cumulative Degree Days
Based on 20-year Average of Daily Values

STATION	1-day	3-day	5-day	10-day	20-day
AUBURN	21.5	60.7	97.0	174.4	386.6
BLUE CANYON WB AP	11.0	31.8	50.5	84.5	150.7
BROOKS FARNHAM RANCH	21.6	61.0	100.8	188.2	234.8
CHICO EXPERIMENT STATION	22.9	68.1	109.7	206.8	488.3
CLARKSBURG	18.8	52.0	84.7	158.4	373.0
COLUSA 1 SSW	22.8	66.1	106.8	203.7	487.5
DAVIS EXPERIMENTAL FARM 1 WSW	20.7	58.2	93.6	176.1	414.6
DE SABLA	15.3	44.2	72.8	129.0	265.4
EAST PARK RESERVOIR	20.7	59.5	97.7	176.2	399.8
GRASS VALLEY					
ORLAND	23.9	68.7	112.0	211.5	502.2
OROVILLE 1 WSW					
PARADISE					
PORTOLA	7.2	18.9	30.0	47.1	83.7
RED BLUFF WB AP	26.1	77.5	125.5	234.9	553.4
REDDING FIRE STATION #2					
SACRAMENTO FAA AP	19.8	59.7	95.6	183.3	426.0
SHASTA DAM	23.9	68.9	114.3	209.2	490.4
STONY GORGE RESERVOIR	22.2	65.5	107.3	201.7	464.9
WINTERS	24.0	68.4	109.5	206.2	491.0
WOODLAND 1 WNW	22.5	64.0	103.6	194.5	461.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	430.4

Table 2.12

Spatial Resolution of Cumulative Degree Days
Based on 10-year Averages of Daily Values

STATION	1 DAY	3 DAY	5 DAY	10 DAY	30 DAY
AUBURN	19.5	55.9	89.3	169.0	398.6
BLUE CANYON WB AP	9.6	28.0	43.9	79.1	165.1
BROOKS FARNHAM RANCH	23.0	61.3	99.0	188.2	450.4
CHICO EXPERIMENT STATION	21.7	62.9	103.7	200.9	496.5
CLARKSBURG	16.6	50.9	74.4	146.1	360.3
COLUSA 1 SSW	21.3	59.5	98.0	191.2	473.9
DAVIS EXP. FARM 1 WSW	15.6	52.0	84.6	166.5	414.1
DE SABLA	14.6	42.3	67.1	121.8	272.9
EAST PARK RESERVOIR	19.5	55.9	92.3	170.7	411.6
GRASS VALLEY	15.4	42.9	70.2	123.3	288.1
ORLAND	22.1	63.5	104.7	204.2	503.9
OROVILLE 1 WSW	23.8	67.9	111.1	212.5	533.3
PARADISE	19.5	56.2	89.0	167.9	395.0
PORTOLA	6.4	15.6	26.0	42.5	85.2
RED BLUFF WB AP	20.8	68.9	114.6	222.5	547.4
REDDING FIRE STN	26.3	76.2	126.9	242.7	619.0
SACRAMENTO FAA AP	18.0	53.5	87.3	171.4	432.9
SHASTA DAM	23.0	65.5	108.1	203.5	506.9
STONY GORGE RESERVOIR	22.1	62.3	102.6	194.8	469.6
WINTERS	22.5	62.8	101.9	197.9	492.8
WOODLAND 1 WNW	20.8	59.3	97.4	190.0	473.1
VACAVILLE	19.6	54.1	87.9	171.4	413.6

Table 2.13

Cumulative Degree Days Ending June 22 1981

	1-day	3-day	5-day	10-day	30-day
CSU,C Farm	31.0	95.0	151.0	231.0	617.5
Nord Fire Station	36.0	108.0	171.0	285.0	689.5
Arbuckle	29.0	84.0	135.0	220.0	-
Sutter County Ag Comm	33.0	99.0	160.0	260.0	-
Corning	31.0	96.0	155.0	230.0	-

These data have been shown in a map display in Figures 2.1 and 2.2. Figure 2.1 presents the 3-day cumulative values based on 10 years of record. The same contours are included in Figure 2.2 as the background against which the observations from Table 2.4 are plotted. The reason for investigating the utility of this approach to the presentation of agricultural weather information was a practical one. Pest-control advisors were interested in making improved use of weather forecast information available to them from various sources. We were asked to prepare prototype displays which might assist them in making more efficient and quantitative judgements about the importance of the period of warm nights in the light of their accumulated experience.

Our direction is to continue to investigate flexible and visual approaches to timely delivery of decision-oriented agricultural weather information. In this way, this particular focus of our research begun with the support of the Almond Board of California has perhaps the greatest potential for industry-wide utility. The view just expressed is rooted in a three-year research grant from the W. K. Kellogg Foundation received by the NOWCASTING Project in August, 1981. Thus, the culmination of work on modern weather products begun with the support of the almond industry in the summer of 1980 will occur in a conference to be held in Chico in the spring of 1984.

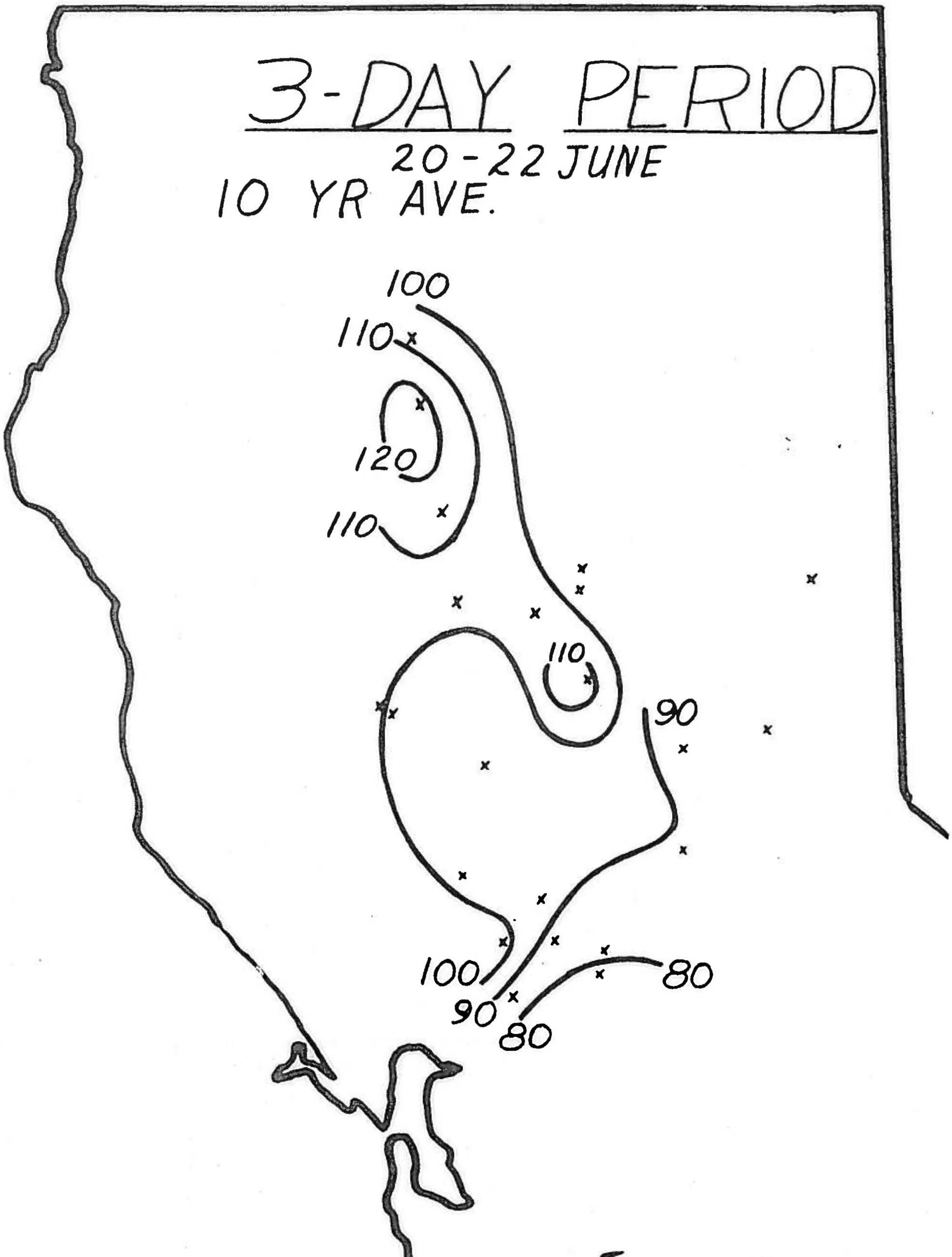

3-DAY PERIOD
20-22 JUNE
10 YR AVE.
100
110
120
110
110
90
100
90
80
80

Figure 2.1

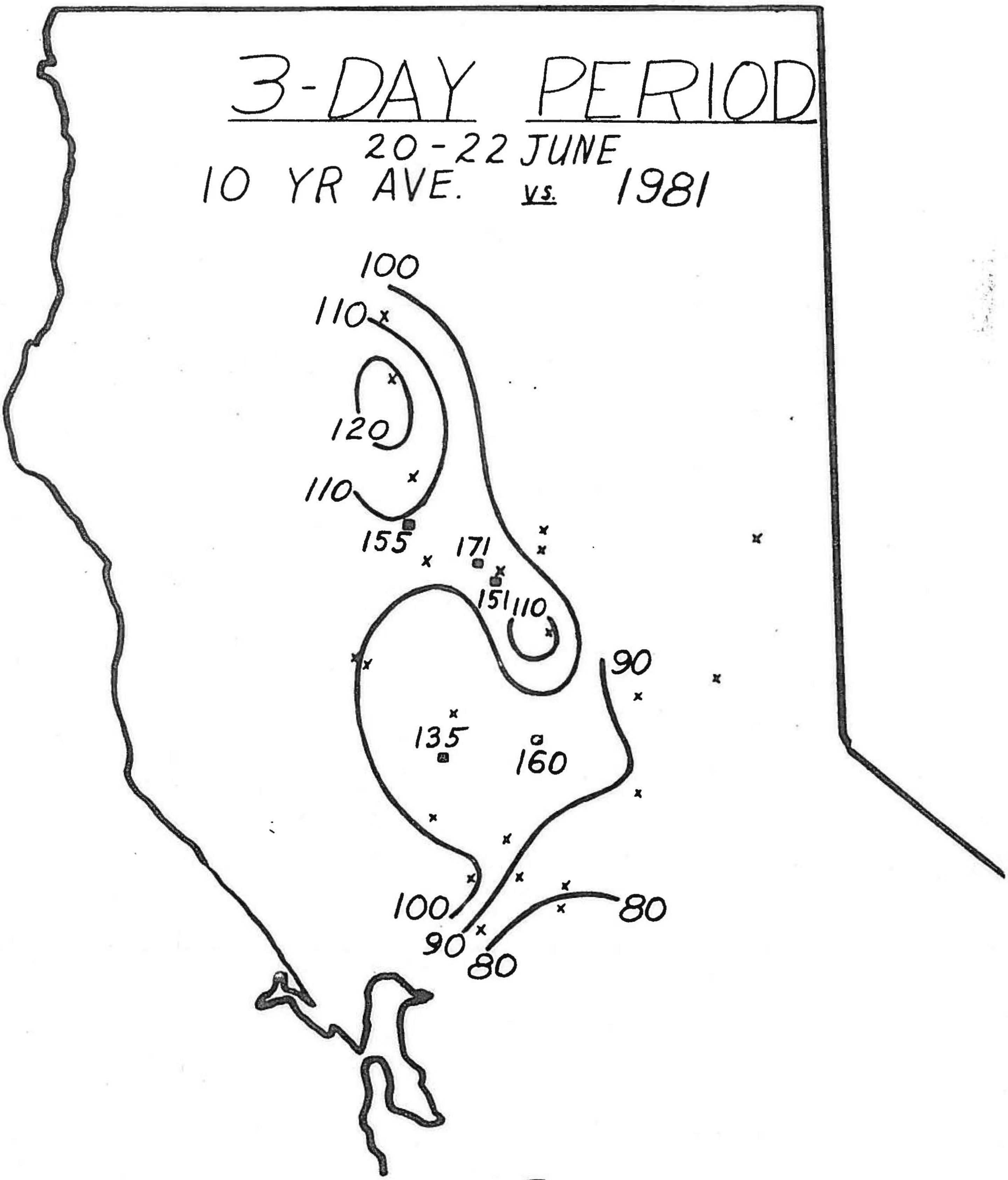

3-DAY PERIOD
20-22 JUNE
10 YR AVE. vs. 1981
100
110
120
110
155
171
151
110
90
135
160
100
90
80
80

Figure 2.2

The second focus on hourly weather information to support agricultural decisions began in earnest in October 1981. At that time hourly data became routinely available in almond growing locations. The analysis of this detail has just begun. Table 2.14 shows comparable data at hourly and daily temperature sampling intervals. While this information is from the fall of 1981, there does appear to be some indication that the relationships, not unexpectedly, are different on sunny days than on cloudly days. We are thus hopeful that this type of comparison during the spring of 1982 (like fall, spring is a "transitional" weather season) may help us begin to understand some of the possible interactions of weather, pest populations, and pest management that were suggested by the results reported in Hauser (1980).

Table 2.14

Comparison of Degree Days (T_{REF}=55F) at
Hourly and Daily Resolution

Station

Date	CPY		AMO		ABK		WEE	
	Hourly	Max-Min	Hourly	Max-Min	Hourly	Max-Min	Hourly	Max-Min
10/10-16	23.4	17.0	M	M	20.0	10.0	19.5	9.5
10/17-23	59.5	82.5	M	M	61.5	67.5	50.5	48.1
10/24-30	21.0*	M	M	M	27.0	16.5	20.0*	19.1*
10/31-11/6	25,5*	28,0*	M	M	31.0*	33.5*	19.5	13.7
11/7-11/13	17.5	17.5	15.5*	14.5*	24.6*	20.0*	15.5*	18.2*
11/14-11/20	11.5	M	16.5	13.0	17.1	13.5	2.0*	1.5*
11/21-11/28	M	M	7.6*	5.0*	8.5*	7.5*	8.0*	8.0*

Tables 2.15 - 18 show a sample of hourly weather information as received for the stations at Arbuckle (ABK), Capay (CPY), Wheatland (WEE), and Durham (AMO).

Table 2.15

REMOTE STATION SUMMARY

STATION # 2005 (ABK)

LAT: 390400   LONG: 1221000   INSTALLED: 09/30/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/10	905	13	97	12	3	166
11/10	1005	14	96	13	4	299
11/10	1105	15	94	13	4	276
11/10	1205	16	91	14	3	147
11/10	1305	16	89	14	4	343
11/10	1405	17	88	14	4	334
11/10	1505	16	90	14	3	148
11/10	1605	16	91	14	2	281
11/10	1705	15	93	13	3	305
11/10	1800	15	94	13	3	331
11/10	1905	15	94	13	2	307
11/10	2005	14	97	13	4	256
11/10	2105	14	97	13	4	292
11/10	2205	14	97	13	3	318
11/10	2305	13	98	12	3	282
11/11	5	13	98	12	2	314
11/11	105	12	99	11	3	291
11/11	205	12	100	11	4	287
11/11	300	12	99	11	2	299
11/11	405	12	99	11	2	289
11/11	505	13	98	12	1	262
11/11	605	13	98	12	2	286
11/11	705	13	98	12	1	155
11/11	805	13	96	12	4	217

LAT: 390400   LONG: 1221000   INSTALLED: 09/30/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/11	905	14	96	13	3	116
11/11	1005	14	95	13	7	113
11/11	1105	15	95	14	6	166
11/11	1205	16	92	14	12	107
11/11	1305	17	88	14	11	147
11/11	1405	18	84	15	13	132
11/11	1505	18	84	15	10	142
11/11	1605	18	84	15	10	139
11/11	1705	17	87	14	11	159
11/11	1805	16	91	14	9	144
11/11	1905	17	87	14	11	159
11/11	2005	17	81	13	12	165
11/11	2105	17	80	13	14	153
11/11	2205	16	84	13	8	159
11/11	2305	15	93	13	10	126
11/12	5	15	93	13	11	136
11/12	605	14	98	13	14	149
11/12	705	14	99	13	14	135
11/12	805	14	98	13	12	163

Table 2.16

REMOTE STATION SUMMARY

STATION # 2003 (CPY)

LAT: 395000 LONG: 1221000 INSTALLED: 09/10/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/10	900	12	100	11	3	86
11/10	1005	13	100	12	6	66
11/10	1105	13	99	12	8	87
11/10	1205	13	97	12	6	129
11/10	1305	14	97	13	5	132
11/10	1405	15	97	14	2	238
11/10	1505	16	92	14	3	156
11/10	1605	15	95	14	2	258
11/10	1705	14	98	13	2	293
11/10	1805	14	98	13	4	284
11/10	1900	13	100	12	5	6
11/10	2000	13	100	12	5	311
11/10	2105	12	100	11	5	310
11/10	2205	12	100	11	2	323
11/10	2305	11	101	11	4	310
11/11	5	10	101	10	4	305
11/11	105	11	101	11	4	318
11/11	205	11	101	11	3	321
11/11	305	11	101	11	3	268
11/11	405	11	101	11	1	245
11/11	505	11	101	11	4	275
11/11	605	10	101	10	1	121
11/11	705	10	101	10	3	119
11/11	805	12	101	12	1	314

LAT: 395000 LONG: 1221000 INSTALLED: 09/10/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/11	905	13	100	12	8	107
11/11	1005	14	98	13	5	122
11/11	1105	16	95	15	4	189
11/11	1205	16	93	14	9	149
11/11	1305	17	91	15	9	178
11/11	1405	17	90	15	11	158
11/11	1505	17	92	15	12	177
11/11	1605	16	94	14	9	167
11/11	1705	15	97	14	9	147
11/11	1805	15	96	14	12	131
11/11	1905	15	96	14	12	133
11/11	2005	15	95	14	16	144
11/11	2105	15	96	14	16	142
11/11	2205	14	99	13	21	110
11/11	2305	14	99	13	15	132
11/12	6	14	94	12	5	187
11/12	605	13	99	12	18	145
11/12	705	13	100	12	17	146
11/12	805	14	100	13	13	151

Table 2.17

REMOTE STATION SUMMARY

STATION # 2004 (WEE)

LAT: 390200 LONG: 1212500 INSTALLED: 09/15/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/10	910	17	76	12	8	150
11/10	1010	16	82	12	5	160
11/10	1115	17	83	13	2	171
11/10	1210	17	81	13	5	196
11/10	1305	17	89	15	2	277
11/10	1410	17	90	15	3	36
11/10	1505	18	87	15	3	72
11/10	1615	17	87	14	4	208
11/10	1715	16	93	14	2	265
11/10	1905	14	96	13	5	36
11/10	2005	13	97	12	4	254
11/10	2105	12	97	11	4	319
11/10	2205	11	98	10	4	73
11/10	2310	12	99	11	4	30
11/11	10	10	99	9	4	331
11/11	115	12	101	12	5	285
11/11	210	11	102	11	4	58
11/11	310	10	103	10	5	102
11/11	410	9	103	9	4	307
11/11	505	9	103	9	2	357
11/11	610	9	103	9	1	244
11/11	710	8	104	8	2	315
11/11	810	9	103	9	6	93

LAT: 390200 LONG: 1212500 INSTALLED: 09/15/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/11	910	13	102	13	6	255
11/11	1005	13	96	12	3	209
11/11	1110	18	77	11	7	111
11/11	1315	20	60	11	9	187
11/11	1405	21	58	12	6	194
11/11	1615	19	65	12	7	168
11/11	1710	17	77	12	6	151
11/11	1815	15	84	12	5	180
11/11	1905	14	88	11	5	143
11/11	2005	14	87	11	5	135
11/11	2205	15	85	12	9	125
11/11	2305	15	86	12	10	142
11/12	600	14	94	12	9	162
11/12	805	14	97	12	11	164

Table 2.18

REMOTE STATION SUMMARY

STATION # 2001 (AMO)

LAT: 393700   LONG: 1215000   INSTALLED: 08/15/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/10	905	14	88	11	2	257
11/10	1005	13	94	11	3	78
11/10	1100	13	94	11	5	73
11/10	1200	14	93	12	2	101
11/10	1300	15	92	13	2	102
11/10	1400	16	90	14	2	146
11/10	1505	16	89	14	5	126
11/10	1605	16	91	14	6	219
11/10	1700	15	92	13	1	282
11/10	1800	14	94	12	2	31
11/10	1900	14	94	12	1	208
11/10	2000	13	94	11	2	295
11/10	2055	13	94	11	3	280
11/10	2155	12	94	10	3	42
11/10	2255	12	95	11	2	290
11/10	2355	11	95	10	2	342
11/11	55	12	95	11	3	152
11/11	155	12	95	11	1	98
11/11	255	11	96	10	3	249
11/11	355	11	96	10	1	309
11/11	500	11	96	10	1	39
11/11	555	11	97	10	1	283
11/11	655	11	97	10	4	75
11/11	800	11	95	10	2	252

LAT: 393700   LONG: 1215000   INSTALLED: 08/15/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
11/11	855	13	94	11	2	86
11/11	955	14	92	12	8	116
11/11	1055	17	82	13	5	194
11/11	1205	18	82	14	9	147
11/11	1300	19	80	15	10	167
11/11	1350	19	79	15	7	183
11/11	1455	19	78	14	9	156
11/11	1500	18	79	14	4	159
11/11	1655	17	84	14	4	151
11/11	1755	15	86	12	6	141
11/11	1855	15	86	12	5	116
11/11	1955	15	87	12	8	115
11/11	2055	16	87	13	11	129
11/11	2155	16	87	13	8	122
11/11	2255	15	86	13	11	115
11/11	2350	15	89	12	12	127
11/12	555	14	94	12	13	141
11/12	650	14	94	12	14	134
11/12	750	13	93	11	12	144

Table 2.19 shows a sample of intermittent weather observations received by Touch-Tone telephone from one of the cooperating observers, Mr. Greg Ramos of Arbuckle (GMR).

Table 2.19

NOWCASTING Fruit Frost Data File

Station Name	Observ-Time Day	Mo	Hour	Moisture WB-Temp	Rel-Hum	Air Hi	Low	Temp Ob	Weather Type	Wind Direc	Speed
GREG RAMOS	1	10	0600			86	64	65		NW	8
GREG RAMOS	1	10	1800					79		SE	2
GREG RAMOS	2	10	0600			86	54	56	PC	N	1
GREG RAMOS	3	10	0600			74	54	55	PC	W	1
GREG RAMOS	3	10	1200					67	PC	NE	3
GREG RAMOS	3	10	1630					71		SE	12
GREG RAMOS	4	10	0730			76	47	76	PC	NW	3
GREG RAMOS	4	10	1745					72		NE	5
GREG RAMOS	5	10	0600			75	47	49		NW	4
GREG RAMOS	5	10	1200					70		NW	2
GREG RAMOS	5	10	1745					74		SE	2
GREG RAMOS	6	10	0600			79	48	49	PC	SE	1
GREG RAMOS	6	10	1800					72	PC	SE	4
GREG RAMOS	7	10	0600			83	55	56	PC	SE	4
GREG RAMOS	7	10	1200					65	PC		
GREG RAMOS	7	10	1700					69	PC	SW	1
GREG RAMOS	8	10	0600			83	46	47		NW	2
GREG RAMOS	8	10	1100					65		NW	1
GREG RAMOS	8	10	1600					69		NE	2
GREG RAMOS	9	10	0600			72	48	49		W	2
GREG RAMOS	10	10	0600			77	57	58	C	SE	5
GREG RAMOS	10	10	1200					70	PC	S	1
GREG RAMOS	10	10	1700					66	PC	NW	4
GREG RAMOS	11	10	0730			75	46	74		SW	1
GREG RAMOS	11	10	1045					61		NE	1
GREG RAMOS	11	10	1600					65		NE	1
GREG RAMOS	12	10	0600			67	42	43	PC	NW	1
GREG RAMOS	12	10	1200					59		NW	8
GREG RAMOS	12	10	1815					59		NW	4
GREG RAMOS	13	10	0600			66	42	43		W	3
GREG RAMOS	13	10	1130					60	PC	NW	5
GREG RAMOS	14	10	0600			67	41	42	PC	NW	6
GREG RAMOS	14	10	1800					64		NW	2
GREG RAMOS	15	10	0600			70	46	49		NW	5
GREG RAMOS	15	10	1200					68		NW	9
GREG RAMOS	16	10	0600			74	46	49		NW	4
GREG RAMOS	16	10	1130					66		NE	7
GREG RAMOS	16	10	1715					72		NE	1
GREG RAMOS	17	10	0600					44		SW	1
GREG RAMOS	17	10	1200					69		NW	3
GREG RAMOS	17	10	1730					71		E	2
GREG RAMOS	18	10	0700			76	46	47		SW	1
GREG RAMOS	18	10	1200					74		NW	3
GREG RAMOS	18	10	1630					79		S	1
GREG RAMOS	19	10	0600			81	46	47		NW	3
GREG RAMOS	19	10	1200					73		NW	4

The third focus of this research topic has been to create an archive of detailed weather information which can be easily accessible to the almond industry anywhere in California that almonds are grown. Beginning with October 1981, hourly surface and twice daily upper-air weather data in either raw or analyzed form can be delivered to data terminals or to properly equipped microcomputers. This process uses the computer equipment and programs of NOWCASTING. Any entity wishing to make use of these archives should contact the author. We intend to continue to refine the methods of delivery and the available formats and displays under the guidance of growers and their advisors.

Appendix A includes samples both of output lists from the numerical archives and of the type of acoustic echo sounder measurements that reveal the strength of low-level nocturnal temperature inversions and "frost ceilings".

c. Results. Most of the work in this area is in progress rather than completed. We have demonstrated that daily climatological detail can be prepared and displayed for the Great Central Valley. In order to study maximum spatial detail, less than 30-year averages must be used. Hourly weather observations can be used to more closely approximate the temporal experiences of agriculturally important commodities and their pests. The effects of increasing temporal resolution appear to be complicated and departures during cloudy or stormy periods *versus* sunny periods can sometimes be of opposite sign at least in the fall. Whether this behavior can be linked to apparent pest-control anomalies, perhaps associated with spring cool periods identified in Hauser (1980), remains to be seen.

We have shown that grower input can successfully impact the acquisition and display of local, timely weather detail. This research has laid the foundation for follow-up and more intensive research on the packaging of weather information for agriculture, sponsored by the W. K. Kellogg Foundation.

But perhaps the most substantial result of this phase of our research is the creation of a numerical archive of surface and upper-air weather observations that can be accessed remotely in raw or analyzed form. We believe that remote access to such an archive will prove of genuine value to all of California agriculture.

4. Data Processing of Navel Orangeworm Field Observations.

a. Interpretive Summary. A three-year data base of field observations of navel orangemworm pest populations has been estalbished for 1979, 1980, and 1981. The data base consists of 7,452 records. Each record contains three types of information:

- Constant information which identifies location, marks physical and biological time, and records available physical and biological information related to the orchard itself and to the grower's cultural practices.
- Raw counts obtained by professional field entomologists who used egg traps, light traps, and the dissection of both overwintering old-crop mummies and hull-split green nuts.
- Derived parameters which combine raw counts, convert raw counts to physical and biological rates, associate location with microclimatic regions, and both link and mark records appropriately for physical and biological time-series treatments and for statistical procedures.

The purpose of our data-processing activities has been to create displays and treatments suitable for identifying differences in the monitoring data which can be related to weather events and to microclimatic regions. The motivation for this approach is rooted in an interest expressed by almond growers in improving the information available to them upon which to base near-real-time pest-management decisions.

Examples of field forms and data-processing outputs are included in our report for grower reference.

The information in this data base indicates that the number of egg-trap observations from 1979 to 1980 has declined while the number of light-trap observations has remained nearly constant and the number of dissection observations has increased.

In a complex assemblage of orchard properties, statistically significant correlation among comparable egg-trap observations ranged from 0.20 to 0.47 while comparable light-trap observations correlated at a value of 0.78. Perhaps economically-motivated attention should be carefully addressed to the most efficient mix of these monitoring devices in programs which make use of both devices.

The most statistically reliable sources of information found in the old-crop stick-tite mummy data refers to the counts of red-eggs, hatched-eggs, and first-instar larvae. Also, it would appear that growers and advisors who successfully use such monitoring techniques are following a different reliability criterion than that which is commonly found in published research results. The percentage life-stages of the post-spray navel orangeworm population dynamics can be followed on a regional basis.

Data processing methods exist which can reduce the scatter among mean daily pest-count values on a regional scale.

The precision with which growers and their advisors time their use of spray materials as a part of a pest-management program can be displayed on a regional scale and can be used to place biological markers in large data bases.

The procedures used to create the 1981 addition to the data base were generally similar to those used to create the original 1979 and 1980 data base. The next section addresses the procedures.

b. <u>Procedure</u>. Raw field counts of navel orangeworm populations were obtained during 1981 using the general methods reported by Dr. Judith Freeman in Hauser (1980). In 1981, the raw counts were made by Dr. Cliff Kitayama and Dr. Barry Wilke, professional entomologists employed by Agircultural Advisors, Inc., Yuba City, CA.

Some minor differences in the 1981 field methods occurred which were accommodated by the research procedures. Counts of adults in light traps were unsexed, rather than sexed. Mummy and hull-split green nut dissection data did not distinguish very new pupae, P1, and other immature pupae, P2.

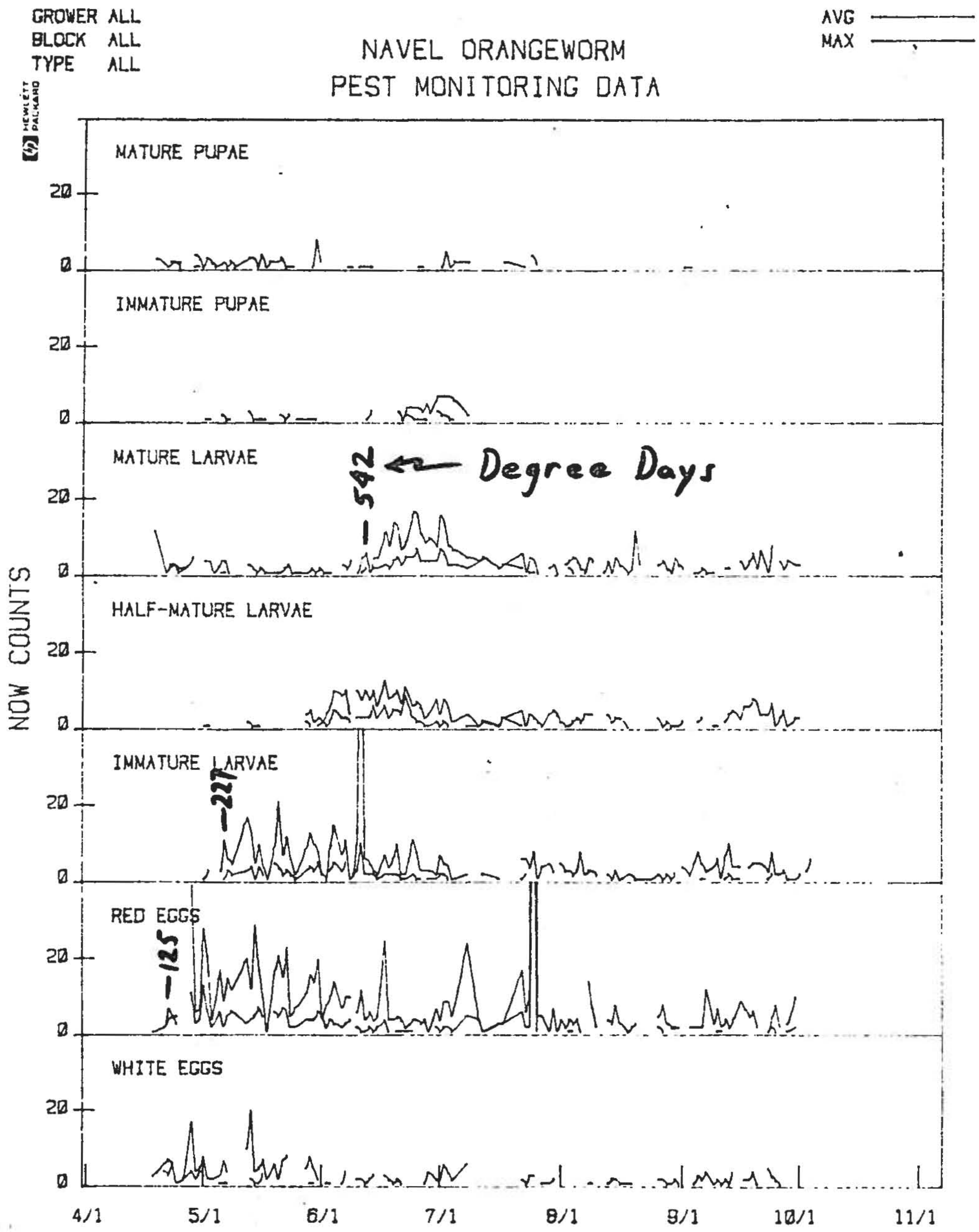
In order to assess the reliability of field data obtained from mummy and green-nut observations, the 1981 data-base at nine locations includes the count of NOW in all stages of development on the individual nuts which comprise the normal ten-nut sample. This addition to the field program was introduced as a result of earlier work with the 1979 and 1980 data sets. For practical reasons a further recommendation to move as far as possible toward a more uniformly spaced sampling interval in physical or biological time could not be completely accommodated.

Figure 4.1 is a copy of the field form used during 1981. Data entry was accomplished in the same fashion as earlier -- from a keyboard terminal into a Hewlett Packard Model 3000, Series III computer operated by the Department of Computer Science, California State University, Chico. Figures 4.2 through 4.4 are examples of output which were used for error checking and to ease the following of individual orchard behavior. These Figures are included here because some defined examples of proven data displays may be of help to growers or their advisors who are interested in automating their own data-management systems.

Figures 4.5 and 4.6 are also examples of output from programs on the HP 3000. These graphical displays were generated at the suggestion of growers and professional entomologists. The purpose of this approach to the data is to facilitate communication among growers and their advisors concerning different seasons and different locations. (Hopefully some aspects of the displays avoid the "some-pictures-take-a-thousand-words" syndrome). Where the Figures show two lines, the upper line is the maximum value and the lower one is the mean. When only one line is shown, the line is the maximum observed value.

For statistical treatment and for conversion to biological time scales (degree days), a computer tape of the entire data base was prepared with the format shown in Table 4.1. Copies of this tape are available to researchers elsewhere for reimbursement of actual cost. (Reimbursement of cost is a requirement of the State of California whose computing equipment is used to make the tape copy).

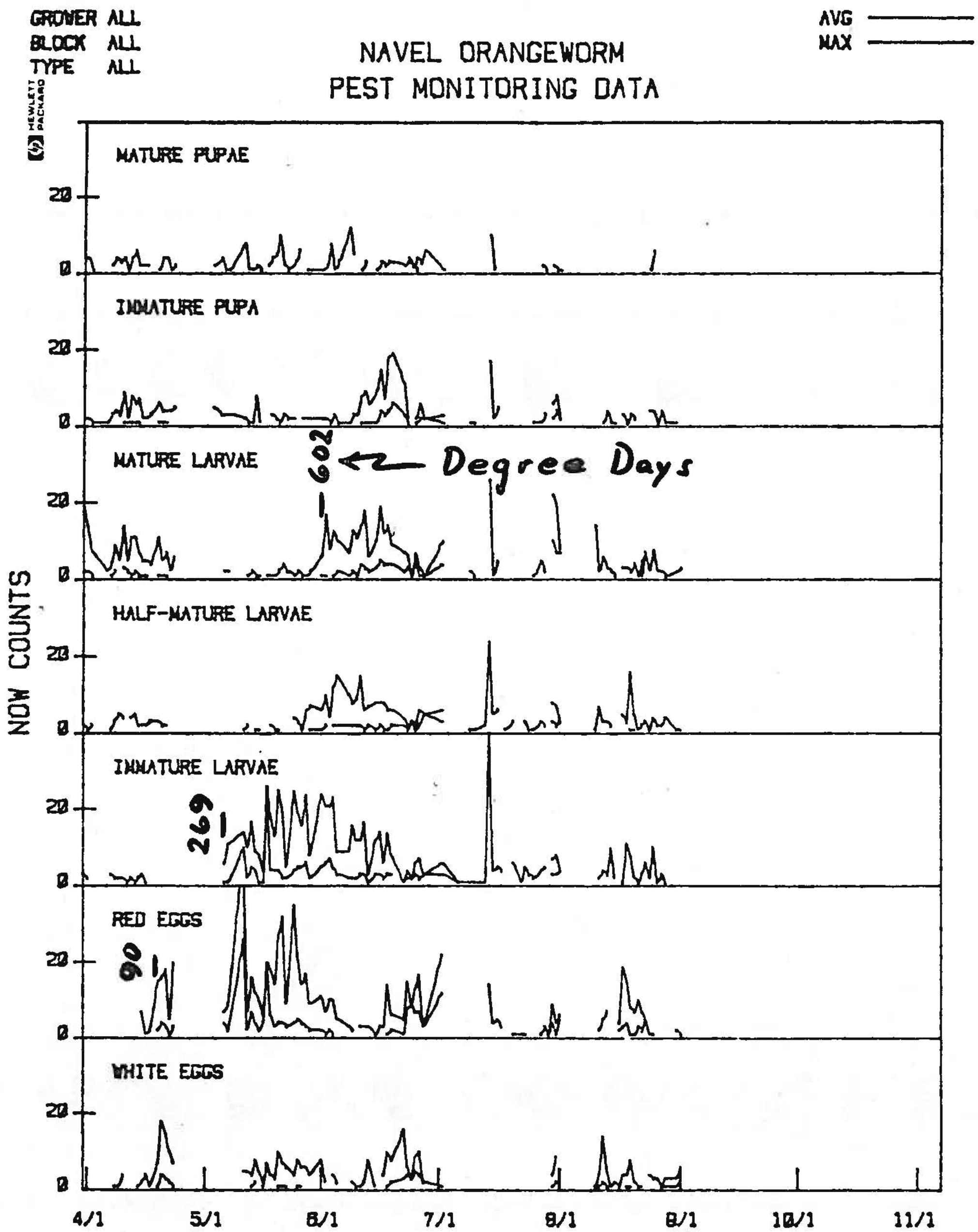
The records from the tape file were read into a CDC CYBER 170/720, where the raw data were manipulated to create physical and biological rates and files were prepared for statistical treatment using two common statistical packages: SPSS (Statistical Package for the Social Sciences) and BMCP (Bio-Medical Computer Programs). A list of the variable lable carried forward is shown on the next page. Because each of the nineteen campuses of the California State University has a similar CYBER computer and because SPSS and BMCP are common statistical packages, the navel orangeworm data base and processing programs created in this research project are transportable throughout California and can be placed within relatively easy access of public or private investigators at locations close to any major almond-growing region in the State.



1312 DATA RECORDS

1980 ALMOND SEASON Figure 4.5

NOWCASTING



1981 ALMOND SEASON Figure 4.6

Table 4.1

This document describes the Tape Record generated from the files "PEST1979" and "PEST1980" to be loaded onto the CSUC CYBER Computer located at CSU, Sacramento. This file will then be used by SPSS to generate a statistical analysis on the data contained therein.

RECORD LEGEND:

Each field in the record layout appears as follows:

```
 ------------------------------------------
| FIELD NUMBER (1-61)                      |
| FIELD NAME - LINE 1                      |
| FIELD NAME - LINE 2                      |
| FORTRAN/SPSS FORMAT SPEC OF FIELD        |
 ------------------------------------------
```

LEGAL AND NO-OBSERVATION VALUES OF FIELDS:

Fields 1, 2 and 3 are mandatory and will appear in all records. All DATES are in the form MM/DD/YY with leading zeros on single digit months and days. All F4.0 fields have legal observation values in the range 0-999 with a "No-Observation" value of -1. All A Format fields have "No-Observation" values of Blanks and the last field (61) (Not Shown) always contains 2 Blanks and has the Format A2.

EXCEPTIONS:

Fields 25, 28, 31 and 34 contain arbitrarily assigned ID numbers for the following "Light Trap" fields. These may have any legal value in the range 0-999 but appear to have been numbered sequentially starting from 1 (i.e. Field 25 would normally contain a 1, Field 28 a 2, etc.). Fields 37 and 49 contain the Category from which samples were taken to derive the counts found in Fields 38-48 and 50-60, respectively. The legal values for these Category Fields are 1-4.

Please note that the F4.0 fields may contain negative numbers other than -1 to indicate the condition of the particular trap associated with that field. It may be wise to ignore ALL negative numbers when computing statistics as they will erroneously bias the results.

PEST-RECORD
EACH RECORD CONTAINS 256 CHARACTERS OF INFORMATION BROKEN UP INTO 61 INDIVIDUAL FIELDS. THE RECORD APPEARS AS FOLLOWS:

FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5	FIELD 6
Grower	Block	Observ.	Spray	Spray	Spray
Number	Number	Date	Beg. Date	End Date	Type
F2.0	F2.0	A8	A8	A8	A10
FIELD 7	FIELD 8	FIELD 9	FIELD 10	FIELD 11	FIELD 12
EggTrapA	EggTrapA	EggTrapA	EggTrapB	EggTrapB	EggTrapB
WhiteEgg	RedEgg	HatchEgg	WhiteEgg	RedEgg	HatchEgg
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 13	FIELD 14	FIELD 15	FIELD 16	FIELD 17	FIELD 18
EggTrapC	EggTrapC	EggTrapC	EggTrapD	EggTrapD	EggTrapD
WhiteEgg	RedEgg	HatchEgg	WhiteEgg	RedEgg	HatchEgg
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 19	FIELD 20	FIELD 21	FIELD 22	FIELD 23	FIELD 24
EggTrapE	EggTrapE	EggTrapE	EggTrapF	EggTrapF	EggTrapF
WhiteEgg	RedEgg	HatchEgg	WhiteEgg	RedEgg	HatchEgg
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 25	FIELD 26	FIELD 27	FIELD 28	FIELD 29	FIELD 30
LightTrap	LightTrap	LightTrap	LightTrap	LightTrap	LightTrap
ID	MaleCnt	FemaleCnt	ID	MaleCnt	FemaleCnt
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 31	FIELD 32	FIELD 33	FIELD 34	FIELD 35	FIELD 36
LightTrap	LightTrap	LightTrap	LightTrap	LightTrap	LightTrap
ID	MaleCnt	FemaleCnt	ID	MaleCnt	FemaleCnt
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 37	FIELD 38	FIELD 39	FIELD 40	FIELD 41	FIELD 42
Mummy	MummyCnt	MummyCnt	MummyCnt	MummyCnt	MummyCnt
Category	W	R	H	L1	L3
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 43	FIELD 44	FIELD 45	FIELD 46	FIELD 47	FIELD 48
MummyCnt	MummyCnt	MummyCnt	MummyCnt	MummyCnt	MummyCnt
L5	P1	P2	P3	E	PA
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 49	FIELD 50	FIELD 51	FIELD 52	FIELD 53	FIELD 54
Mummy	MummyCnt	MummyCnt	MummyCnt	MummyCnt	MummyCnt
Category	W	R	H	L1	L3
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0
FIELD 55	FIELD 56	FIELD 57	FIELD 58	FIELD 59	FIELD 60
MummyCnt	MummyCnt	MummyCnt	MummyCnt	MummyCnt	MummyCnt
L5	P1	P2	P3	E	PA
F4.0	F4.0	F4.0	F4.0	F4.0	F4.0

Figure 4.1

1981 N.O.W. PROJECT

Date 5-26-81

Grower Block Code: 7-4

ATTRACTANTS	Moth Light Trap #1		Moth Light Trap #2		Egg Trap #1			Egg Trap #2			Egg Trap #3			Egg Trap #4		
	N.O.W.	P.T.B.	N.O.W.	P.T.B.	White Eggs	Red Eggs	Hatched Eggs	White Eggs	Red Eggs	Hatched Eggs	White Eggs	Red Eggs	Hatched Eggs	White Eggs	Red Eggs	Hatched Eggs
	0	0			3	27	4									

PHEROMONE TRAPS (Moths)	PTB #1	PTB #2	PTB #3	OFM #1	OFM #2	OFM #3	CM #1	CM #2	CM #3

MUMMY (OR GREEN NUT) COUNTS

	No N.O.W.	White Eggs	Red Eggs	Hatched Eggs	Small Larvae	Medium Larvae	Large Larvae	Young Pupae	Old Pupae	Empty Pupal Cases	Total	COMMENTS
1		2	2	1						1		
2		1	2	9	4					1		
3				5								
4				2	2							
5			2	8	5					1		
6			1	2								
7				3	1							
8			1	6	6					1		
9			1	12	1							
10		1		2								
Total	10	4	9	50	19	0	0	0	0	4		

NOW = Navel Orange Worm; PTB = Peach Twig Borer; OFM = Oriental Fruit Moth; CM = Codling Moth

Figure 4.2

FILE: PEST1980 PAGE **31

MUMMY COUNT, CATEGORY: ~~TREE~~ GROUND — W R H L1 L3 L5 P1 P2 P3 E PA

MUMMY COUNT, CATEGORY: ~~GROUND~~ TREE — W R H L1 L3 L5 P1 P2 P3 E PA

MUMMY COUNT, CATEGORY: GREEN NUT — W R H L1 L3 L5 P1 P2 P3 E PA

GRO	BLK	DATE	SPBG	SPED	SPTP	TREE W	R	H	L1	L3	L5	P1	P2	P3	E	PA
6	5	0627														
15	2	0627														
15	3	0627														
2	2	0629				0	1	20	2	2	4	3	0	0	4	0
2	3	0629				0	4	24	1	0	1	5	0	0	0	0
5	22	0629	0629	0629	ZOOLONE											
8	1	0629														
8	5	0629				0	2	10	2	4	5	0	0	0	0	2
14	1	0629				0	1	6	1	2	2	3	1	0	0	0
14	3	0629				2	7	57	2	8	6	3	7	0	2	0
14	4	0629				2	1	29	0	0	2	7	1	0	2	0
14	5	0629				0	2	45	1	2	8	4	0	0	0	0
14	6	0629														
1	1	0630				2	2	69	6	2	14	7	11	1	8	0
1	3	0630				0	4	32	1	0	1	0	1	0	19	1
1	5	0630				0	0	6	0	0	2	2	0	0	6	2
1	8	0630														
1	9	0630														
1	10	0630														
3	4	0630														
3	6	0630				0	1	49	3	3	14	4	4	0	0	0
3	7	0630				1	1	52	0	1	7	1	0	0	0	0
5	16	0630														
5	21	0630														
7	3	0630														
7	4	0630				0	2	83	7	1	16	5	2	0	1	3
7	5	0630				0	0	63	1	3	3	2	5	0	2	0
7	6	0630														
13	3	0630														
16	1	0630														
16	2	0630				0	0	17	0	4	9	0	0	0	6	1
20	1	0630				0	0	9	2	0	3	0	0	0	8	4
2	1	0701				2	4	63	0	0	5	5	4	0	1	0
2	4	0701				1	2	61	2	3	3	4	1	0	2	0
3	5	0701														
3	8	0701				6	2	44	4	8	12	5	5	4	7	0
5	1	0701				1	2	60	0	2	3	1	4	1	11	0
5	2	0701														
5	3	0701														
5	4	0701				1	1	82	1	0	5	0	0	0	10	1
5	5	0701				2	1	49	2	4	4	3	0	0	7	0
5	6	0701				0	1	20	3	1	3	4	3	1	6	0
5	7	0701				4	3	88	2	1	8	0	2	0	4	0
5	8	0701				2	3	53	0	1	5	1	3	2	6	3
5	12	0701														
5	13	0701				0	1	15	4	1	6	0	1	0	12	0
5	14	0701				2	7	108	1	2	14	0	1	0	8	3
5	15	0701														
5	16	0701				0	0	35	2	0	5	0	0	0	7	3

Figure 4.3

MUMMY DATA BY CATAGORY

CATAGORY: TREE

GRO	BLK	DATE	W	R	H	L1	L3	L5	P1	P2	P3	M
3	13	05/12	--	1	9	3	--	--	--	1	--	--
3	13	05/20	--	3	20	3	--	--	--	--	--	--
3	13	05/27	--	2	14	3	4	--	--	--	--	2
3	13	06/09	1	4	30	3	8	--	--	--	--	4
3	13	06/13	1	--	20	3	2	2	--	--	--	5
3	13	06/17	--	1	49	1	4	--	1	--	--	--
3	13	07/23	--	--	--	--	--	--	--	--	--	--
3	13	07/29										
3	13	08/13										
3	13	08/29										
3	13	09/02										
3	13	09/11										

CATAGORY: GREEN NUT

GRO	BLK	DATE	W	R	H	L1	L3	L5	P1	P2	P3	M
3	13	05/12										
3	13	05/20										
3	13	05/27										
3	13	06/09										
3	13	06/13										
3	13	06/17										
3	13	07/23										
3	13	07/29	--	--	--	--	--	--	--	--	--	--
3	13	08/13	--	--	--	--	--	--	--	--	--	--
3	13	08/29	--	--	--	--	--	--	--	--	--	--
3	13	09/02	--	--	--	--	--	--	--	--	--	--
3	13	09/11	--	--	--	1	--	--	--	--	--	--

CATAGORY: GROUND

W	R	H	L1	L3	L5	P1	P2	P3	M

Figure 4.4

```
                                                                                                  FILE: PEST1981  PA
GROWER BLOCK   OBSERV.     SPRAY     SPRAY      SPRAY        EGGTRAP A  EGGTRAP B  EGGTRAP C  EGGTRAP D  EGGTRAP E  EGGTR
NUMBER NUMBER   DATE       BEGIN      END       TYPE          W  R  H    W  R  H    W  R  H    W  R  H    W  R  H    W  R
  13      3    06/10/81

       LT **1  LT ***  LT ***  LT ***       MUMMY COUNT, CATEGORY: TREE         MUMMY COUNT, CATEGORY:
        M  F    M  F    M  F    M  F        W  R  H L1 L3 L5 P1 P2 P3  E PA     W  R  H L1 L3 L5 P1 P1 P3  E PA
        2  0                                0  0 67  8  4  0  0  0  0  3  0

------------------------------------------------------------------------------------------------------------------------
GROWER BLOCK   OBSERV.     SPRAY     SPRAY      SPRAY        EGGTRAP A  EGGTRAP B  EGGTRAP C  EGGTRAP D  EGGTRAP E  EGGTR
NUMBER NUMBER   DATE       BEGIN      END       TYPE          W  R  H    W  R  H    W  R  H    W  R  H    W  R  H    W  R
  13      3    06/16/81

       LT **1  LT ***  LT ***  LT ***       MUMMY COUNT, CATEGORY: TREE         MUMMY COUNT, CATEGORY:
        M  F    M  F    M  F    M  F        W  R  H L1 L3 L5 P1 P2 P3  E PA     W  R  H L1 L3 L5 P1 P1 P3  E PA
        0  0                                0  0  0  2  1  8  5  0  1  0  0

------------------------------------------------------------------------------------------------------------------------
GROWER BLOCK   OBSERV.     SPRAY     SPRAY      SPRAY        EGGTRAP A  EGGTRAP B  EGGTRAP C  EGGTRAP D  EGGTRAP E  EGGTR
NUMBER NUMBER   DATE       BEGIN      END       TYPE          W  R  H    W  R  H    W  R  H    W  R  H    W  R  H    W  R
  13     90    04/01/81

       LT ***  LT ***  LT ***  LT ***       MUMMY COUNT, CATEGORY: TREE         MUMMY COUNT, CATEGORY:
        M  F    M  F    M  F    M  F        W  R  H L1 L3 L5 P1 P2 P3  E PA     W  R  H L1 L3 L5 P1 P1 P3  E PA
                                            0  0  0  0  0  0  0  0  0  0  0

------------------------------------------------------------------------------------------------------------------------
GROWER BLOCK   OBSERV.     SPRAY     SPRAY      SPRAY        EGGTRAP A  EGGTRAP B  EGGTRAP C  EGGTRAP D  EGGTRAP E  EGGTR
NUMBER NUMBER   DATE       BEGIN      END       TYPE          W  R  H    W  R  H    W  R  H    W  R  H    W  R  H    W  R
  13     90    04/10/81

       LT ***  LT ***  LT ***  LT ***       MUMMY COUNT, CATEGORY: TREE         MUMMY COUNT, CATEGORY:
        M  F    M  F    M  F    M  F        W  R  H L1 L3 L5 P1 P2 P3  E PA     W  R  H L1 L3 L5 P1 P1 P3  E PA
                                            0  0  0  0  0  0  0  0  0  0  0

------------------------------------------------------------------------------------------------------------------------
GROWER BLOCK   OBSERV.     SPRAY     SPRAY      SPRAY        EGGTRAP A  EGGTRAP B  EGGTRAP C  EGGTRAP D  EGGTRAP E  EGGTR
NUMBER NUMBER   DATE       BEGIN      END       TYPE          W  R  H    W  R  H    W  R  H    W  R  H    W  R  H    W  R
  13     90    04/14/81

       LT ***  LT ***  LT ***  LT ***       MUMMY COUNT, CATEGORY: TREE         MUMMY COUNT, CATEGORY:
        M  F    M  F    M  F    M  F        W  R  H L1 L3 L5 P1 P2 P3  E PA     W  R  H L1 L3 L5 P1 P1 P3  E PA
                                            0  0  0  0  0  0  0  0  0  0  0

------------------------------------------------------------------------------------------------------------------------
GROWER BLOCK   OBSERV.     SPRAY     SPRAY      SPRAY        EGGTRAP A  EGGTRAP B  EGGTRAP C  EGGTRAP D  EGGTRAP E  EGGTR
NUMBER NUMBER   DATE       BEGIN      END       TYPE          W  R  H    W  R  H    W  R  H    W  R  H    W  R  H    W  R
  13     90    04/20/81

       LT ***  LT ***  LT ***  LT ***       MUMMY COUNT, CATEGORY: TREE         MUMMY COUNT, CATEGORY:
        M  F    M  F    M  F    M  F        W  R  H L1 L3 L5 P1 P2 P3  E PA     W  R  H L1 L3 L5 P1 P1 P3  E PA
                                            0  0  0  0  0  0  0  0  0  0  0

------------------------------------------------------------------------------------------------------------------------
```

List of Variable Labels on Statistical Treatment Files

GROWER	BLOCK	OBMON
OBDAY	OBYEAR	SPBMON
SPBDAY	SPBYEAR	SPEMON
SPEDAY	SPEYEAR	SPTYPE1
SPTYPE2	DDLS	DDETA
DDETB	DDETC	DDETD
DDLT1	DDLT2	DDLT3
ETAW	ETAR	ETAH
ETBW	ETBR	ETBH
ETCW	ETCR	ETCH
ETDW	ETDR	ETDH
ETEW	ETER	ETEH
ETFW	ETFR	ETFH
LT1ID	LT1M	LT1F
LT2ID	LT2M	LT2F
LT3ID	LT3M	LT3F
LT4ID	LT4M	LT4F
MUMCAT1	WEGS1	REGS1
HEGS1	LAR11	LAR31
LAR51	PUP11	PUP21
PUP31	EMPC1	PARW1
MUMCAT2	WEGS2	REGS2
HEGS2	LAR12	LAR32
LAR52	PUP12	PUP22
PUP32	EMPC2	PARW2
DLS	DLEA	DLEB
DLEC	DLED	DLT1
DLT2	DLT3	DLT4
DLM1	DLM2	DLM3
DDDUR	DDNOR	DDLT4
DDLM1	DDLM2	DDLM3
GROBLK	SITE	LOCTTM
SIMETOBS	SIMLTOBS	SIMMMOBS
PAR	SAN	MAYSPY
AGE	NEWLOC	ONENUT
JULCON	TIME	SPETIME
SPETIME	SUMEGS1	SUMPUP1
SUMPUP2	SUMETA	SUMETB
SUMETC	SUMETD	SUMLT1
SUMLT2	SUMEGS2	SUMLT3
MUMTOT1	WEGPT1	REGPT1
LAR1PT1	LAR3PT1	LAR5PT1
PUP1PT1	PUP2PT1	PUP3TT1

The statistical properties of the data base are germane to the work reported in this section and are the tope of the next subsection.

c. The Navel Orangeworm Data Base. The number of records that contain one or more raw pest-monitoring observations is shown in Table 4.2. Table 4.2 also includes some basic time and location information.

Table 4.2

Major Navel Orangeworm Data Sets

Year		Number of Records	Number of Growers	Number of Blocks
1979		2411	10	51
1980		2810	20	106
1981		1809	40	151
	Total	7030	10-40	51-151

The remaining 422 records contain only information relating spray applications during 1980. Spray data for 1981 are not yet available. While not a part of the machine-compatible records, some yield and damage information is available for 1980 and will later become available for 1981.

Each record contains one or more raw counts as they were reported by field entomologists engaged in pest-control advisory activities, rather than in research. Thus the records contain egg-trap, light-trap, old-crop mummy, and hull-split green nut observations which occur in different combinations that vary according to the requirements of the commercial interests of the growers and their advisors. Table 4.3 shows both the number of records containing raw counts, according to the type of monitoring device or method, and the total number of observations these records contain.

The small number of dissection observations of hull-split greent nuts in 1981 is misleading. The 1981 data base extends only through mid-August while the 1979 records include observations through early November and mid-October respectively.

Table 4.3

Type of Navel Orangeworm Monitoring Data

	Egg-Traps		Light-Traps		Dissection Observations		
					Old-Crop Mummies		Hull-Split
Year	Records	Observa-tions	Records	Observa-tions	Stick-tite	Ground	Green-nut
1979	2,079	4,208	1,569	1,682	589	68	542
1980	1,512	2,576	1,490	1,552	607	1	702
1981	975	1,300	1,374	1,402	1,396	25	147
	4,566	8,084	4,433	4,636	2.592	94	1,391

In the 1979 data, the locations which were monitored were assigned to one of three microclimatic regions based on weather data from: two nearby long-term climatological stations; special weather observations made by growers and entered into the NOWCASTING weather system; and the collective advice both of technically alert growers and of the agricultural meteorologist with the longest experience in the local area. In the 1980 and 1981 data, blocks which did not fit these regional assignments were designated "other", as were a few new blocks from regions 1-3 which could not produce interannual comparisons as earlier data were not available. Table 4.4 shows both the number of records and the total number of observations for each microclimatic region.

Table 4.4

Regional Breakdown of Navel Orangeworm Data

Year	Region	Egg-Trap Records	Egg-Trap Obser.	Light-Trap Records	Light-Trap Obser.	Dissection Observations Old-Crop Mummies Stick-tite	Old-Crop Mummies Ground	Hull-split Green-Nut
1979	1	502	686	249	249	130	20	131
	2	110	171	142	144	12	-	16
	3	1,466	3,350	1,178	1,289	447	48	395
	Other	1	1	-	-	-	-	-
1980	1	224	361	173	173	72	-	79
	2	80	148	69	69	16	-	9
	3	965	1,607	982	1,031	425	1	479
	Other	243	460	266	279	94	-	135
1981	1	74	96	128	128	152	1	7
	2	11	21	42	43	30	-	1
	3	388	518	572	594	608	6	57
	Other	502	665	632	637	606	18	82
	TOTAL	4,566	8,084	4,433	4,636	2,592	94	1,391

Because of the operational, rather than research, nature of the monitoring activity which produced the data base we are analyzing, opportunities to rigorously assess the variability of individual raw counts are somewhat limited. Neverthless, we have begun to examine some of the opportunities which do exist in the data. For larger blocks, some simultaneous egg-trap and light-trap observations were made. And in 1981, the data base includes a sample of the single-nut dissection observations which, when summed over 10 nuts were the source of the data normally recorded in the dissection categories. Table 4.5 shows the sample size available for variability analyses.

Table 4.5

Navel Orangeworm Data for Variability Analyses

Year	Simultaneous Egg-Trap Counts Records	Simultaneous Egg-Trap Counts Observations	Simultaneous Light-Trap Counts Records	Simultaneous Light-Trap Counts Observations	Single-Nut Diss. Obser. Old-Crop Stick-tite Mummies	Single-Nut Diss. Obser. Hull-Split Green-Nut
1979	1,478	3,607	129	258	-	-
1980	851	1,835	62	124	-	-
1981	280	605	28	56	963	104
	2,609	6,047	219	438		

d. Variability. Most of the orchards in which these pest-population data were gathered are neither large acreages, uniform in variety and age, nor isolated from sources of infestation. Many of them are not cleaned in the winter to an average of 2 mummies per tree (Engle and Barnes, 1981 -- in Barnes, et al, 1981). There are many instances of advertent and inadvertent replacement of trees. Near some orchards the signs of urban encroachment and the accompanying decline in management practices are evident. Perhaps such characteristics add interest in, as well as difficulty, to studies of variability in these data.

Since we are interested in using variations in these records to distinguish regions and times, we must direct some attention to the variations inherent in the observations themselves. We will briefly discuss, in turn, simultaneous egg-trap counts, simultaneous light-trap counts, and single-nut dissections.

Tables 4.6 through 4.8 show the Pearson product-moment correlation coefficients and their significance for three subsets of the simultaneous egg-trap counts shown in Table 4.5. The first subset consists of 228 cases over three years for which the block contained four egg traps and the physical time interval between successive egg-trap observations was unperturbed by trap problems such as dislocation or desication, for example.

Table 4.6

Correlations Among Four Egg Traps in Same Block

	A		B		C		D	
Egg Trap	r	sign	r	sign	r	sign	r	sign
White Eggs per Night								
A	-	-	.47	.00001	.35	.00001	.18	.00283
B	-	-	-	-	.41	.00001	.28	.00001
C					-	-	.33	.00001
D							-	-
Red Eggs per Night								
A			.20	.00001	.41	.00001	.35	.00001
B	-	-	-	-	.22	.00071	.39	.00001
C					-	-	.39	.00001
D							-	-
Hatched Eggs per Night								
A	-	-	.40	.00001	.26	.00004	.20	.00110
B			-	-	.23	.00018	.10	.06050
C					-	-	.33	.00001
D							-	-

The second subset is shown in Table 4.7 and refers to 353 cases in which three good egg trap observations were made per block.

Table 4.7

Correlations Among Three-Egg Traps in Same Block

	A		B		C	
Egg Trap	r	sign	r	sign	r	sign
White Eggs per Night						
A	-	-	.21	.00004	.07	.08852
B			-	-	.25	.00001
C					-	-
Red Eggs per Night						
A	-	-	.25	.00001	.32	.00001
B			-	-	.23	.00001
C					-	-
Hatched Eggs per Night						
A	-	-	.34	.00001	.20	.00011
B			-	-	.11	.1722
C					-	-

Finally, Table 4.8 presents similar information for the (mainly) smaller blocks which yielded 1700 cases of two good egg-trap observations.

Table 4.8

Correlations Among Two Egg Traps in Same Block

	r.	sign
White Eggs per Night	.26	.0290
Red Eggs per Night	.31	.00001
Hatched Eggs per Night	.45	.00001

The relatively low correlation values reported here may reflect genuine variability of biological conditions across the blocks which, to be followed more accurately with egg traps, would require a significant increase in their density and the expense of their maintenance and observation. To the extent that complex plantings are important to California's almond industry, this is a topic which may reward further investigation.

In the case of simultaneous light-trap observations, Table 4.9 displays the correlations for unsexed adults for 178 cases. Again, cases of equipment problems have been removed and all observation intervals are identical.

Table 4.9

Correlations Among Two Light Traps in Same Block

r	sign
.78	.00001

The relatively high values of the correlation coefficient for light traps compared to the egg-trap values indicates that maintenance of the light traps apparently was sufficient to counteract many of the known problems associated with this device related to battery life and lamp non-uniformity, for example.

Finally, an analysis of variance was performed using the raw count of eight life-cycle stages determined by examining and dissecting 940 old-crop stick-tite mummies which, when appropriately summed to create 94 ten-nut observations, would normally have been entered into the data base. The results of the anova are shown in Table 4.10. It is intended that the "reliability" be interpreted as the average self-correlation coefficient, r_{xx}, and the upper limit to the correlation with another variable, r_{xy}, (or validity).

Table 4.10

Results of Anova Using Single-Nut Members of Ten-Nut Samples

Life-Stage	Mean Square	Error Term	Reliability Single-Nut	Reliability 10-Nut Sample
White Eggs, WE	0.27234	0.17803	0.050309	0.3463
Red Eggs, RE	2.8271	0.69873	0.233485	0.7528
Hatched Eggs, HE	52.015	5.4427	0.461144	0.8954
Immature Larvae, L1	3.4054	0.88821	0.220820	0.7392
Half-Mature Larvae, L3	0.33778	0.18478	0.076469	0.4530
Mature Larvae, L5	0.86672	0.40660	0.101659	0.5309
Immature Pupae, P1 & P2	0.45376	0.18411	0.127751	0.5943
Mature Pupae, P3	0.02983	0.024469	0.021451	0.1798

For the red-eggs stage, sample calculations are given to inform the reader of the origins of the reliability figures:

$$\text{Reliability of Single-Nut} = \frac{2.8271 - 0.69873}{2.8271 + (9)\ (0.69873)} = 0.233485$$

$$\text{Reliability of 10-Nut Sample} = \frac{(10)\ (0.233485)}{1 + (9)\ (0.233485)} = 0.7528$$

An estimate of the multiplicative factor required to use single-nut samples to achieve relaibilities of 0.5, 0.94, and 0.98 were computed. The results are presented in Table 4.11.

Table 4.11

Sample Size Factors, F_R, to Achieve Reliability R

Life-Stage	$F_{0.5}$	$F_{0.94}$	$F_{0.98}$
White Eggs, WE	19	296	926
Red Eggs, RE	4	52	161
Hatched Eggs, HE	2	19	58
Immature Larvae, L1	4	56	173
Half-Mature Larvae, L3	13	190	592
Mature Larvae, L5	9	139	433
Immature Pupae, P1 & P2	7	107	335
Mature Pupae, P3	46	715	2,235

A sample calculation is shown for red eggs:

$$F_{0.5} = \frac{0.5\ (0.233485 - 1)}{0.233485\ (0.5 - 1)} = 3.3$$

which is rounded upward to 4 nuts.

We turn now to a sampling of figures which both illustrate some of the comments made above and address temporal patterns in the data. Figures 4.7 and 4.8 are sample scattergrams prepared for egg-trap and light-trap observation rates respectively. These Figures also illustrate some of the simpler data selection techniques. Figure 4.8 shows the 1980 data for Region 3 while Figure 4.7 uses all simultaneous observations. The data plotted consist of the count of red eggs (Figure 4.7) and of adults (Figure 4.8) divided by the number of days since the last time the trap was observed.

SCATTERGRAM OF (DOWN) ETAR
(ACROSS) ETDR

Figure 4.7

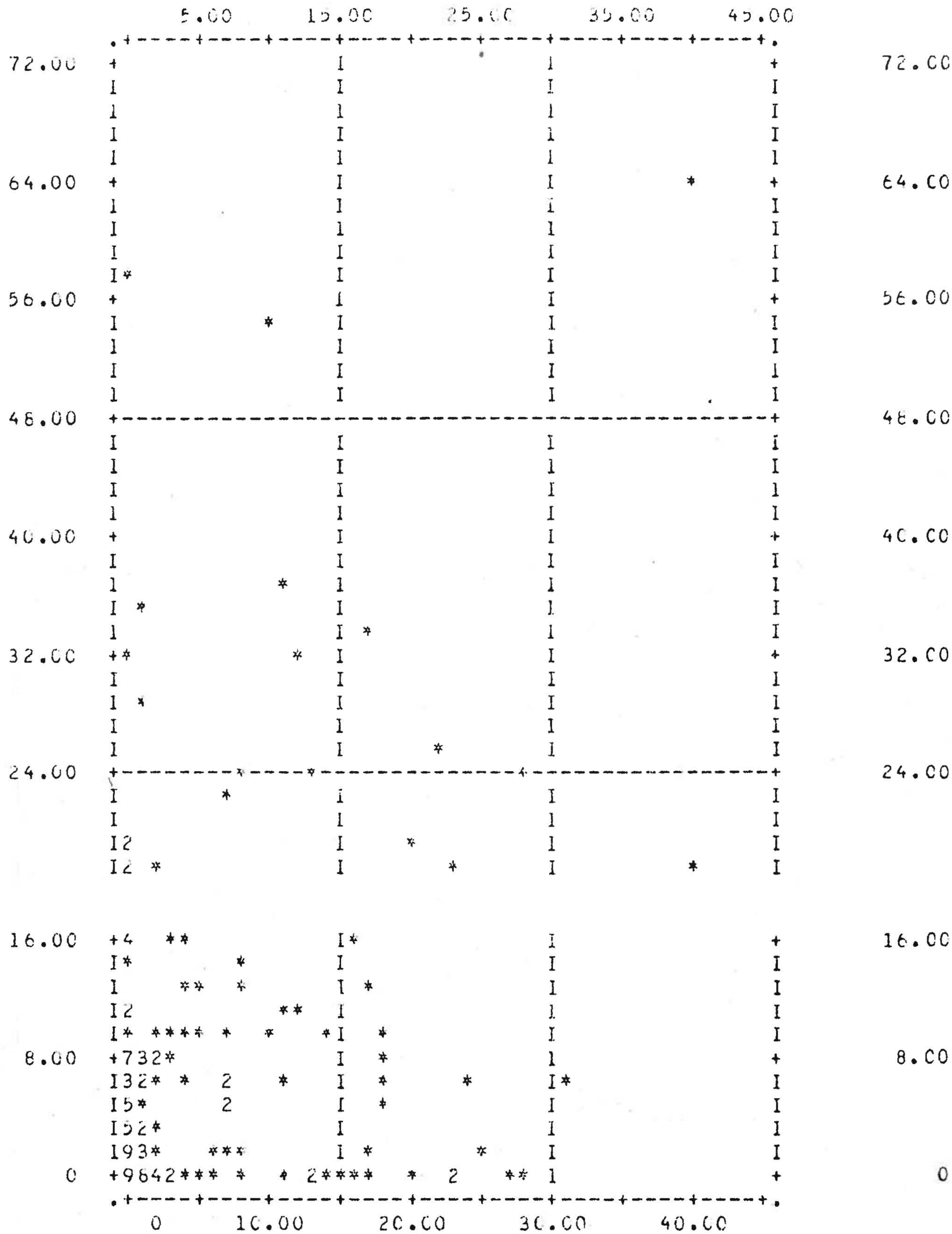
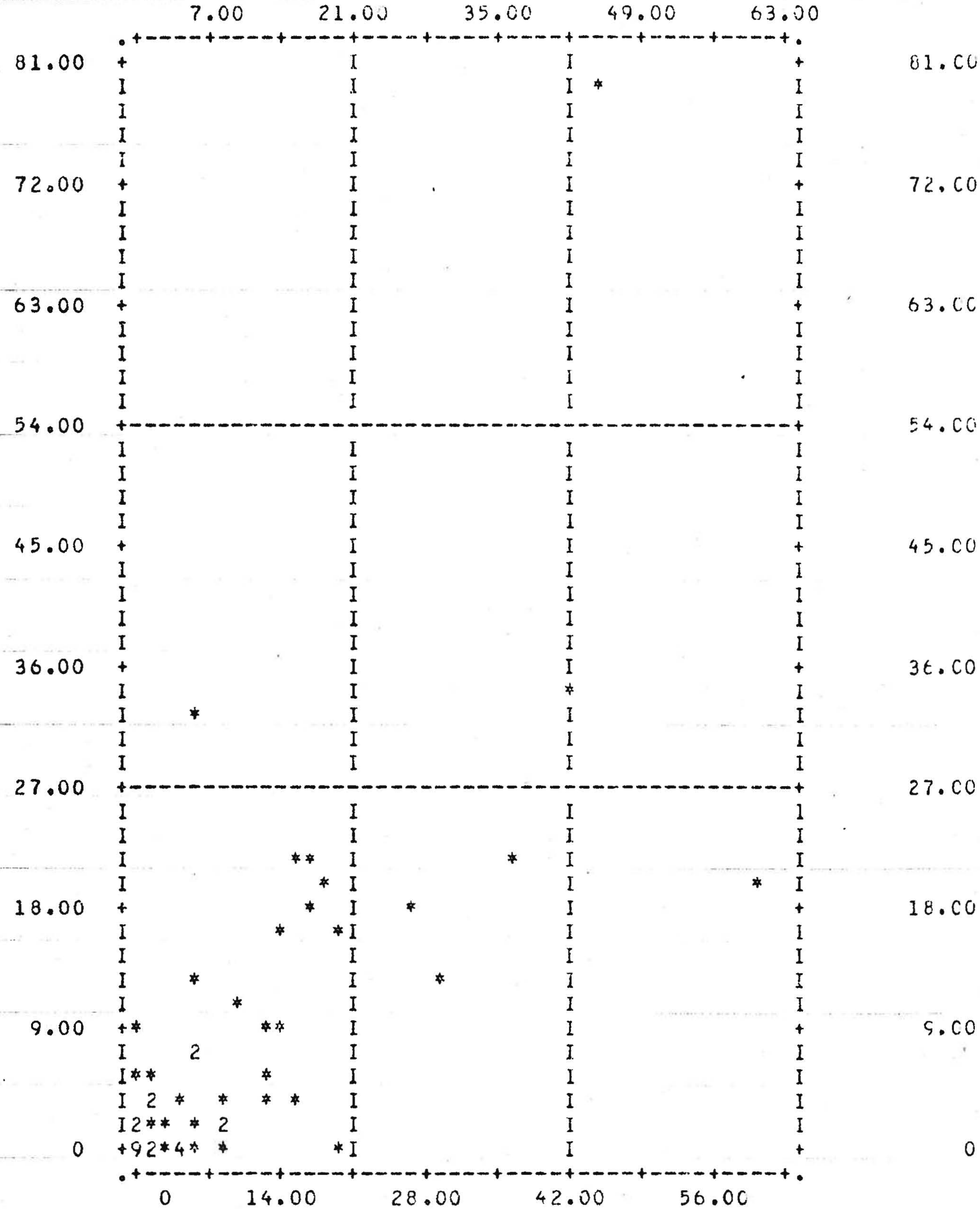


Figure 4.8

SCATTERGRAM OF (DOWN) SUMLT1 SUM OF MALES AND FEMALES IN LIGHT TRAP I
(ACROSS) SUMLT2 SUM OF MALES AND FEMALES IN LIGHT TRAP 2



e. Temporal Patterns. The remaining Figures illustrate methods of displaying pest monitoring observations for possible use by growers or their advisors who may be interested in grouping information according to microclimatic regions. Some of the methods used can be easily adapted to produce similar displays using popular microcomputer equipment.

Nearly all the orchards received spray treatments; they consist of non-uniform varieties, planting patterns, and ages; and they are in a variety of conditions. Each of these topics is a source of variability in the data.

Of course, the time of peak pest activity differs from orchard to orchard. To prepare these Figures, the expertise of the grower and his or her advisors was used to provide a biological marker which can bring a first study-set of the otherwise scattered field data to a common reference frame. It was assumed that the May spray was properly timed with regard to pest activity. Only observations after the May Spray were used to prepare the Figures (N = 199), and both the physical time interval (number of days) and the biological time interval (number of degree days) were determined from the date of last spray as the origin for creating the denominator of the rate calculation. Each plotted value is the mean of three or more observations made at a common number of degree days elapsed from the date of last spray. In each of the blocks used to prepare these Figures, old-crop stick-tite mummies were present. The temperature records used in these calculations were from the standard weather shelter at the University Farm, California State University University, Chico, which is near the blocks grouped microclimatically as Region 3.

Figures 4.9 - 4.14 refer to mean egg-trap counts or count rates: 4.9 -- white eggs; 4.10 -- red eggs; 4.11 -- hatched eggs; 4.12 -- the sum of red and white eggs; 4.13 -- the physical rate at which eggs were deposited on the traps; and 4.14 -- the biological rate at which eggs were deposited on the traps.

If one views these Figures successively, the utility of conversion to rate information would seem apparent. Some shape also seems apparent in the much more variable raw counts of eggs (Figures 4.9, 4.10, and 4.12); however, the raw count of hatched eggs (Figure 4,11) is an exception to this statement. The lines drawn in these Figures were drawn by eye. Even so, the Figures would appear to contain information pertinent to the effectiveness of spray programs, and to the definition of the decline of the first flight and the beginning of the second flight. Similarly, there would appear to be some possibly different rates visible in the right hand portions (400 to 600 degree days since last spray) of Figures 4.12 through 4.14. We seek to discuss these matters with University, government, and private entomologists prior to continuing our analysis of these data.

Figure 4.15 through 4.17 show similar treatment of light-trap observations. In this case, the efficacy of using biological rate transformations is clearly shown. The perhaps poorly supported maxima drawn in Figures 4.15 and 4.16 do not survive well into Figure 4.17 The biological rate data in Figure 4.17 are more scattered than those in Figure 4.14 for egg traps. In preliminary discussions with entomologists, the possible grouping of quantitative rate data

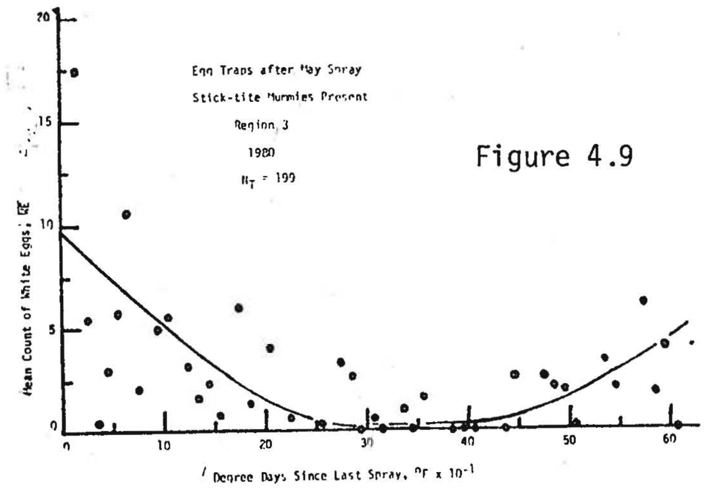


Figure 4.9

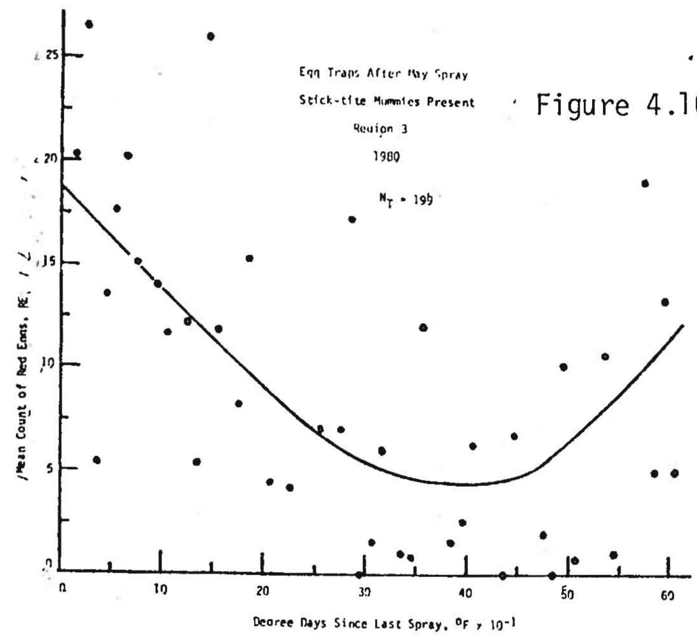


Figure 4.10

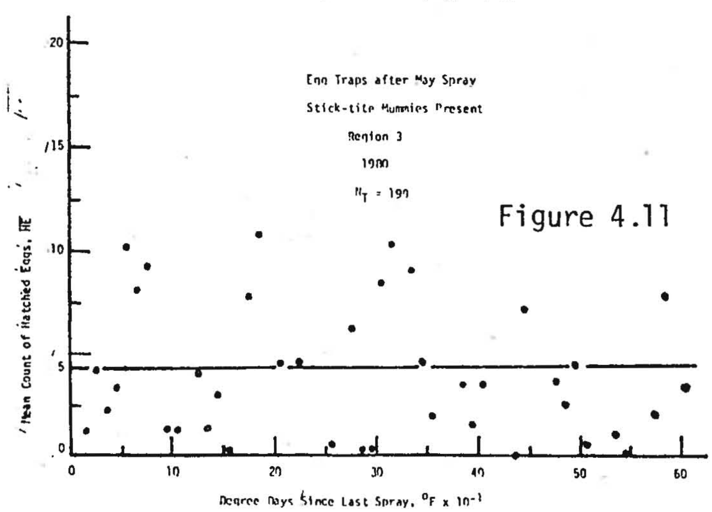


Figure 4.11

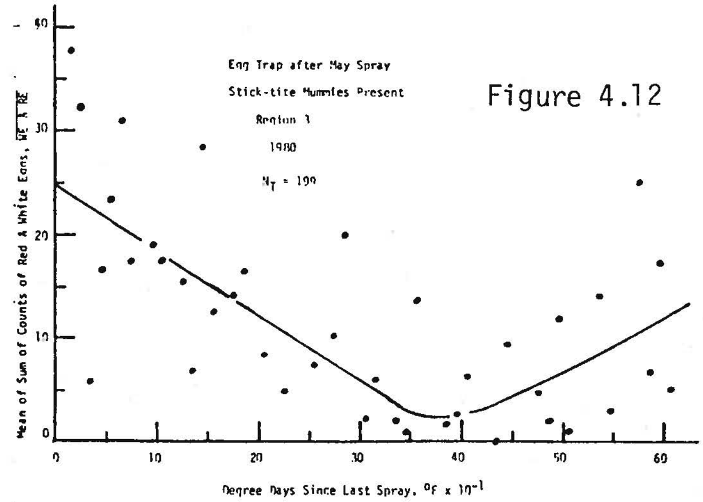


Figure 4.12

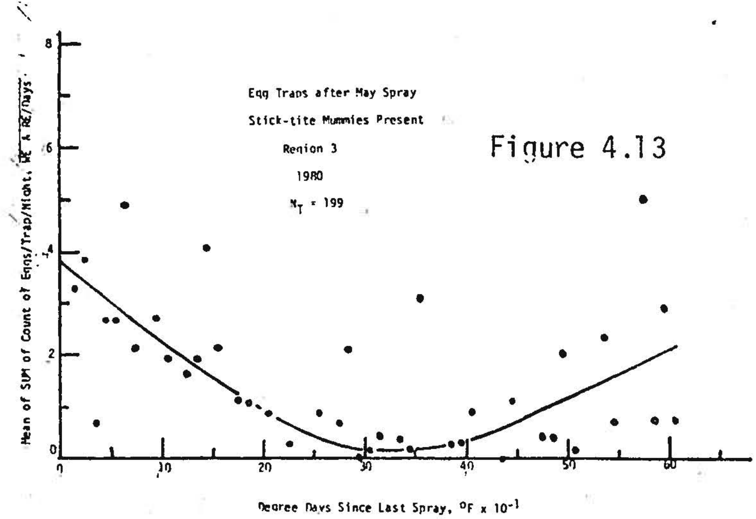


Figure 4.13

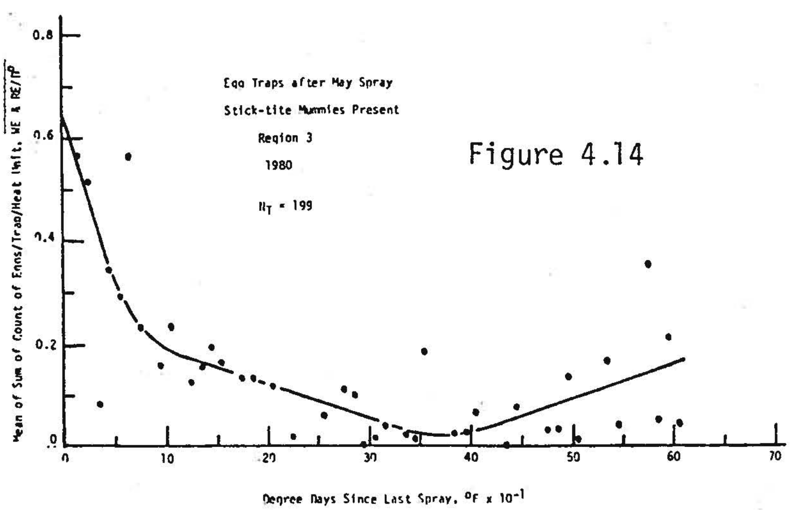


Figure 4.14

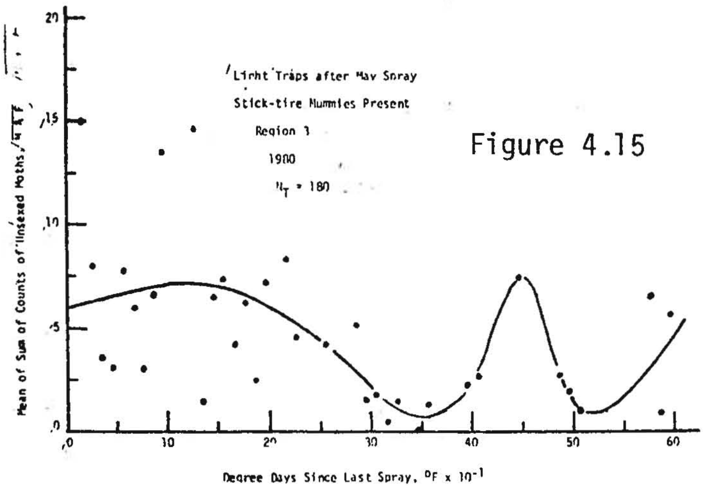


Figure 4.15

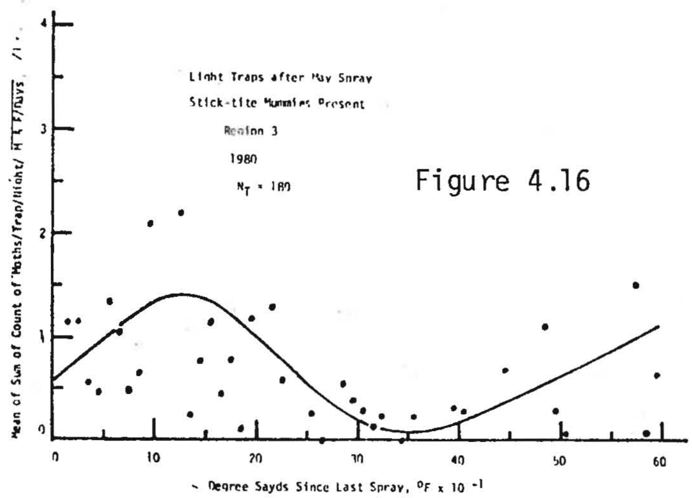


Figure 4.16

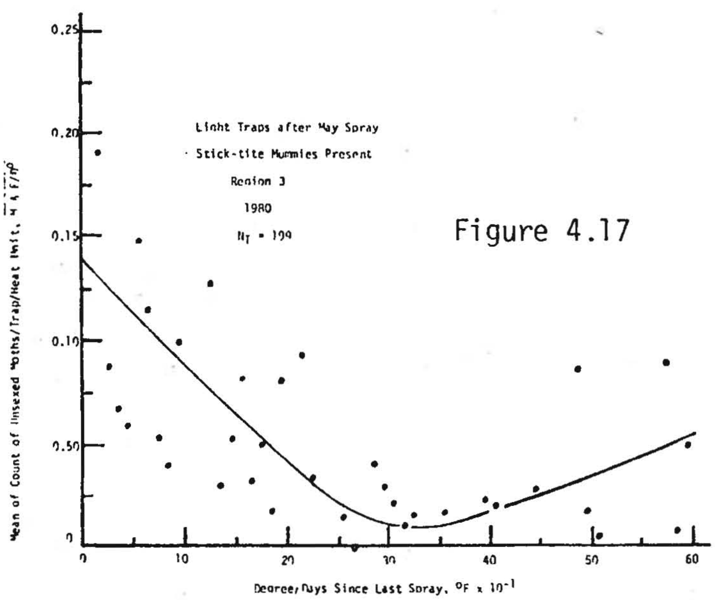


Figure 4.17

suggested in the left-hand portion of Figure 4.17 (0 to 250 degree days since last spray) may be associated with different types of spray materials.

The mummy data that are available in the first study set have been treated for display and are shown in Figures 4.18 through 4.30 Figure 4.18 is an attempt to show the evolution of life stages on a percentage basis through the first 600 degree days following a spray application. For this purpose mummy observations form the only economically practical route using actual field data. Perhaps such a data-base can also prove useful in the verification and replication of research work on population models underway elsewhere. In addition, the data may serve as a useful test bed for modelling approaches as applied to practical problems in a complex orchard environment.

Figures 4.19 to 4.30 are plots of raw counts only, rather than rates, and exhibit considerable scatter. Work with these data is continuing, and discussions with entomologists have begun concerning the placement in the population of degree-day check points derived from data discussed briefly in Section 2.

Finally, times have been identified in the mummy and green-nut dissection data when the greatest degree of comparable spatial coverage is available. Comparison of 1981 spatial patterns to 1980 spatial patterns has just begun. We have no new results to report on this portion of the data-processing topic.

f. Results. Table 4.1 shows an evolution of monitoring methods and indicates that the 1979 and 1980 experience has suggested some ways to accomplish expanded advisory services in an efficient fashion.

Table 4.2 shows decreased season-long reliance on egg traps as a monitoring tool while attention to the dissection of old-crop stick-tite mummies has increased. The 1981 decrease shown in dissection of hull-split green nuts is

Old-Crop Stick-tite Mummies, Region 3, 1980, N_M = 337

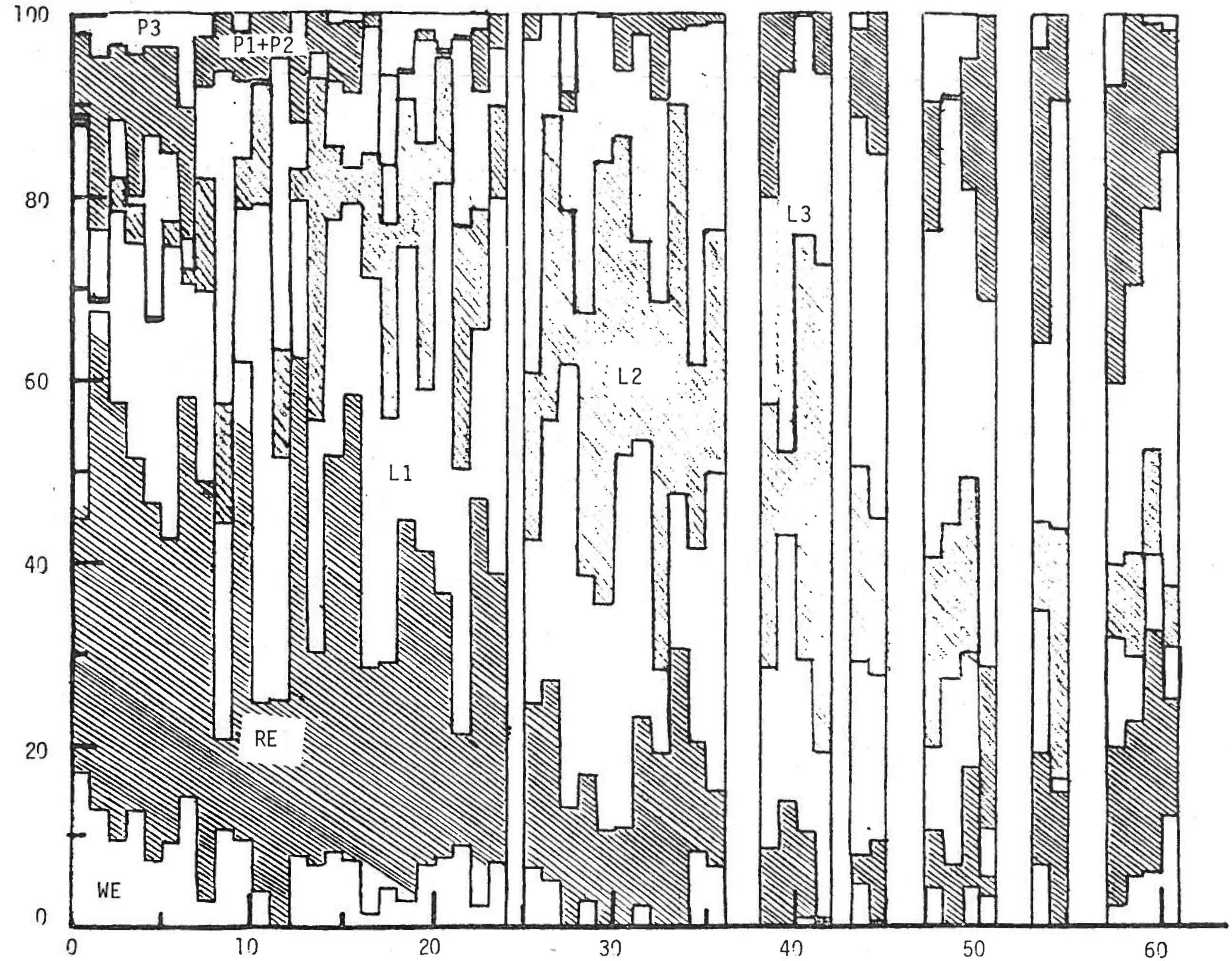


Figure 14.18

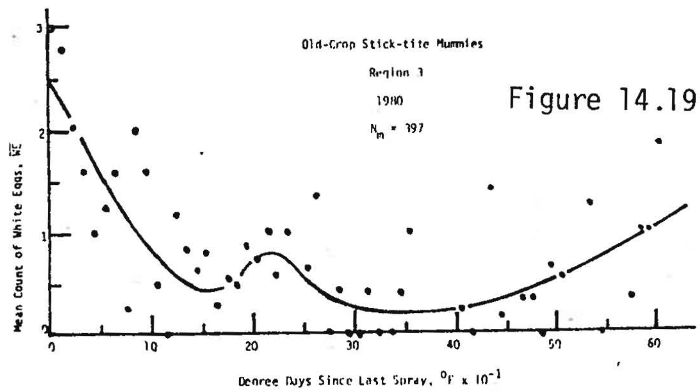


Figure 14.19

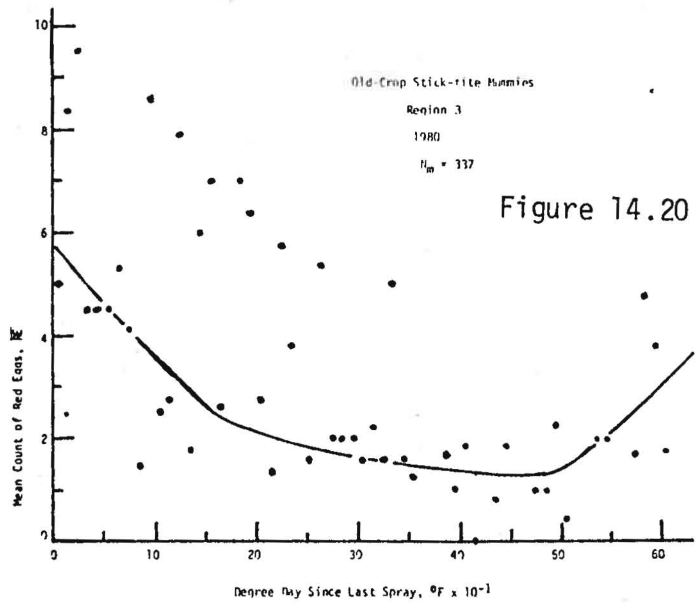


Figure 14.20

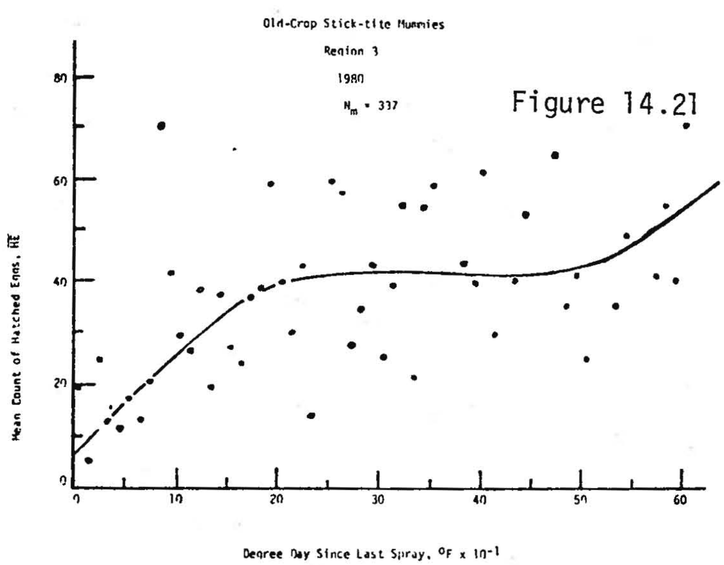


Figure 14.21

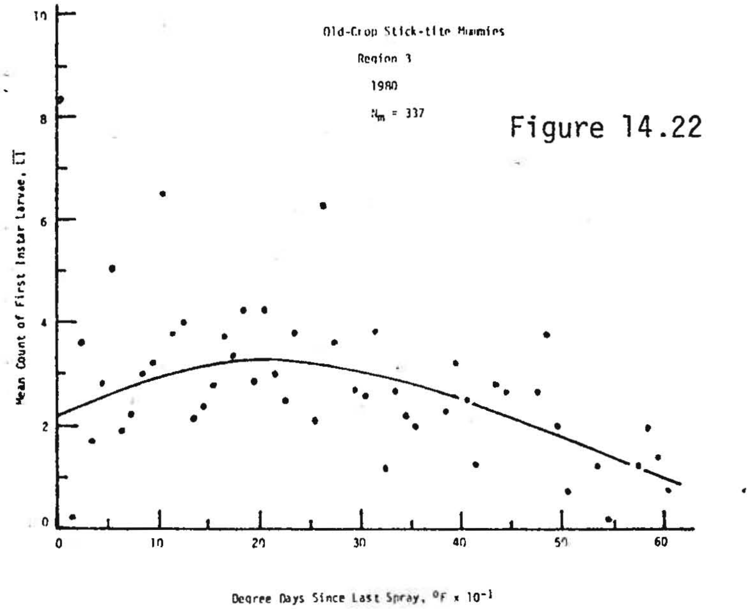


Figure 14.22

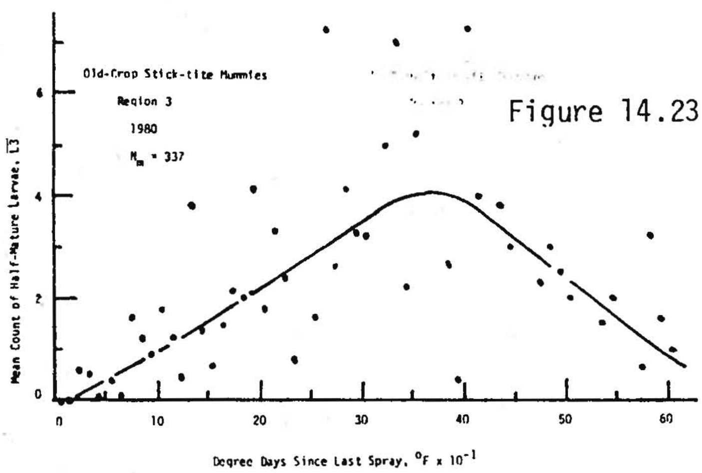


Figure 14.23

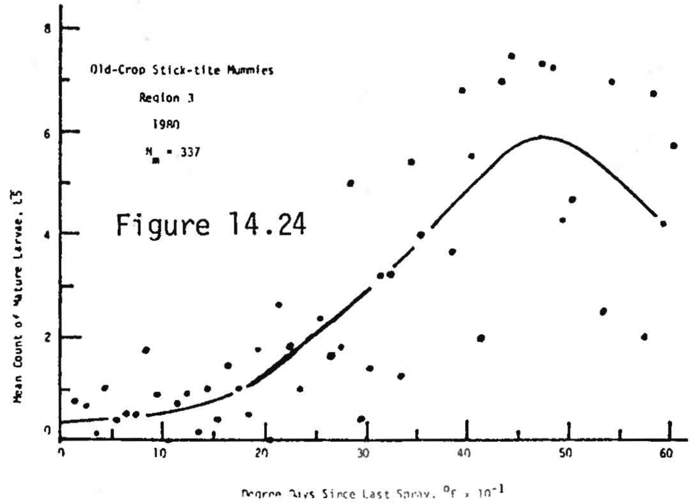
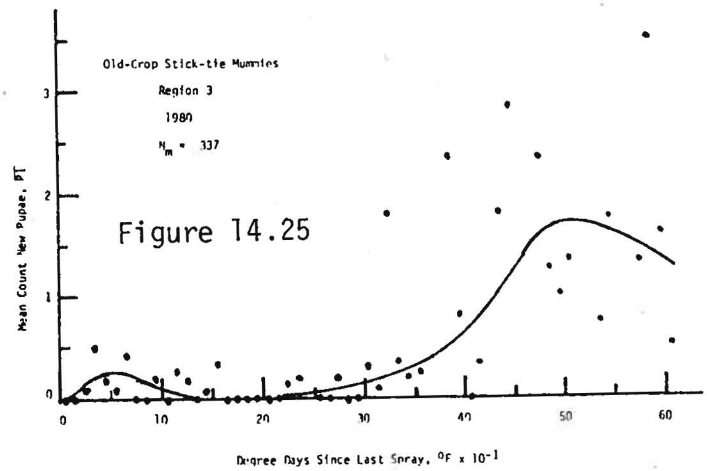
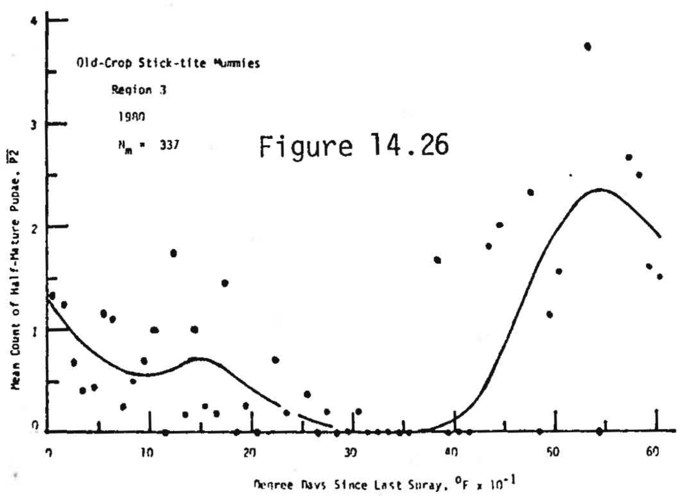
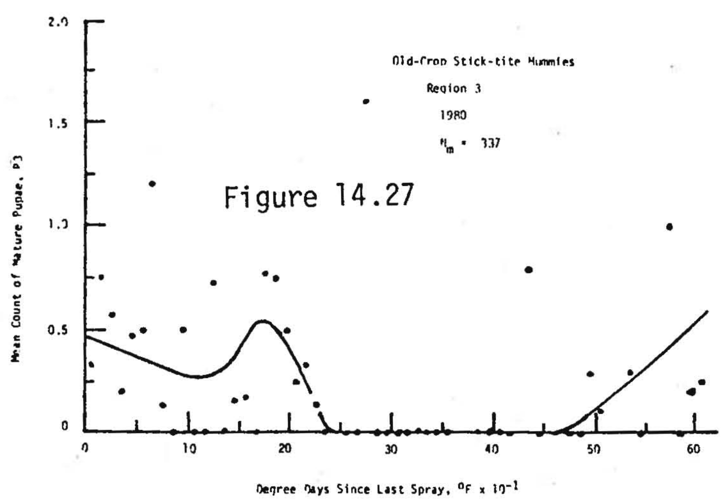


Figure 14.24


Old-Crop Stick-tie Mummies
Region 3
1980
N_m = 337
Figure 14.25
Mean Count New Pupae, PT
Degree Days Since Last Spray, °F x 10⁻¹
0
1
2
3
0
10
20
30
40
50
60


Old-Crop Stick-tite Mummies
Region 3
1980
N_m = 337
Figure 14.26
Mean Count of Half-Mature Pupae, P2
Degree Days Since Last Spray, °F x 10⁻¹
0
1
2
3
4
0
10
20
30
40
50
60


Old-Crop Stick-tite Mummies
Region 3
1980
N_m = 337
Figure 14.27
Mean Count of Mature Pupae, P3
Degree Days Since Last Spray, °F x 10⁻¹
0
0.5
1.0
1.5
2.0
0
10
20
30
40
50
60

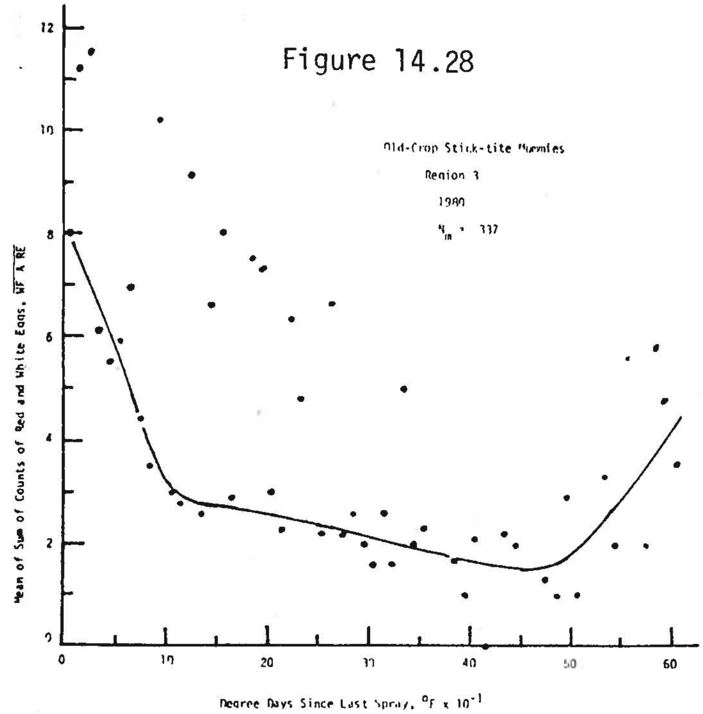


Figure 14.28

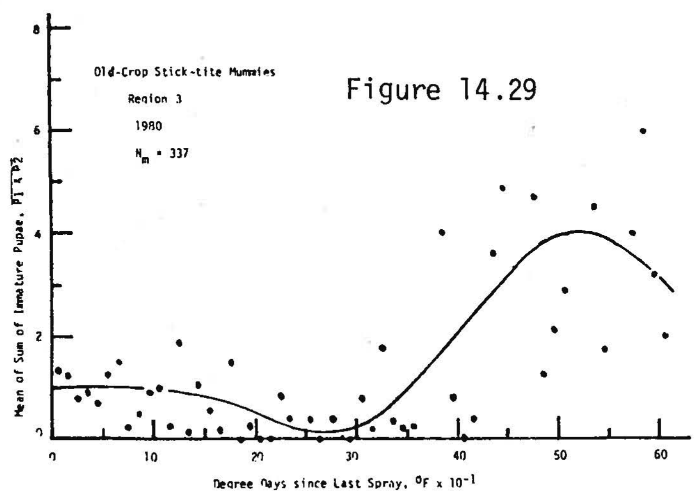


Figure 14.29

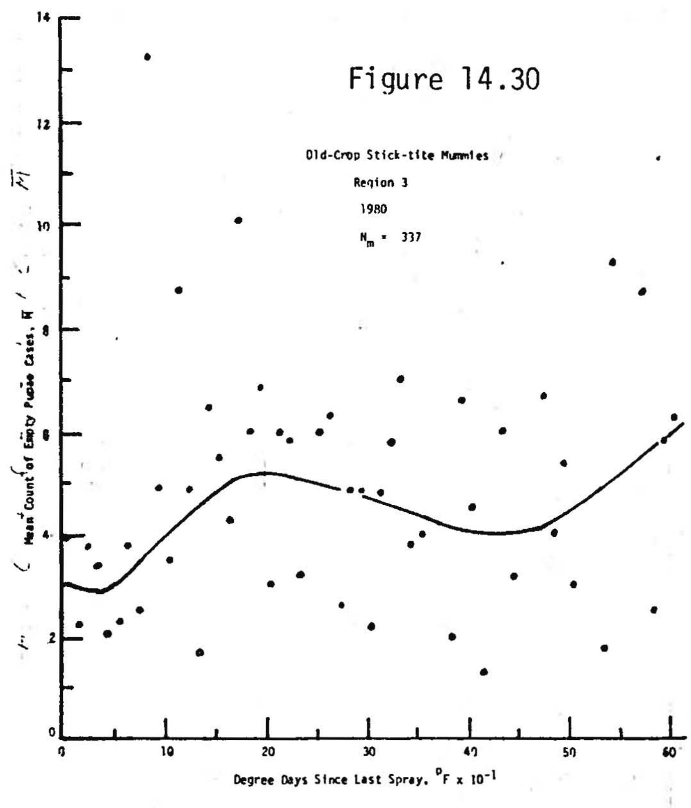


Figure 14.30
Old-Crop Stick-tite Mummies
Region 3
1980
N_m = 337
Mean Count of Empty Pupae Cases, $\overline{M}$
Degree Days Since Last Spray, °F x 10^{-1}
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60

misleading. The 1981 data base extends only through mid-August while 1979 and 1980 include records that extend through early November and mid-October, respectively.

Tables 4.5 - 4.7 show relatively low correlations among the simultaneous egg-trap count rates that have been a part of a three-year commercial pest advisory program in a complex assemblage of orchard properties. The complexity of varieties, ages, and planting patterns contributes to the low correlation values, of course. But more importantly this complexity would appear to support an economically based trend to de-emphasize the use of egg traps in this kind of situation.

Table 4.8 indicates that pest-monitoring information from light traps may be representative of larger areas within an orchard than may be the case for egg traps. This may be a practical factor that the grower and his or her advisors may wish to weigh carefully as they consider economic and manpower choices while setting up a pest-management program.

Table 4.9 shows that the reliability of using red eggs or mummies as an indicator of pest activity is increased as a result of the relatively longer duration of this stage compared to the fresh-laid, white-eggs stage. The computed reliability of the hatched-egg count should probably be down-graded because of the accumulative, rather than event-related, nature of this indicator. The computed reliability of more-mature larval stages and the pupal stages may be affected by the spray programs applied to these orchard blocks.

Table 4.10 clearly shows that:

- the red-egg, hatched-egg, immature larval, mature larval, and immature pupal life stages are those which best reward the pest manager who seeks to gather information by examining an economically practical number of old-crop stick-tite mummies.

- practical pest-management decisions are based on applying information, the standard reliability of which is substantially below that typical of normal experimental designs found in the world of research.

Figures 4.7 through 4.17 and 4.19 through 4.30 indicate that raw field data can be processed to reduce scatter and may be helpful both in aiding the grower in understanding the dynamics of navel orangeworm populations in his orchards and in timing the more difficult hull-split sprays. They also suggest that, properly normalized to an appropriate biological check-point and displayed on a biological time scale, field data from complex orchard situations may prove useful in validating pest-population models and spray program effectiveness. Finally, there is a degree of regional coherence visible in the data that may be of economic significance to growers and their advisors.

Figure 4.18 indicates that raw, field mummy dissection observations can be grouped and combined to present a relatively coherent and simple picture of pest-population dynamics which, again, may help the grower in understanding his navel orangeworm pest problems. With the increasing interest and activity in agribusiness directed toward applications of microcomputers, it may be timely for the Almond Board to be in the position of having research results that can assist the end user with problems related to data processing of his or her own information and to providing a local context for its interpretation.

Acknowledgements

This research would not have been possible without the help of the following people: Mr. Gregory Shubin wrote the computer programs that resulted in weather graphics and text for remote display in field offices and that enabled their transmission. He wrote the data-processing specifications, created the internal record format and data-plotting programs. He also wrote the programs that merge standard and non-standard weather observations. Mr. James Conery wrote the computer programs that acquired non-standard weather data and transmitted it to the main NOWCASTING computing machinery. Mr. Dennis Lundy checked out automatic weather station equipment, programmed the field microprocessors, and installed and performed field maintenance on automatic weather stations and acoustic echo sounders. Mr. H. Douglas McBride checked out processors, installed data communications equipment, data entry and printing programs, and provided systems and technical advice. Dr. Edwin X Berry assisted in the evaluation of candidate weather station equipment. Ms. Karen Tobin created the map backgrounds for graphics products. Mr. John Bohn provided necessary documentation, created second-generation plotting software, and supervized data entry.

It was the cooperation and support of George Post, Bob Hanke, and the growers in the Chico-Durham N.O.W. Project that enabled this work to occur. It was the foresight and courage of Fred Nottleman, Fred Montgomery, and Lynn Hawkins which created the fertile ground on which technical capability could take root. It was the Board of Governors of The University Foundation, Acting President of California State University, Chico, Robert Fredenburg, and Len McCandliss who permitted an unprecedented exercise in joint public/private research and service to begin and to develop. It was Sam Lewis, Jr., Louis Ybanez and Robert Ott who helped at a critical time. Thanks are also due to many others for whom space does not permit individual mention.

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APPENDIX A

McIDAS Surface Data Archive

McIDAS Upper-Air Archive

Apple Automatic Weather Station Archive

Acoustic Echo Sounder Archive

McIDAS Surface Data Archive

McIDAS Upper-Air Archive

*** M C I D A S *** CPUIL: CSI PROGRAM: RAOBDI

72493 051200

1006	8.6	7.5	300005	1	745	-2.9	-3.6	315012	2439
1000	8.2	6.9	300005	51	717	-4.6	-5.1	310014	2743
969	7.1	6.1	315006	304	700	-5.7	-6.1	305013	2934
934	5.8	5.0	320008	609	669	-7.3	-17.3	291013	3289
926	5.4	4.7	322008	684	638	-9.5	-17.3	275014	3658
916	6.4	3.4	325009	774	625	-10.5	-17.3	273014	3817
900	5.6	3.0	330011	914	617	-11.5	-15.5	270014	3963
867	3.8	2.1	330014	1219	589	-13.6	-20.1	265019	4268
850	2.8	1.5	330015	1384	557	-16.7	-26.7	265021	4694
804	.4	-.6	320017	1829	543	-18.1	-27.9	265023	4878
774	-1.2	-2.1	320015	2134	500	-22.9	-31.9	260024	5490

459	-27.6	-47.3	260025	6097	235	-49.5		240032	10670
424	-32.1	-62.1	254025	6676	217	-51.3		247033	11197
404	-34.2	-64.2	250024	7012	200	-52.1		255035	11730
400	-34.7	-64.7	250023	7090	161	-53.5		250041	13109
370	-37.5	-67.5	250029	7621	150	-54.1		255035	13590
347	-39.9	-69.9	250034	8072	115	-57.5		265030	15243
339	-40.3	-73.3	250036	8231	104	-58.8		260028	15853
300	-42.7		240028	9060	100	-59.5		260028	16150
296	-43.0		240027	9146					
255	-47.3		250042	10060					
250	-48.3		250041	10270					

72597 051200

966	-2.3	-2.9	000000	405	770	-13.5	-14.6	319004	2170
950	-2.9	-3.0	275001	539	761	-13.7	-23.7	315004	2260
941	-3.0	-3.1	325002	609	752	-14.1	-26.1	310005	2351
921	-3.5	-3.6	325002	785	743	-12.5	-25.3	305006	2439
906	-3.7	-5.6	325001	914	731	-9.9	-23.9	305009	2569
892	-3.9	-7.7	341002	1039	714	-10.7	-24.7	305014	2743
872	-5.3	-7.0	005004	1219	700	-11.5	-25.5	300015	2900
864	-5.9	-6.6	005004	1291	685	-12.5	-26.5	297016	3067
850	-6.9	-10.5	005005	1407	669	-11.1	-25.1	294017	3249
837	-7.9	-11.1	005005	1524	634	-14.0	-27.0	285020	3658
805	-10.5	-12.7	345004	1829	599	-17.1	-29.1	285022	4086
773	-13.1	-14.3	320004	2134	584	-17.3	-29.3	285023	4268

578	-17.5	-29.5	284023	4356	300	-48.9		250026	8930
561	-19.1	-30.9	280025	4577	290	-49.8		250027	9146
538	-21.4	-32.9	275025	4878	259	-53.1		253027	9887
500	-25.7	-36.7	270023	5420	250	-52.1		255028	10120
458	-30.5	-41.5	275024	6051	231	-49.5		260026	10636
449	-32.3	-37.1	273024	6193	200	-49.1		265227	11570
443	-31.5	-38.5	272024	6289	190	-49.0		265027	11890
400	-36.3	-45.3	260025	7000	167	-48.7		270023	12755
379	-39.7	-47.7	260025	7372	150	-51.7		275018	13450
365	-42.1	-62.7	260024	7621	113	-54.1		285014	15243
336	-47.7		256024	8182	103	-54.9		285011	15853
304	-48.7		250025	8641	100	-55.3		290011	16070

Apple Automatic Weather Station Archive

REMOTE STATION SUMMARY

STATION # 2008

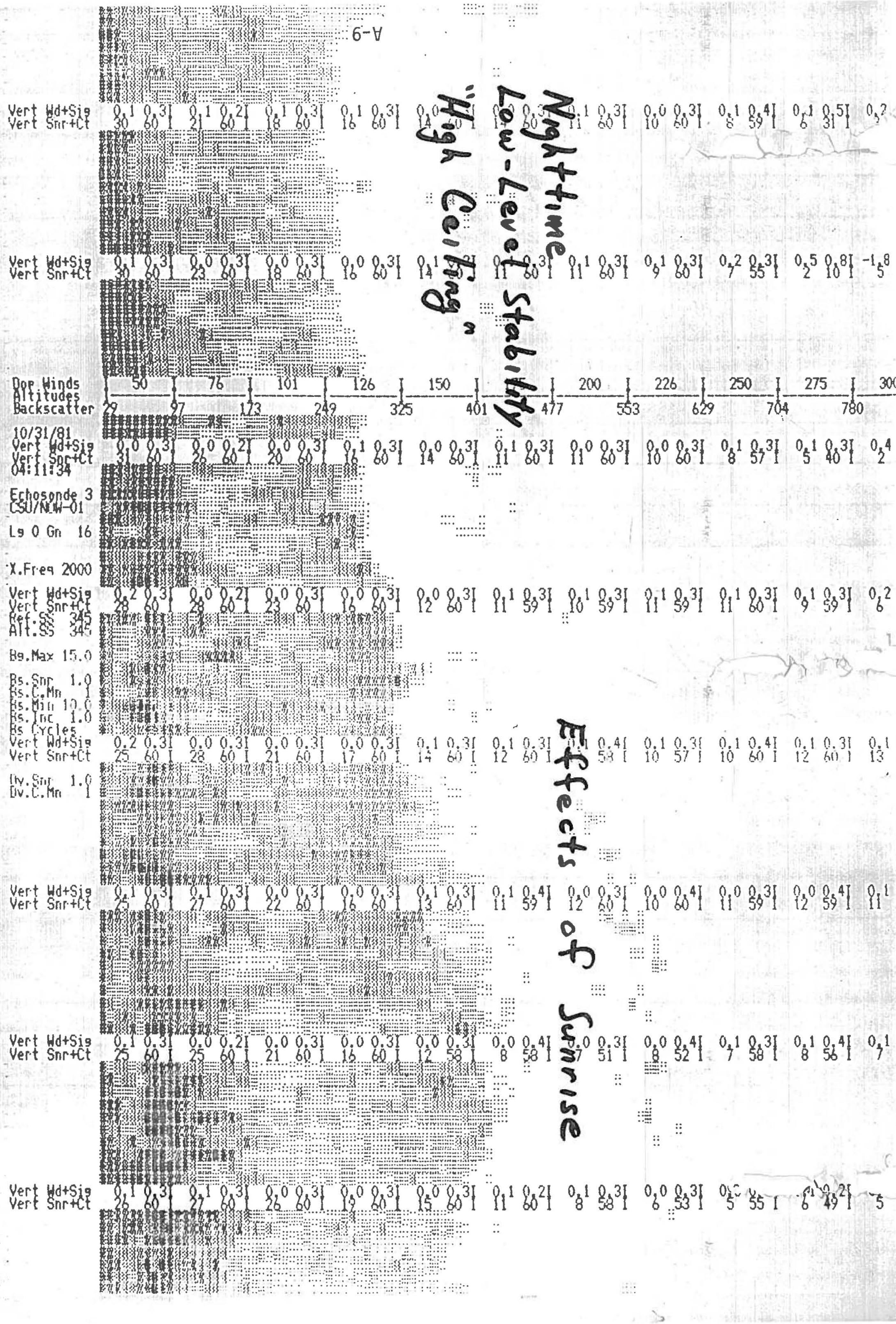
LAT: 384600 LONG: 1213400 INSTALLED: 09/25/81

DATE	TIME	TEMP	HUM	DEWPT	WIND SPD.	WIND DIR.
10/14	900	10	84	7	2	206
10/14	1000	12	74	7	4	270
10/14	1100	14	65	7	6	307
10/14	1200	16	56	7	8	264
10/14	1300	17	49	6	4	220
10/14	1400	19	41	5	8	306
10/14	1500	19	40	5	4	214
10/14	1600	19	39	4	5	277
10/14	1700	19	41	5	5	350
10/14	1800	15	57	6	5	16
10/14	1900	13	63	6	3	15
10/14	2000	12	70	6	1	26
10/14	2100	10	79	6	1	260
10/14	2200	9	84	6	5	207
10/14	2300	7	88	5	1	214
10/15	0	6	92	4	7	305
10/15	100	6	91	4	8	283
10/15	200	5	92	3	6	3
10/15	300	6	89	4	8	329
10/15	400	4	93	2	1	275
10/15	500	4	94	3	4	329
10/15	600	3	94	2	3	209
10/15	700	4	94	3	2	278
10/15	800	7	88	5	6	329

Acoustic Echo Sounder Archive

```
Vert Wd+Sig  0.3 0.5|  0.0 0.2|  0.0 0.3|  0.0 0.3|  0.4 0.4|  0.6 **|  0.9 0.2|  *** **|  0.6 1.1|  0.1 1.1|  0.5
Vert Snr+Ct  31  60 |  10  60 |  6   56 |  4   38 |  0   6  |  -1  1 |  -1  2  |  0   0 |  2   5  |  2   2  |  0

Vert Wd+Sig  0.2 0.3|  0.1 0.3|  0.0 0.2|  0.2 0.5|  0.6 0.5|  0.8 **|  0.7 1.8|  0.2 **|  0.4 **|  -1.0 **|  ***
Vert Snr+Ct  33  60 |  14  60 |  7   59 |  0   10 |  1   4  |  -2  1 |  4   2  |  6   1 |  3   1 |  -2   1 |  0

19:00:19
Vert Wd+Sig  0.1 0.2|  0.1 0.3|  0.1 0.3|  0.2 0.3|  0.5 0.4|  0.8 **|  0.6 1.7|  *** **|  0.2 1.7|  0.0 0.3|  -1.1
Vert Snr+Ct  33  60 |  21  60 |  4   49 |  2   41 |  0   10 |  7   1 |  2   2  |  0   0 |  2   5  |  0   2  |  3

Vert Wd+Sig  0.2 0.3|  0.1 0.3|  0.0 0.3|  0.0 0.3|  0.3 0.8|  *** **|  -1.6 **|  0.2 **|  0.2 0.5|  0.3 0.5|  0.4
Vert Snr+Ct  31  60 |  15  60 |  9   59 |  6   45 |  4   3  |  0   0 |  1    1 |  14  1 |  5   3  |  8   2  |  1

Vert Wd+Sig  0.2 0.2|  0.1 0.3|  0.0 0.3|  0.1 0.4|  0.7 0.9|  -2.2 **|  0.1 **|  -1.4 **|  -2.8 **|  -2.3 **|  -1.3
Vert Snr+Ct  32  60 |  18  60 |  17  60 |  11  48 |  7   5  |  6    1 |  2   1 |  0    1 |  2    1 |  0    1 |  -1

Vert Wd+Sig  0.2 0.2|  0.1 0.3|  0.1 0.3|  0.1 0.4|  0.7 **|  0.9 **|  0.9 **|  *** **|  *** **|  *** **|  -3.2
Vert Snr+Ct  32  60 |  20  60 |  18  60 |  7   41 |  -1  1 |  2   1 |  4   1 |  0   0 |  0   0 |  0   0 |  7

Vert Wd+Sig  0.2 0.3|  0.0 0.3|  0.1 0.2|  [illegible] 0.4|  *** **|  -1.1 0.1|  -1.2 **|  *** **|  *** **|  -1.5 **|  ***
Vert Snr+Ct  32  60 |  22  60 |  19  60 |  7   52 |  [illegible] 0 |  -1   2 |  7    1 |  0   0 |  0   0 |  -2   1 |  0

Vert Wd+Sig  0.2 0.3|  0.1 0.3|  0.0 0.2|  0.0 0.4|  [illegible] **|  *** **|  0.1 0.6|  -1.2 0.4|  *** **|  *** **|  0.7
Vert Snr+Ct  29  60 |  20  60 |  19  60 |  10  59 |  0   0 |  0   0 |  3   2  |  0    2  |  0   0 |  0   0 |  -2

Dop Winds      50    76    101    126    150    175    200    226    250    275    300
Altitudes
Backscatter  29    97    173    249    325    401    477    553    629    704    780
```

Nighttime
Low Level Stability
"Low Ceiling"


A-9
Nighttime
Low-Level Stability
"High Ceiling"
Effects of Sunrise
Vert Wd+Sig
Vert Snr+Ct
Dop Winds
Altitudes
Backscatter
50 76 101 126 150 200 226 250 275
29 97 173 249 325 401 477 553 629 704 780
10/31/81
04:11:34
Echosonde 3
CSU/NOW-01
Lg 0 Gn 16
X.Freq 2000
Ref.SS 345
Alt.SS 345
Bg.Max 15.0
Bs.Snr 1.0
Bs.C.Mn 1
Bs.Min 10.0
Bs.Inc 1.0
Bs Cycles
Dv.Snr 1.0
Dv.C.Mn 1

80-ZA2

HYPOTHESIS FORMULATION FROM NAVEL ORANGEWORM FIELD DATA

R.K. Hauser, J. Freeman, H.D. McBride, G. Shubin, and J. Bohn
The NOWCASTING Project, California State University, Chico
101 Salem Street, Suite 4, Chico, California 95926
(916) 895-5082

Observations: This project used data from the light and egg traps and from the mummy and split green-nut sampling of the Chico-Durham Navel Orangeworm Project activities of Agricultural Advisors, Inc., of Yuba City CA. During 1979 about 3,000 acres of almonds were observed; during 1980, the acreage reached 6,000.

Weather data were examined from local climate stations and were also entered by growers themselves into the NOWCASTING computer system at Chico State. The general number of heat units in 1979 exceeded those in 1980, except for a brief period near May 1 when 1980 exceeded 1979 by 50%. Both springs experienced 3- to 5-day cool spells.

Conclusions: Egg-deposition on egg traps varied from block to block. Activity in younger orchards appeared to peak earlier than in older blocks.

The "effect" of spring sprays appears to depend on precise timing, both relative to the level of pest activity in the block and to the detail of the weather conditions that follow the application.

Mummy observations, where available, permit the historical and, possibly, the near real-time monitoring of the rate of development of the navel orangeworm's life cycle within successive generations.

It is possible to process pest monitoring data into formats that are informative to growers and their advisors, and to deliver the displays in time to inform their decision-making processes.

It may be possible to use mapped information and time-pattern methods to identify individual blocks for intensive monitoring with the goal of providing useful early guidance to growers and their advisors.

Recommendations: Emperical methods and modern computer data processing techniques should receive wider application for the purpose of helping to design practical pest-control programs.

Effective control of the navel orangeworm in almonds appears to require precise timing, more so when the spring weather acts to lengthen the period of egg-deposition activity and more so later in the summer as the differences among orchards magnify.

Precise timing requires an appropriate mix of pest observing methods and it requires that the individual block be examined to determine the best timing for it.

NOWCASTING
Suite 4, 101 Salem Street
Chico, California 95926

N E W S L E T T E R #2

Progress Report: The NOWCASTING Project has started to test information displays with selected test users. These users are located at several different points in California and are engaged in the fields of public agency meteorology, private meteorological consulting, agriculture, integrated pest management, and education. Both text and numerical lists transmitted by telephone-lines and instructional television graphics displays have begun trial use. The development has begun of display graphics which are compatible with certain popular home computers. The Touch-Tone method of entering local weather data has been expanded to include some locations in the San Joaquin Valley and the observations are now a part of the weather data base accessible to McIDAS analysis and display programs. The means to accomodate other measurements that depend, in part, on weather now exists and is in use for research purposes funded by the Almond Board of California. The paragraphs below give some details.

Highlights: During the next few months, we will begin to learn whether the initial test displays are useful and understandable. We will then begin to revise them in response to suggestions received from test users. Also during this period, we will begin to acquire and integrate observations from special-purpose weather data bases and using telephone-lines to transmit graphics products to Apple II-Plus home computer systems. In the area of pest management, navel orangeworm field data include pest counts from both 1979 and 1980. Local weather data is now being added to that system and provisions for automatic weather inputs from orchard locations has been initiated.

Voluntary Cooperators for Touch-Tone Reporting: The roster of volunteer cooperators for Touch-Tone weather observing has doubled from 20 to 40. The area of coverage has expanded southward to Lindsay and westward to Paskenta. On several occasions, the information provided by the Touch-Tone stations has allowed us to make a more detailed analysis of weather patterns in the Sacramento Valley.

We appreciate the efforts of these volunteer observers and continue to solicit additional observers. Interest in, and the need for, these observations continues to increase. The information you provide helps identify the details of local weather and fill in the gaps in existing weather observations.

Special recognition is focused on Mr. Al Benefield and the Dixon Fire Department who provide an average of three to four observations daily! Second place goes to Mr. Steve Horn at the Nut Tree Airport. Keep up the good work.

Invitation: Voluntary cooperators will soon receive an invitation to visit the NOWCASTING facility and see what happens to their beeps and whistles.

Video Displays Under Test: Beginning Monday, October 27th, television transmissions began. These transmissions use the Instructional Television Fixed Services (microwave) network, in cooperation with NORCAL Cablevision, Yuba City, and the Extended Education Offices of Chico State and U.C. Davis. Highlighted

More Interested Parties: Since our last newsletter we have received support from or have made arrangements, more or less formal in nature, to work with the following organizations:

Atmospheric Research & Technology
Butte County Schools
Butte College, Physical Sciences Department
IPM Farm Advisor, Yuba County
McGowan & Associates
Modesto Junior College Energy Center
NASA Lewis Research Center, Visitor Center
National Weather Service, Agricultural Weather Field Programs in Chico and in Lindsay
San Jose State, Meteorology Department
U.C. Davis, Atmospheric Sciences Program
Wells Fargo Bank Foundation

A Plug For A Good Publication: There is a new publication entitled AgCOMP Bulletin, the first issue of which just arrived. It is a good way to keep in touch with the explosion of computer services to agriculture. It costs $10.00 per year and can be obtained by writing the Editor, Dr. Stephen M. Welch, Dept. of Entomology, Kansas State University, Manhattan KS 66506.

Users: The Project is currently serving two long-term contract users on an annual contract basis: The California Air Resources Board and the California Department of Food and Agriculture. Test users who make much less extensive use of the NOWCASTING system, fall in two categories according to the type of communications link:

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Butte College, Physical Sciences Dept.	
University of California, Davis, Dept. of Land, Air & Water Resources	
San Jose State, Meteorology Department	
Rick Fay & Associates	
National Weather Service, Fire Weather Office, Redding	
Sacramento County Air Pollution Control District	
Chico Aerial Ambulance Service	
NASA Lewis Research Center, Visitor Center	
Sutter County IPM Farm Advisor	
Butte County Superintendent of Schools	

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