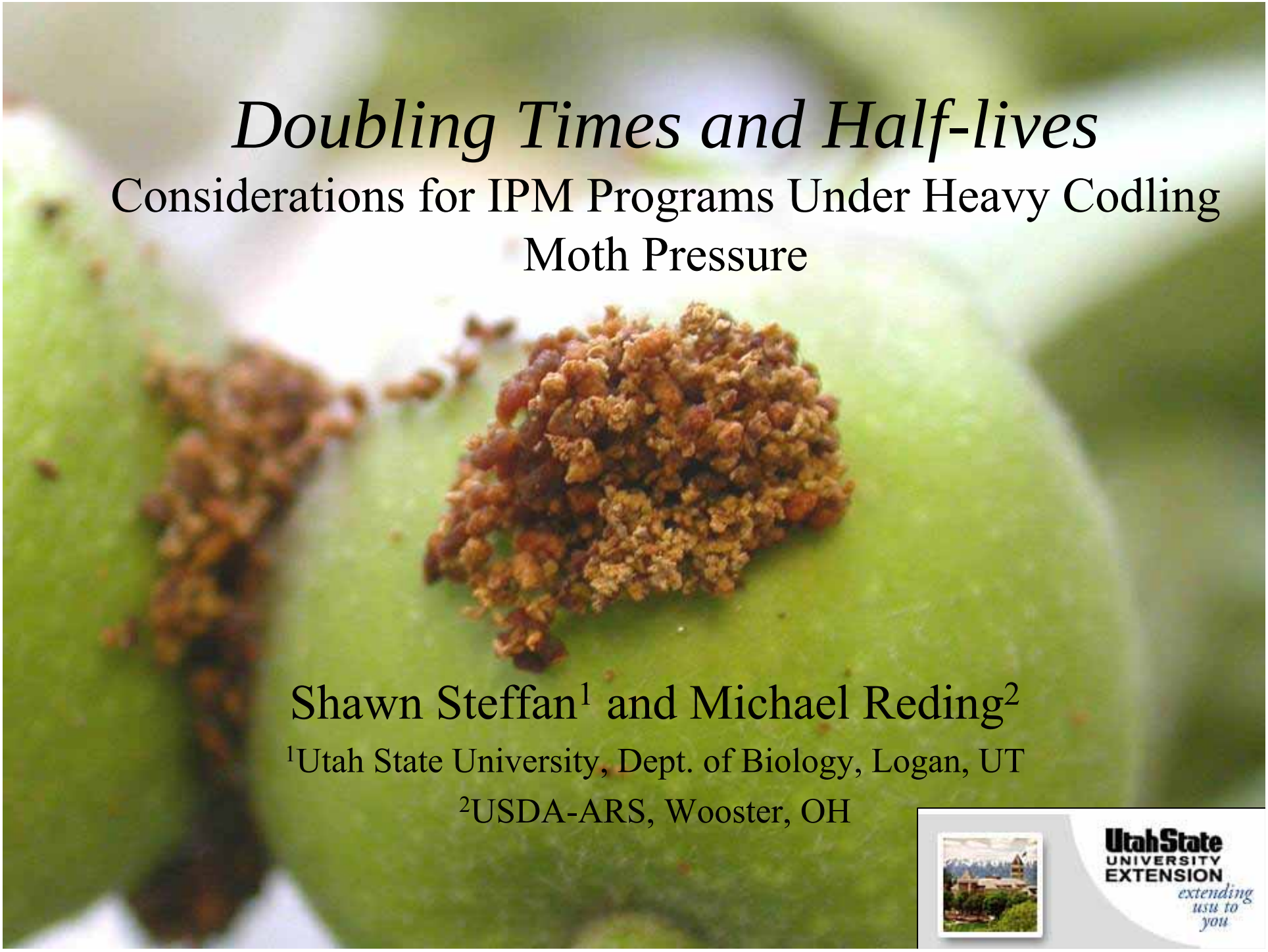

Doubling Times and Half-lives

Considerations for IPM Programs Under Heavy Codling Moth Pressure

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Apple Growth and CM Phenology

- *How does fruit growth affect CM management?*
- *How do SA dynamics correspond with particular CM biological events?*
- *What is the role of insecticide degradation in CM management?*
- Profound changes in fruit SA are coincident with critical phenological events.

Codling Moth Pressure in Northern Utah

- Pheromone-based trapping:
  - In 2003, over 4,000 moths caught from 16 traps.
  - 9 orchard blocks: over 450/block
  - Approx. 229 moths/trap
- Damage range:
  - < 1% to 83%
- Reasons for High CM pops:
  - Mild winter
  - Insecticide resistance
  - Very little adoption of MD
  - Coverage & spray timing

Fundamentals & Assumptions

- Apples tend to grow at a relatively linear rate through the season.
- An increase in fruit diameter translates into an increase in surface area.
- Assuming a somewhat spherical apple, its surface area (SA) can be approximated using the formula , $4\pi r^2$.
- Since SA is a function of the square of the radius, any increase in diameter allows for exponential rise in SA (graph).

Diameter (in)	SA (in^2)	*multiplier*
0.25	0.20	**4.00**
0.50	0.78	**2.24**
0.75	1.77	**1.78**
1.00	3.14	**1.56**
1.25	4.91	**1.44**
1.50	7.07	**1.36**
1.75	12.56	**1.31**
2.00	19.63	**1.26**
2.25	28.27	

Doubling Times

- Early-season doubling times: *very short.*
- SA dynamics affect insecticide concentrations on the fruit.
- For any application, **doubling** the fruit SA will **halve** the residual (per unit area) on the fruit.

- Example from 2003:
  - In **late-May**, fruit radii were ~ 1 cm. By **late-June**, radii were ~ 2 cm = four-fold increase.
  - Four-fold increase over four weeks = **average doubling time of 2 weeks.**
  - As the season progresses, SA doubling-time increases markedly.

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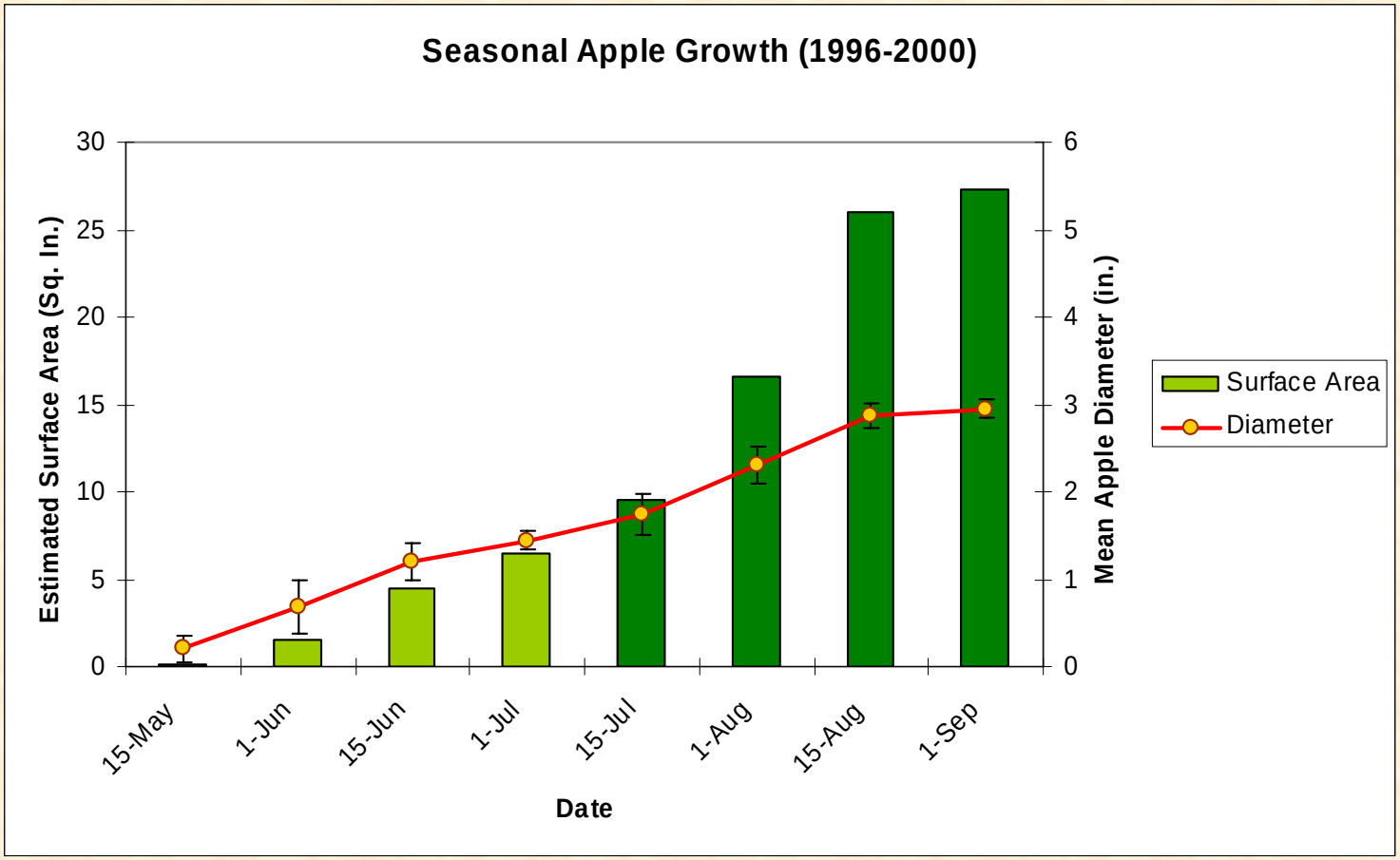
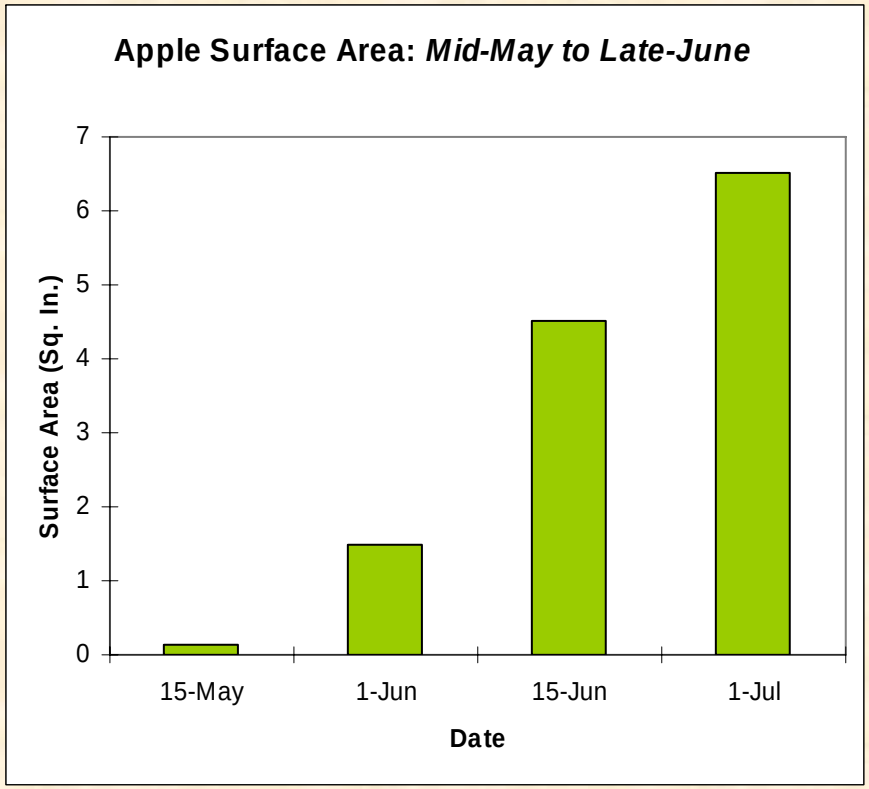
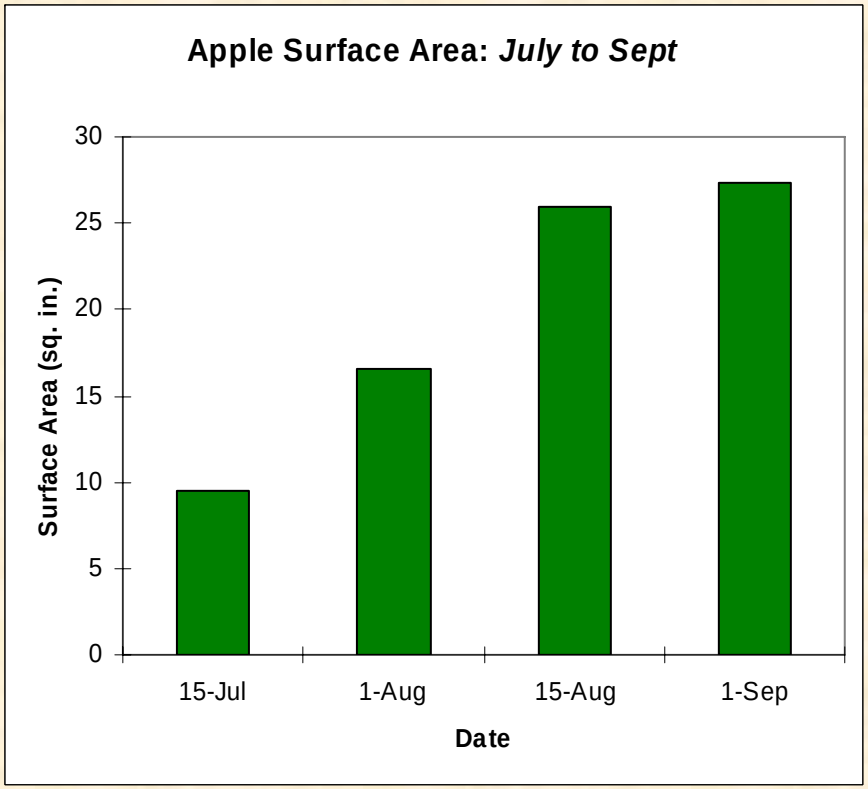
Fruit Growth Pattern in Northern Utah and Corresponding SA Values



A Closer Look at Apple SA





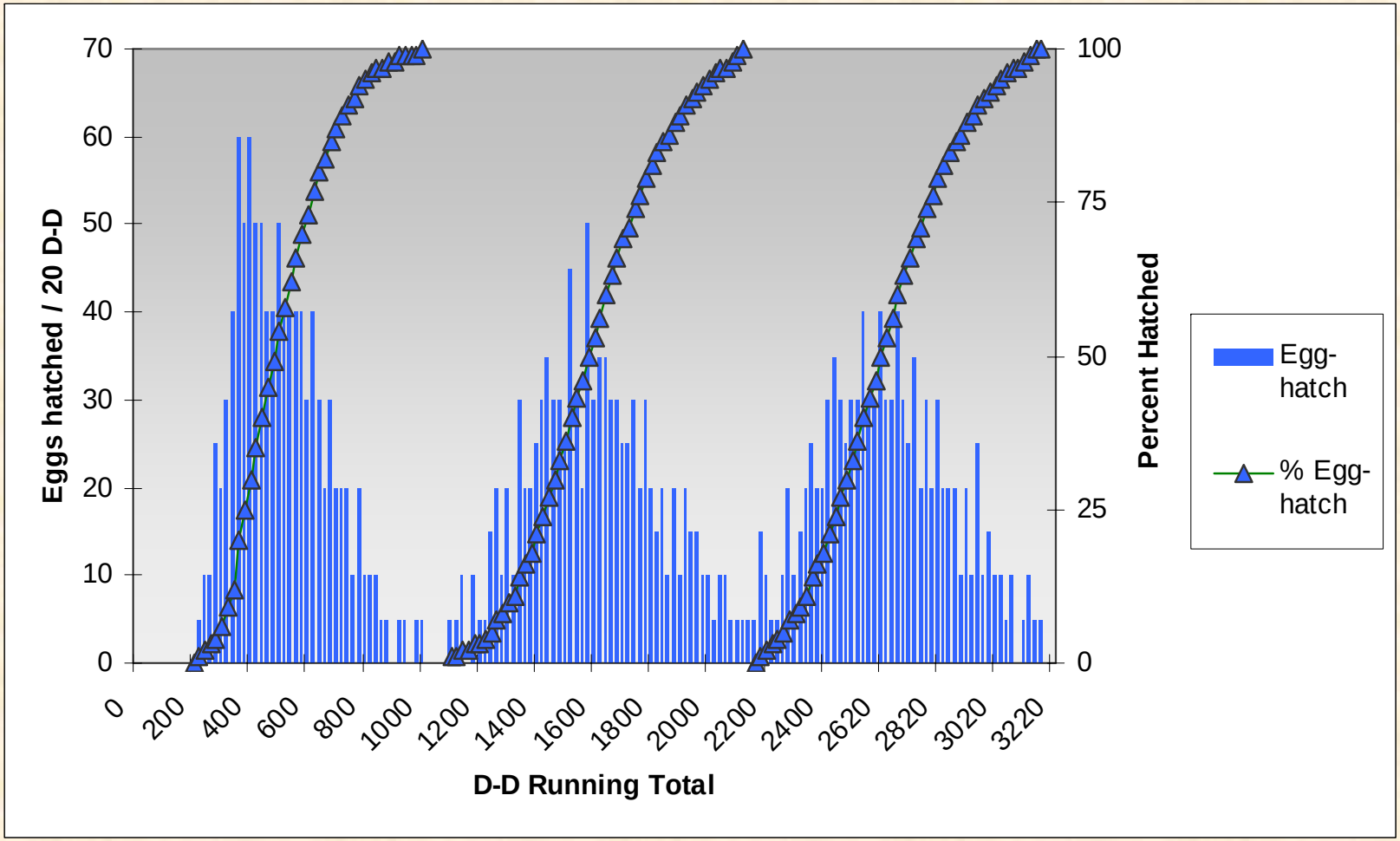
Changes in SA at 2-week intervals

Date	SA	*Multiplier*
5/15	0.13	11.5
6/1	1.49	3.1
6/15	4.52	1.4
7/1	6.53	1.5
7/15	9.48	1.7
8/1	16.62	1.6
8/15	25.96	

A Critical Early Event

- **1st Generation Egg-Hatch.**
  - **The success/failure of 1st gen. larvae set the stage for the remainder of the season.**

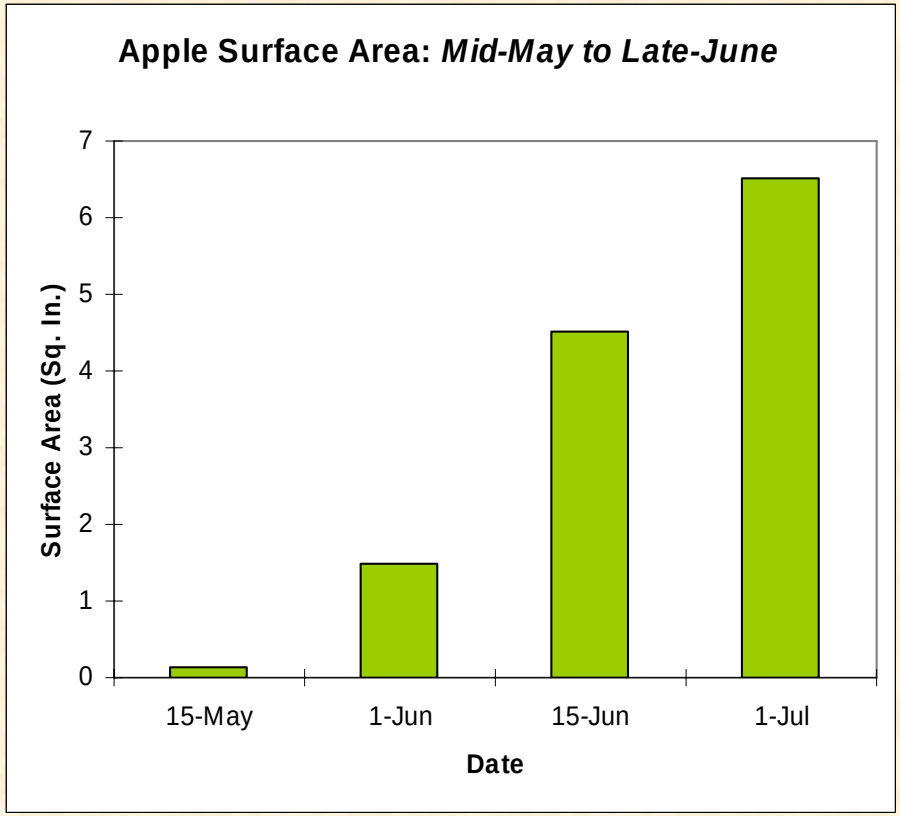
Peaks of Egg-Hatch*



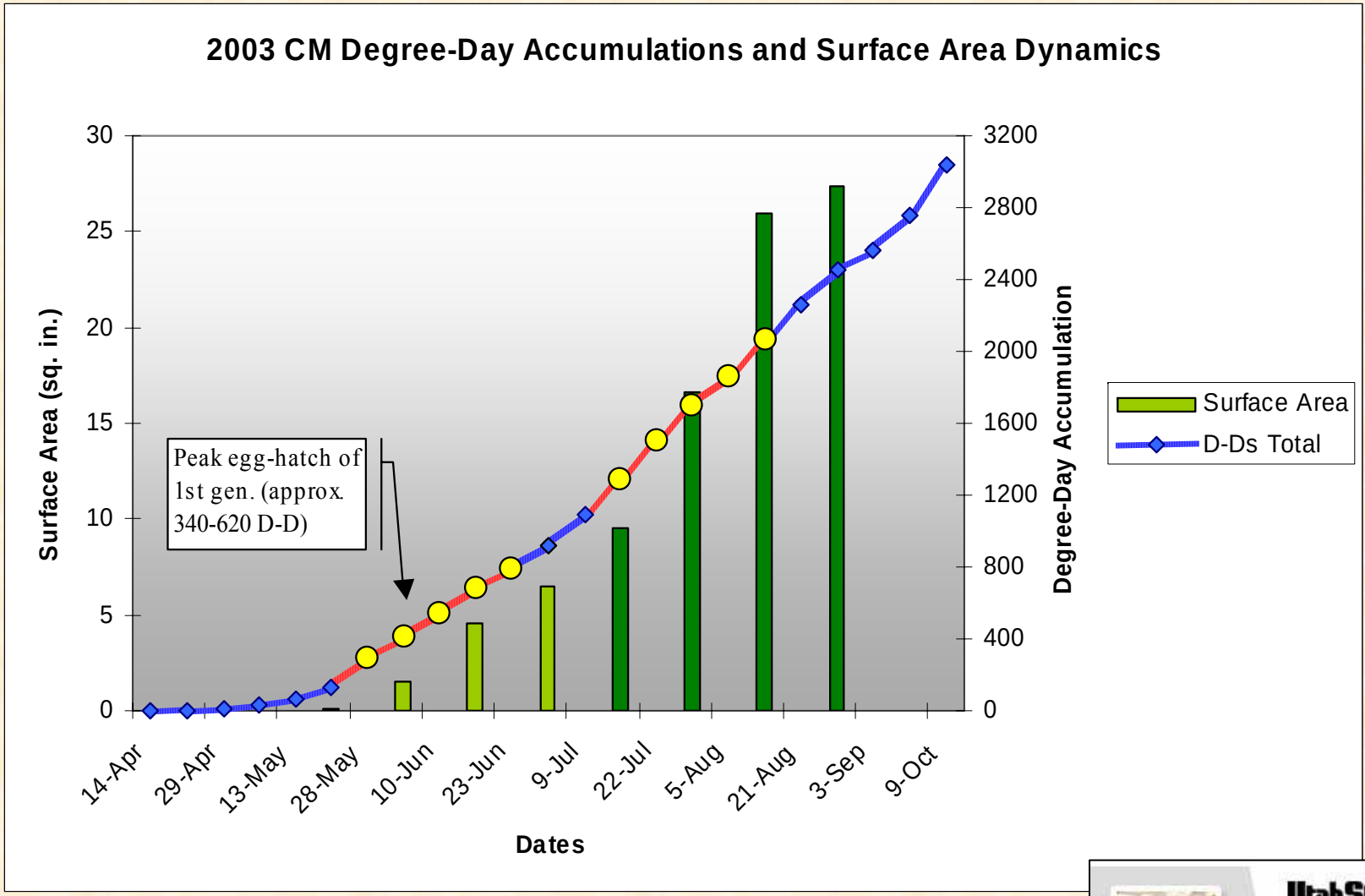
*Based on Degree-Day/Development Tables in *Orchard Pest Management: A Resource Book for the Pacific Northwest*. E.H. Beers, J.F. Brunner, M.J. Willett, and G.M. Warner [eds.], Good Fruit Grower, Yakima, WA.

CM Egg-Hatch and Fruit Growth Patterns

- *Egg-hatch*:
  - 220 DD through 900 DD (3-98% egg-hatch)
- Peak egg-hatch:
  - typically between **340** and **620 DD**.
  - These numbers correspond respectively to *late-May and late-June* for much of northern Utah.



2003 Flight Data and DD Accumulations



Annual Phenomena

- Greatest increase (shortest doubling-times) in SA occurs at approximately 200-800 DDs.
- Peak 1st gen egg-hatch will likely be between 340 and 620 DD.
- During the highest intensity larval hatch-out, apples are experiencing a dramatic increase in SA.

Effects of Insecticide Decay:

% residual remaining after n *days*

Half-life	7 days	10 days	14 days	21 days	28 days
1 day	0.8	0.1	trace	trace	trace
2 days	8.8	3.1	0.8	0.1	trace
3 days	19.9	10.2	3.9	0.8	0.2
4 days	29.7	17.7	8.8	2.6	0.8
5 days	37.9	25.0	14.4	5.4	2.1
7 days	50.0	37.1	25.0	12.5	6.2
10 days	61.5	50.0	37.9	23.3	14.4
14 days	70.7	61.0	50.0	35.4	25.0
20 days	78.4	70.7	61.6	48.3	37.9
28 days	87.5	78.1	70.7	59.5	50.0
50 days	90.8	87.1	82.4	74.7	67.8

- Computed using the following formula: $\mathbf{100*(0.5)^{n/t}}$
  - where $\boldsymbol{n}$ = number days of decay; $\boldsymbol{t_{1/2}}$ = material half-life; 100 is conversion factor for %

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Material Half-lives

Material	Half-life (in days) On leaf/bark	In soil	Trade-Names	Toxicity Class
azinphos-methyl	**3-6**	**5**	Guthion	**I**
Bt	**0.5**	**2**	DiPel	**III**
carbaryl	4-10	**7-28**	Sevin	**II**
chlorpyrifos	**3-4**	**11-141**	Lorsban	**II**
diazinon	6-14	**14-28**	Diazinon	**II**
endosulfan	**3-7**	**50**	Thiodan	**I**
esfenvalerate	**14-28**	**15-90**	Asana	**II**
imidacloprid	39	26-229	Provado	**II**
malathion	**1.5**	**1-25**	Malathion	**III**
methoxyfenozide	77	173	Intrepid	**III**
permethrin	**4-5**	**30-38**	Ambush	**II**
phosmet	**7**	**4-20**	Imidan	**II**

Sources: *Extension Toxicology Network*, http://ace.orst.edu/info/extoxnet/pips/ghindex.html
Spectrum Chemical Factsheets, http://www.speclab.com/compound/
Crop Protection Handbook 2003, Meister Publishing Company

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Possible Scenario

- Short half-life material (Guthion = 3-6 d)
- Gallonage: 50 gpa
- 1st cover spray applied at 250 DD from biofix
- No MD used
- 21 d spray interval

2 weeks after the spray:

- Apple SA has quadrupled
- Degradation of residual after 14 days: 4-20% of initial amount
- Spray coverage: 80%

During the last week of a 21 day spray interval:

$0.8\% < C < 4.0\%$

[(0.25)(0.04)(0.8) = 0.008]

[(0.25)(0.20)(0.8) = 0.040]

Effects of Scaling

The Effects of Scale

- Codling moth pressure is a function of the resident population.
- 95% control of each CM generation merely prevents the population from growing.
- Percent kill from a spray is not the only measure of *control* or *management*.

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Solutions & Strategies

- **Use mating disruption** to reduce the egg-load (MD works 24-7, for months).
- Use DD accumulations to **optimize spray timings**.
- **Coverage** is extremely important (increase gallonage/A and decrease tractor speed).
- **Monitor** traps, fruit growth, infestation/damage

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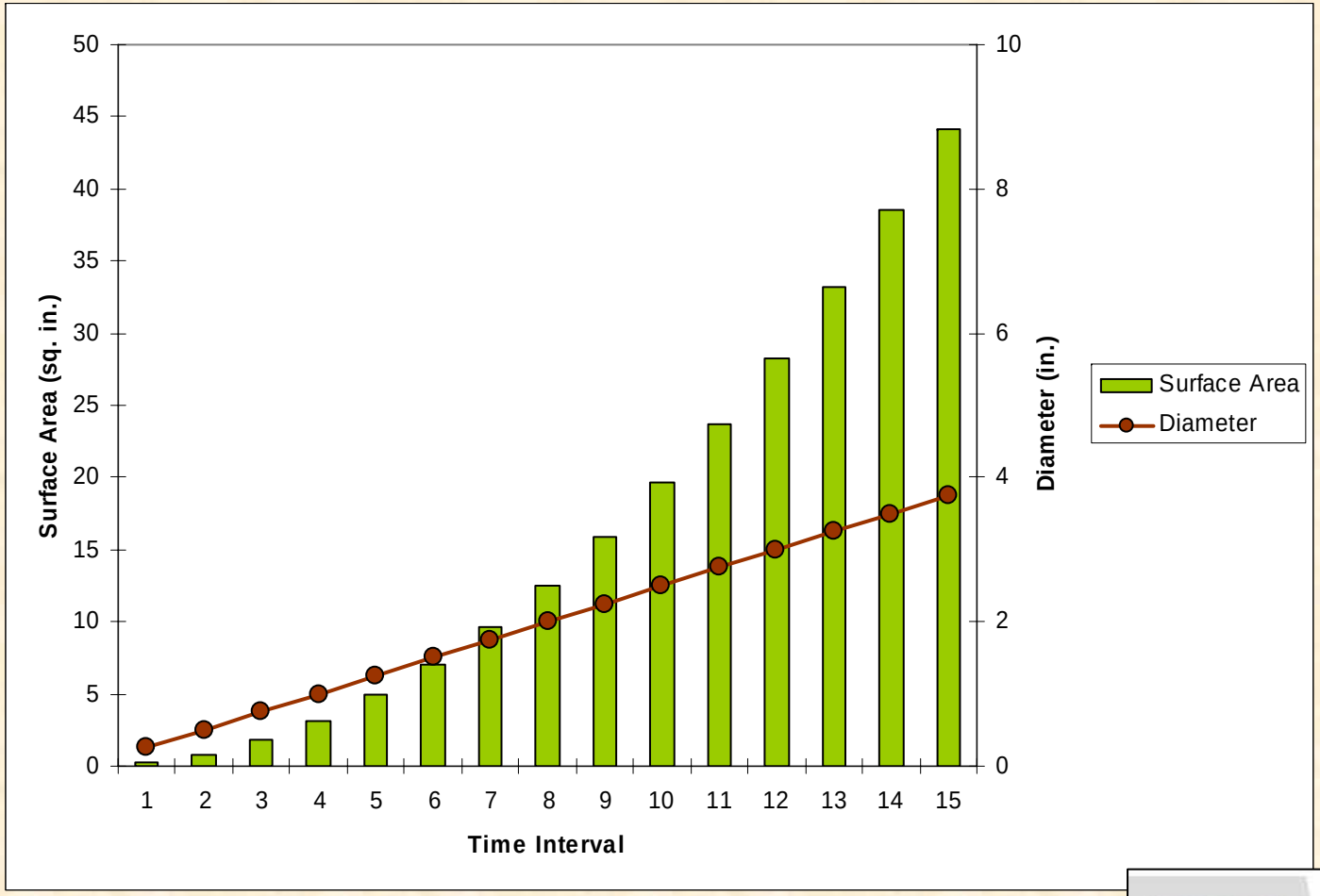
Increasing Diameter and Surface Area of a Sphere



2003 Flight Data and D-D Accumulations