Overview

• What do mythological symbols like Black Swans, Dragons and the Phoenix have to do with HLB?
• An economic perspective on HLB: How bad is it?
• Reflections on the role of research for rebuilding citrus after HLB
  • Lessons from my research and experience in pest economics and agricultural biotechnology
Black Swan

- An old phrase meaning something “impossible”
- A perfect wife is *rara avis in terris nigroque simillima cygno*
- Roman poet Juvenal late 1\textsuperscript{st} early 2\textsuperscript{nd} century
- Popular usage for centuries, then in 1590’s, the Dutch found real black swans in western Australia!
- Usage changed to become something thought impossible that is later proven possible

Thanks Wikipedia!
Black Swan

  - The event is a surprise (to the observer)
  - The event has a major effect
  - After the event, it is rationalized by hindsight
- World War I, fall of the Soviet Union, the personal computer, the Internet, and the September 2001 attacks
- Can’t be predicted using standard or usual statistical models, rather we need to make society more “black swan robust” (resilient)

Thanks Wikipedia!
Effects of a Black Swan Event

- The path you are following **permanently** shifts, you cannot go back, but you have embarked on a new trajectory
- New attitudes, new ways of thinking, new institutions
- A paradigm shift, a revolution, …

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The world has changed.  
I see it in the water.  
I feel it in the Earth.  
I smell it in the air. 
Much that once was is lost,  
For none now live who remember it.
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*J. R. R. Tolkien*

*British scholar & fantasy novelist (1892 - 1973)*

http://www.quotationspage.com/quote/31877.html

- The Great Recession
Real gross domestic product per capita (A939RX0Q048SBEA)

Source: https://fred.stlouisfed.org/series/A939RX0Q048SBEA
We seem to be on a new trajectory

Source: https://fred.stlouisfed.org/series/A939RX0Q048SBEA
Huanglongbing is a Black Swan

Florida Citrus Production

Source: USDA-NASS
Huanglongbing is a Black Swan

We seem to be on a new trajectory

Source: USDA-NASS

Florida Citrus Production

2004 – 2015
61% decrease
Florida production held steady as citrus bearing acres declined, until HLB

Source: USDA-NASS
Florida yield/A held steady, until HLB
Florida yield/A held steady, until HLB

1989-2004: 363 boxes/A

2005-2015: 309 boxes/A

Source: USDA-NASS
Florida yield/A held steady, until HLB

Yield (boxes per acre)

Source: USDA-NASS
What Fundamentally Transforms Nations?

- HLB is fundamentally changing US citrus production
- Walter Scheidel (Stanford history professor) new book on what stops socio-economic inequality “The Great Leveler”
  - Government Collapse
  - Revolutions
  - Pandemics
  - Total War
- See the book reviews in the New York Times (Dec 12, 2016) or the Atlantic Monthly (Feb 2017)
  - https://www.nytimes.com/2016/12/06/business/economy/a-dilemma-for-humanity-stark-inequality-or-total-war.html
What happens when a Black Swan lands?

People do stupid things!
Panic, Fear, Anger,
Denial, Disbelief, …

How do people respond to a crisis?

- Initial Responses
  - Panic: The sky is falling!
  - Blame Game: Who moved my cheese!
  - Denial: Stick your head into the sand
How do people respond to a crisis?

- False Hope: Grasp at Straws
- Depression
  - Passive: Dazed & confused, listless, withdrawn, wander
  - Active: Keep Calm & Carry On, Go thru the motions, Sisyphus
- Fight: Circle the Wagons, Defense
- Quit: Abandon ship, lose hope
• Dragon = Power, grandeur, a primal force
• Political power often uses dragon iconography
  • East: Lucky, wise, benevolent (Mushu in Mulan)
  • West: Malice, trickery (Smaug in The Hobbit)
• HLB is both types of dragons
• Chinese word for crisis = danger + opportunity
  • Not true, but we want it to be!
• The space between black swans and dragons is where opportunity exists
• Yellow Dragon Disease or Yellow Shoot Disease?
Huanlongbing

• The HLB crisis is on-going, but we are in the middle of building a new path
  • Not everyone will make it
• Hard work, science and innovation, and luck needed to rebuild the citrus industry after HLB
• The Phoenix is the symbol of rebirth, with one generation born from the ashes of the previous
• Citrus will see new leaders, new intuitions, new ways of doing things
• Return to glory?  Collapse?  Smaller & leaner?
Why all the Myth and Symbolism?

- Humans have used myths and stories, symbols and imagery to motivate and inspire for thousands of years.
- Humans are social and spiritual beings and we all need inspiration and motivation, even scientists.
- We should remind ourselves that improving the science about HLB to help rebuild citrus globally is an useful and honorable activity worth our time and effort.
- Scientists need inspiration too: “the day-to-day work of science is intensely boring” (Stephen J. Gould, Sci Am 1995)
Economic Research: How bad is HLB?

- Joint research led by Dr. Fengxia Dong at UW
- What is the economic impact of HLB in Florida?
- In what way and how much has HLB contributed to the decline in citrus bearing acres?
- Analyze newly planted citrus acres and removal of citrus acres and yields
Florida Citrus Bearing Acres: Declining since 1997

Source: USDA-NASS
Florida Citrus New Plantings and Removed Acres 1990-2015

Source: USDA-NASS
New Citrus Planting (w/ Dr. Fengxia Dong)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Acres: 5-Yr Average</td>
<td>0.051*</td>
<td>0.065</td>
</tr>
<tr>
<td>Expected Long Run Profit</td>
<td>32.4**</td>
<td>0.041</td>
</tr>
<tr>
<td>HLB</td>
<td>-5.29*</td>
<td>0.096</td>
</tr>
<tr>
<td>New Acres as % of Bearing Acres</td>
<td>12.6</td>
<td>0.554</td>
</tr>
<tr>
<td>Expected Long Run Yield</td>
<td>0.002</td>
<td>0.969</td>
</tr>
</tbody>
</table>

- As expected long run citrus profit increases, new citrus planting increases
- When HLB arises, new citrus planting decreases
- As the long-run average bearing acres decrease, new citrus planting decreases
Citrus Removal (w/ Dr. Fengxia Dong)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Acres: 5-Yr Average</td>
<td>-0.026</td>
<td>0.649</td>
</tr>
<tr>
<td>Expected Short Run Profit</td>
<td>-40.4*</td>
<td>0.053</td>
</tr>
<tr>
<td>HLB</td>
<td>-17.2</td>
<td>0.251</td>
</tr>
<tr>
<td>Hurricane</td>
<td>3.16</td>
<td>0.765</td>
</tr>
<tr>
<td>Housing Price Index</td>
<td>0.178***</td>
<td>0.009</td>
</tr>
</tbody>
</table>

- As expected short run citrus profit increases, citrus removal decreases.
- When the price for houses increases, citrus removal increases.
- HLB does not significant effect on aggregate removal.
## Citrus Yield: Boxes per Bearing Acre (w/ Dr. Fengxia Dong)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing Acres Decrease</td>
<td>-0.130</td>
<td>0.283</td>
</tr>
<tr>
<td>Expected Short Run Profit</td>
<td>122.5***</td>
<td>0.010</td>
</tr>
<tr>
<td>HLB</td>
<td>-106.5***</td>
<td>0.001</td>
</tr>
<tr>
<td>Hurricane</td>
<td>25.8</td>
<td>0.319</td>
</tr>
<tr>
<td>Trend</td>
<td>1.49</td>
<td>0.512</td>
</tr>
</tbody>
</table>

- As expected short run citrus profit increases, citrus yield increases.
- When HLB arises, citrus yield decreases.
Citrus Market Before and After HLB

Before

After
Impact of HLB on Social Surplus

$ Value Economists use to Measure Impact

Surplus Before = \( CS_0 + PS_0 \)  
Surplus After = \( CS_1 + PS_1 \)  
HLB Impact = \( (CS_1 + PS_1) - (CS_0 + PS_0) \)
Impact of HLB on Social Surplus (w/ Dr. Fengxia Dong)

• Estimated yield loss due to HLB = 29.3%
  • Singerman and Useche (2016) = 33% for Southwest Florida based on grower survey
• Cost impact of HLB = 27.5% increase based on Muraro (2012) average for 2007-2010 across regions
• HLB causes $466 million per year in Losses (Preliminary)
  • $125 million in Consumer Losses
  • $341 million in Producer Income Losses
• Does not include the multiplier effects
• Average farm value of Florida Citrus over the last 10 years (2006-2015) = $1.237 billion
Implications of $466 Million Loss

- $341 million annual producer income loss means less money for growers to do and to fund research and to invest in mitigation and management alternatives
  - Singerman and Useche (2016) report larger losses for other Florida regions
- Can estimate how large the social losses could be for California or other regions (Mediterranean)
- Cost-benefit analysis would justify lots of spending for
  - Prevention, monitoring, eradication, delay, containment
  - Research for solutions, mitigation and management alternatives and outreach education and training
Rebuilding Citrus after HLB

- What will the new citrus industry be?
  - A return to the glory days?
  - A smaller and leaner citrus?
  - Collapse?

- Innovation and Research will be the foundation
- Different types of innovation and research needed and best done by different agents with different funding and incentives and rewards
  - University and government
  - Private industry: multi-nationals and businesses
  - Farmers and crop consultants

Rebuilding Citrus after HLB

• “Traditional” research and innovation
  • Temporary/short-term management of the problem?
  • Help industry survive until better alternatives found?
  • As good as it gets? The new reality of citrus production?
• Research and innovation roles for everyone
• Risks and economics better understood

• Biotechnology
  • Lots of possibilities
  • Mostly by government, university, multi-nationals
  • Risks and economics less understood
Insect Vector Management

- Insecticides/Biocides to manage the vector or pathogen
  - Usually only multi-nationals can afford to discover, register and distribute a new AI and earn ROI
  - Adding new pest/crop to an existing label cheaper
- Biological Control
  - Often only public sector, difficult to make commercially viable ROI
  - Practical application needs farmers and consultants
- Insect and Pathogen Biology
  - Governments, universities or multi-nationals
  - Helps improve chemical and biological control
  - Local/practical knowledge from farmers and consultants

http://californiacitrusthreat.org/pest-disease
Insect Vector Management

- Areawide management likely needed to coordinate actions, to reduce inoculum, to clean up abandoned acres
- Requires developing and implementing new institutions or processes to facilitate cooperation
- Social innovation and research: behavioral economics: need both theoretical and practical knowledge
  - Universities/government research, with key outreach and extension roles
- How do you pay for these institutions and activities?
- Citrus will not be the same, the social fabric of the industry will change

http://californiacitrusthreat.org/pest-disease
Resistance Management

- Pests and pathogens will become resistant to control methods eventually, can only slow/delay the inevitable
- Biological issues differ by species and control methods
  - Multiple methods/modes, rotate modes, full dose, …
- Social aspect important: How do you get farmers and industry to follow resistance management?
- Common issue underlying many problems: Current costs with future benefits or Current benefits with future costs
- Social innovation and research, behavioral economics, both theoretical and practical knowledge
- Research at all levels: university, government, extension, large corporations, farmers and agricultural professionals
Citrus Under Protective Screen (CUPS)

- Cultural control, more than just HLB, other pests/pathogens, sunburn, wind scaring, humidity, food safety, …
- Used globally for different crops
- Highly managed system: pests, water, nutrients, …
  - Trend towards data-driven adaptive management, tree-specific monitoring and management
- Research and innovation: universities/government to estimate efficacy, productivity gain, & cost
- The real innovation will be by farmers and private companies to make it commercially viable

Biotechnology

- Transgenic/Cisgenic Crops: move genes between or within species
  - Roundup Ready and Bt crops
- RNAi: Species-Specific AIs
  - Foliar sprays field testing
  - PIPS in corn for corn rootworm commercialized soon
- Gene Editing: CRISPR/Cas9, TALENS, ZFNs, …
- Gene Drives: Introgress desirable genes into populations
Potential HLB Applications

• Trees that are immune, resistant or tolerant to HLB
  • Transgenic Trees: Spinach defensins (SoD2) in process
• Rootstocks that convey immunity, resistance or tolerance to HLB in the whole (grafted) tree
• Species-specific RNAi sprays or PIPS for HLB vectors
• Transgenic/Cisgenic/Gene Edited insects that no longer transmit the HLB pathogen, then add a gene drive to make them the dominate population type
• Gene edited insects plus a gene drive to eradicate HLB insect vectors
• More ideas and inventions will come and will be needed
Lessons to Learn from Biotech Crops

• Roll out of Roundup Ready® and Bt crops did not go well!
  Failure to explain, educate public about GM: a mistake: Monsanto

• Recent food crops
  • Arctic Apples: Fuji, Granny Smith, Golden Delicious
  • Simplot’s Innate® White Russet Potatoes

http://www.arcticapples.com
http://www.innatepotatoes.com
http://www.innatepotatoes.com
White Russet Lessons

- Names carefully chosen: Innate, white russet
  - Cisgenic, no antibiotic or herbicide markers
- Consumer traits the initial focus
  - Gen 1: Bruise resistant/anti-browning, low acrylamide
    - Sold in 2015 ~2,000 acres, 2016 ~5,000 acres
  - Gen 2: Late blight resistance, reduced sugar-end defect
    - Approved for sale in 2017, planted this spring
- Careful supply chain control, segregation, contracting
- Focus on institutional, pre-processed uses (diced), chips
  - Currently not accepted by McDonalds or Frito-Lay
- Built industry/stakeholder and consumer awareness early

http://www.innatepotatoes.com
Specialty Crops Regulatory Assistance (SCRA) Workshop Sep 2016

Tuesday, 20 September 9:00am - 5:00pm

9:00am  Case Study 1 - Citrus Tree Defensin Protein. Moderator: Beth Hood
         Overview and Introduction by developer: Mike Irey, Southern Gardens Citrus

9:45am  Presentations by agency representatives
         APHIS (30min) Margaret Jones, USDA-APHIS BRS
         EPA (30min) Milutin Djurickovic and Shannon Borges, EPA

10:45am Break

11:00am Presentations by agency representatives continued
         FDA (30min) Bob Merker, FDA

11:30am Case Study 1 Discussion

12:30pm Networking Boxed Lunch

1:30pm  Case Study 2 - Simplot W-8 Potato. Moderator: John Cordts, Cordts Consulting
         Overview and Introduction by developer: Susan Collinge, J.R. Simplot

2:15pm  Presentations by agency representatives
         APHIS (30min): Kate Rappaport, USDA-APHIS BRS
         EPA (30min): Milutin Djurickovic and Shannon Borges, EPA

3:15pm  Break

3:30pm  Presentations by agency representatives continued
         FDA (30min): Bob Merker, FDA

4:00pm Case Study 2 Discussion

http://www.specialtycropassistance.org/content.cfm?m=247&id=247&startRow=1&mm=0

- Citrus Tree Defensin Protein
- Simplot’s Innate Potato
Citrus vs Potato Biotech

- Meeting regulatory hurdles takes a long time: Years
  - Corn/Soy: new active ingredient or biotech event costs $250-$280 million and takes 10-15 years
  - $20-$30 million in regulatory costs (McElroy 2003)
- Both agreed that regulators are there to help, but you have to follow their process
- Lessons potato mentioned that citrus did not
  - Inform industry stakeholders of commercial intentions and timelines: communicate early
  - Think about trait stewardship and trait durability for commercial business, how to extend trait
    - How will you determine if field failures are trait failures, resistance or due to some other cause?
What will Consumers Think?

- Perceptions are reality in marketing
- Deployment process will matter: keep building awareness of the HLB problem and efforts to find solutions
  - Most Midwesterners do not know about HLB
- Perceptions of biotech citrus will partly depend on who owns it and makes money from it
  - Ringspot virus resistant papaya vs Roundup Ready® soybean: GM opposition as anti-corporate
  - Supportive or at least not automatically against GM
  - How do you manage to keep this positive image going?
Biotech Citrus

- Inform industry of commercial intentions and timelines
- They can develop and recommend marketing and deployment strategies
- Marketing is actually quite expensive, let them help!
A Dose of Reality

• Biotech solutions will take time to be developed, registered and commercially used – years
  • Traditional insect vector management, foliar-tree feeding, CUPS, etc. will be needed, likely for years
  • They will be part of resistance management for traits
  • They may be the only solutions we ever have
• We never “solve” pest problems, just manage them
  • Species are under tremendous pressure to evolve resistance to any management: insecticide, cultural control, RNAi, gene drive, …
  • If eradicate one pest, another one will take its place!
• Sustainable pest management means using multiple methods: biotech is not a silver bullet, just one tool
Summary

• HLB is a Black Swan event
  • Large losses and big changes, but also opportunities
  • Careers will be made, new leaders and new institutions will emerge, citrus will change
  • Future still uncertain, collapse could occur
  • Need good science and innovation, motivation matters

• HLB is bad: preliminary estimate is $466 million/year loss
  • Justifies a lot of spending for research on solutions and on prevention and containment
  • As losses continue, lose infrastructure and capital, citrus erodes in consumer consciousness
  • Now is not the time for complacency
Summary

- Biotech solutions for HLB
  - Transgenic citrus in process: Spinach defensins (SoD2)
  - Lots more options possible: other transgenic and cisgenic, RNAi, gene editing, gene drives, …
- Commercialization takes years after the Eureka!
- Communicate with stakeholders early and often
- Consumer preferences seem to be changing, pay for savvy marketing and watch potatoes and apples
- Technology stewardship is important: the insect vector and/or pathogen will develop resistance
  - Have a stewardship plan & a process for field failures
Summary

- Traditional management practices will be needed for some time
  - Insecticides, biocontrol, cultural control, agronomics, …
  - Survive until biotech or better alternatives emerge
  - May be the only management options we have
  - Part of resistance management for biotech solutions
  - Some consumers will reject biotech citrus: niche market
- Innovation does not only happen in labs or field plots
  - Social science: New institutions and coordination, extension, organizations, private sector
  - Business: Good ideas still need to acquire capital, coordinate efforts, create cash flow and generate ROI
Questions?
Comments?

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