Best Practices for Parasite Control in Beef and Dairy Cattle

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Why me?

- Not a parasitologist
- Live in parasite heaven
- Interest and passion
Goals

- Go back to biology of nematodes
  - Will learn from past mistakes in small ruminants
  - Will use beef cattle as template
  - Cover dairy at the end
- Think through some scenarios
- Leave you *Dazed and Confused!*
Parasite *Control Program vs. Deworming Program*

- There is no cookbook deworming program
- Depends on location in US
- Depends on management on individual herd
  - Cow-calf vs. stocker vs. feedlot
  - Grazing management
    - Rotational grazing
    - Permanent vs. prepared seedbed
    - Total confinement
Parasite control recommendations are not made in a vacuum!
Parasites

- Decreased feed intake
- Decreased milk production
- Decreased reproduction
- Decreased weight gains, etc.
Life Cycle

Parasite Resistance in Livestock

- Is there a problem?
  - Goats—absolutely
  - Horses—yes
  - Cattle—rising
Anthelmintic Resistance

- Inevitable with drug use
- Can also come in with animals – BIOSECURITY!
Anthelmintic Resistance

- Is a demonstrated reduction in the efficacy of an anthelmintic against a nematode species.
  - Reduction in the % kill against a specific worm species, compared to a proven baseline.
- It is due to a change in the genetic makeup of the worm population that allows it to survive the drug
- “Bad” worms
Refugia

- The proportion of the population that is not selected by drug treatment
  - “In Refuge” from drug
- Population of worms with susceptible genes
  - Dilutes resistant worms in that population
  - On pasture (main area) + in animal
- Key component of slowing drug resistance selection
- “Good worms”
Parents

Selection for Drug Resistance

Drug Treatment

Next Generation

Susceptible

Resistant
Anthelmintic Resistance

- Resistant alleles initially at very low numbers (genotypic resistance)
- Selection pressure
- More worms with resistance genes
- Ultimately phenotypic resistance
  - When ivermectin first released it was not 100% effective
    - Resistance genes pre-exist in worm populations ("tolerance")
Genetics: Worms

- Innate resistance
  - Some worms more resistant than others to certain products—or some products work better against some parasites than others

- Genetic “true” resistance
  - Genetic mutations selected for with drug use over time

- Change in population balance
  - Now more pure *Cooperia* infestations
Gastrointestinal Nematode Resistance Across Active Ingredients

• Typically, gastrointestinal nematode resistance to one active ingredient of a chemical family results in resistance to other active ingredients in that same chemical family

• Within parasite genus or species, resistance to multiple chemical families has been observed

• Resistance is forever
Selection Pressure

- Level of refugia
- # of treatments
- Pharmacokinetics of drugs
- Host parasite interactions
- Biology of the parasite
- Very complicated
Are You Confused Yet?
Are their lessons learned from other livestock species?
Haemonchus contortus
(Barber Pole Worm)

• Sheep, goats, deer, exotic ruminants
  – Also growing problem in cattle
• Blood-sucking worm
  – highly pathogenic
  – anemia
  – hypoproteinemia -- “bottle jaw”
• Most important parasite in sheep/goats raised in warm/wet environments
  – Southern US
Why is *H. contortus* such a problem?

- Very fecund ~ 5,000 eggs per day
  - 300 worms 1.5 million epd per animal
  - 30 goats/sheep 1 billion eggs over 3 weeks
So What Happened in Sheep and Goats?

• The Perfect Storm
  – *Haemonchus contortus*
    • Very fecund
  – Less than 3 week life cycle
    • Lots of infective larva very quickly
    • Many generations over a summer
  – Long transmission season - southern US
    • All year long in some parts
  – Goats acquire little immunity
    • Immunity is slow to develop in sheep
Background to the Problem

- Age of modern anthelmintics
- Parasitologists (and subsequently veterinarians in the field) recommended strategies that maximized benefits of treatment
- Over-reliance on anthelmintics
  - Over-use of anthelmintics
  - Therapeutic vs. prophylactic
  - Loss of common sense management-based approaches
Managing Toward Resistance

• Deworm 6-12X per year
  – Whether needed or not to keep sheep/goats alive
• Underdosing
• Treat everything and move to “safe” pasture
  – NO REFUGIA!
• No pasture rotation
  – Parasites build up – More need for treatment
• The Boer goat arrived
  – No biosecurity
  – “Condominiums for Haemonchus” DG Pugh
The End Result

• Multi-drug resistance is widespread and getting wider in sheep and goats
• Many farms have worm populations that are resistant to all products currently available
  – 1 in 5 in SE (2008)
Cattle Parasites

- *Ostertagia ostertagi*
  - Most pathogenic parasitic species in cattle
- *Haemonchus placei*
- *Trichostrongylus axei*
- *Cooperia sp.*
- *Nematodirus*
- *Bunostomum*
- *Strongyloides*,
- *Oesophagostomum*
- ETC.
Cattle: Ostertagia

- Cool season parasite
  - Loves winters in the south
  - Loves summer in the north
  - Somewhere in-between in the rest

- Hypobiosis
  - Hates summers in the south, etc.

- Type I
- Type II
Cooperia and Haemonchus placeii

- Immunity develops by about one year
- Warm season parasites
  - More of problem in summer
- Rarely cause problems unless in high numbers
  - Intense grazing systems
  - Same pastures used for young calves year after year
    - Few studies (and old) and usually C. oncophora which is considered least pathogenic
    - punctata > pectinata > oncophora
- Resistance is a concern with these parasites at this time
  - Usually C. punctata
  - Don’t know if resistant parasites will be more pathogenic
  - Recent study of pure C. punctata in feedlot showed significant decreases in ADG and intake
Parasites in Cattle

- *Haemonchus contortus*
  - Increasing reports of this in cattle
  - Calves exposed to high levels
  - Pastures with previous goat grazing
  - Low immunity - DAIRY CALVES
Parasite Control: Historical

- Strategic deworming for Ostertagia
  - When parasites can’t survive in environment
  - Most of parasites are in animal
  - Deworming + environmental control = best knockdown
  - Prevents Type II disease
  - Knocks down parasites going into tough nutritional times

- IS THIS STILL A GOOD RECOMMENDATION?
  - Million dollar question
Anthelmintic Resistance: Situation in Cattle
Anthelmintic Resistance in Cattle Parasites

- **US**
  - Well-documented peer reviewed case reports in literature are increasing
  - Started with high-intensity stocker operations
    - >20 yrs use of ivermectin 6-12X per year
  - Two research stations in LA so far
  - Many anecdotal reports
Anthelmintic Resistance in Cattle Parasites

• Kaplan lab, UGA
  – Cow calf operations in Georgia
    • Eprinex, Dectomax, combo Safeguard/Dectomax
    • ML-resistant Cooperia were present on 5 of the 6 farms
    • One farm also ML-resistant Ostertagia (FECR=84.7%, 90%) and Haemonchus (FECR=16.3%, 45%) Epx and Dect. respectively
Anthelmintic Resistance in Cattle Parasites

• Worldwide
  – Name a parasite-dewormer combo and probably a report
  – Ostertagia rising
Anthelmintic Resistance in Cattle Parasites

• Highly effective dewormers available
• Started relying on anthelmintics for strategic control
• Forgot about other methods
  – Reason we have had cases in stockers
    • Paid on gains
    • Use “better” dewormer more frequently
Compounding Factors

- Acquired Immunity
  - Variable
  - Never complete
  - Some exposure is good/needed

- Age
  - Immunity to Ostertagia takes longer
  - Adults never exposed

- Breed
  - Brahman

- Sex
  - Males

- Nutrition

- Larval inhibition

- Within breed
  - Heritability Index = 0.3
Treatment failure ≠ Resistance
Non-Resistance “Treatment Failures”

- **Inadequate dose administered**
  - Underestimated weight
  - Drug was spilled/spit-out
  - Calculation errors
  - Suspensions not thoroughly mixed
  - Invalid extrapolation of dose
  - Treatment not actually given

- **Activity of the drug reduced**
  - Beyond expiration date
  - Stored improperly
  - Generics
  - Very thin animals?

- **Reinfection!**
Non-Resistance “Treatment Failures”

• **Errors in FECRT**
  – Improper or non-quantitative egg counting technique
  – Re-infection
    • Sampled too late after treatment
    • Variation among species & strains
  – Inadequate time for drug to work
    • Sampled too soon after treatment
  – Wide variation within and between animals
What Does All This Mean???

- A diagnosis of parasitism is not indicative of an anthelmintic deficiency, but of a management problem
- Anthelmintics can no longer be thought of as a management tool to be used as needed to improve animal productivity
- Control must be practiced with an eye to the future
- Reality = effective long-term control will only be possible if anthelmintics are used intelligently with prevention of resistance as a goal
What about diagnostics?
Fecal Egg Count Reduction Test

- Suspect lack of efficacy if less than 95% reduction in Fecal Egg Count (FEC)
  - Really for sheep and goats
    - Cattle/horses not validated
    - FEC should start out greater than 100? 200? to be valid
  - Cutoff should be 98%?
  - Compared to pretreatment counts
    - Each animal is its own control
  - Compared to control group
    - Pour-ons and licking behavior

- “Zero-inflated Bayesian hierarchical models”
FECRT Phenotypic Resistance

- Perhaps not think about resistance as “yes” or “no” but as sliding scale
  - FECRT won’t detect until 25% genetic resistance (in sheep and goats)
  - Then it’s too late
Cattle FECRT Issues

• Often low beginning EPG
  – Account for statistical variability??

• Fecundity
  – *Cooperia* & *Haemonchus* more fecund
    • EPG higher but less pathogenic worms
  – Changes with immune status, season

• *Ostertagia* Pre-type II infestation
Cattle FECRT Issues

• Fecal water and volume influence weight and EPG
• Anthelmintics may temporarily sterilize but not kill worms
  – Falsely low EPG-miss resistance?
• You can take multiple samples from the same fecal pat and get varying numbers
  – Can vary with time of day
FECRT Issues

• Variation within lab

• Method
  – Sugar with centrifugation is gold standard
  – Salt/McMasters and Flotac
    • Not as sensitive
  – Standing sugar float
    • Not quantitative
    • StatSpin OvaTube, SqueezeTest
      – May be superior to just standing float for recovery of eggs and make centrifugation less messy
      – Still not quantitative
Hill Farm Research-Summer 2011 (drought)
Dean Lee Research-Summer 2013 (high rainfall and age)

Average EPG
Strongyliid Eggs

• Cannot differentiate HOTC complex eggs
  – “The mother worms cannot even differentiate the baby eggs”
    Dr. Tom Craig, TAMU
Fecal Egg Counts

- Economics vs. disease/welfare
- Economic threshold (USA)
  - Cows - 20 EPG
  - Calves - 50-500 EPG
Other Diagnostics for Evaluating Resistance

- Coproculture
  - Hatch eggs then actually identify and count larvae
- PCR
  - Can give semi-quantitative results as to which eggs are from which species
  - Quantitative techniques under investigation
- Genetic tests
  - Have to know mutation, probe for each mechanism
- Pooled fecal tests, Flotac, phone counting app. Etc.
Other Diagnostics for Evaluating Resistance

- **Drenchrite®**
  - Larval development assay
  - Validated for *H. contortus* (sheep/goats)
    - Detects genetic resistance at 10%
    - Only for drugs effective against larval stages
    - Get “titered” results, larvae identification
- **“Tracer” animals**
  - To estimate pasture contamination/efficacy
  - Expensive/time consuming
  - *Only definitive test for efficacy/resistance*
What About Control?
Targeted Treatment (TT) and Targeted Selective Treatment (TST)

• TT
  – Treat whole herd based on risk keeping refugia in mind
  – Goal is to reduce number of treatments to herd of flock
    • Opposite of “strategic deworming”
      – More prophylactic based on historical epidemiology
• TST
  – Only treat those that will benefit most
  – Based on parasite or production indicators
    • Sheep simulation study indicated that live weight may be best indicator
  – Some studies show it only takes leaving 10% of group untreated to work
    • Likely animal-parasite-age-locale dependent
TST of Sheep/Goats

- Worms not equally distributed
  - 80:20 Rule
- Most worms = most anemic
  - *Haemonchus contortus*
  - Treat or cull (FAMACHA)
  - Genetic selection tool
  - Minimize pasture contamination
- Maximize production vs. sustainable business
  - Survival of the fittest
Selective Treatment

FAMACHA
Five Point Check©

- Eye, back, tail, jaw, nose/coat
- Addresses limitations of FAMACHA
- Helps deal with decision on FAMACHA score 3s
Bottom Line-Goats in Louisiana

- Purebred ("line" bred) show goats
  - Do not ever live on grass
  - Drylot

- Commercial goats
  - Crossbred does
  - FAMACHA to select survivors
  - Purebred bucks for genetics
    - Only on grass during breeding season
Beef Cattle
The Good

- *Haemonchus* (sheep/goats) vs. *Ostertagia* (cattle)
  - *Haemonchus* very fecund compared to *Ostertagia*
  - If combined with bad management- quickly get large numbers of resistant parasites
  - (High output good if need refugia)
  - Could be bad for stockers under “bad” pasture management
    - *Cooperia/Haemonchus*
  - *H. placeii* most common in calves=longer prepatent perion than *H. contortus*
The Good

• *Ostertagia* usually doesn’t kill
  – *Haemonchus* in sheep/goats does
    • Leads to more need for treatment
• *Ostertagia* least likely to get resistance “buildup”
  – Short lived adults-die off quicker
  – Less time to produce eggs
  – Buildup of resistant parasites will take longer
• Cows act as vacuum cleaners for *Cooperia* and *Haemonchus*
The Good

• There is hope for diagnostics
  – Drenchrite
  – Statistical modeling -diagnostics and epidemiology
  – Genetic tests for worm populations and animals (SNPs)
• There is hope for increasing refugia
• Because of awareness, producers more likely to listen to us
The Bad

- Resistant genes already there
  - No way yet to detect
- No product is immune
- Resistance is forever
  - Except for levamisole
    - Reversion to susceptible in 7 years with no use (sheep)
- We are less likely in cattle to have something clinical, simple, effective and chuteside like FAMACHA
The Ugly

• What we don’t know
  – What role does refugia play in cattle?
    • Should we continue to recommend strategic deworming of all cattle at once?
      » Decreases refugia but also decreases the need for as many future treatments
  – How exactly should we modify our current recommendations
    • Different types of operations (cow-calf vs. stocker)
    • Different parts of the country
    • Different times of year
    • Grazing-young before old or vice versa
The Ugly

• If we want to selectively treat/cull susceptible individuals, how do we do that?
  – FEC?
  – Body condition?
    • Young vs. older
    • Sheep and goats
      – most resistant usually not best growth
The Ugly

- Heritability of FEC is low to moderate
- Correlations of FEC to other production traits
  - Mixed results
    - Cattle-FEC and weaning/yearling weight was .41/.34
      - Positive but unfavorable correlation might be due to resilience-ability of host to maintain undepressed production under parasite challenge
Genetic Markers: Animals

• One gene or multiple?
• Same for all parasites or parasite dependent
  – BRDS
• Animal species/breed dependent
  – Taurus vs. indicus
• Genotype x environment interactions
  – Organic, high rainfall, arid, etc.
The Ugly

• Will we see resistance in *Ostertagia*?
  – Or better question-when will we see…??

• Is resistant *Cooperia* more pathogenic?
  – Will that change expected patterns?
    • Number of parasites to be pathogenic
    • Problems in older animals
    • Changes in seasonal patterns

• It is a moving target
  – Can we figure our what to do before it changes again
Now What?

• Based on what we know and surmise, what are best practices for diagnosis and control?
Best Management Practices: Fecal Sample Collection and Quantitative Egg Counts for Detecting Anthelmintic Resistance in Cattle

- Collect approximately 20 fecal samples (more is better) from group of cattle of similar age at the time of deworming. Always take samples from the rectum and place in a plastic bag. Remove any excess air and seal the sample. Refrigerate if samples will not be performed the same day.
- Perform McMaster’s technique for quantitative fecal egg counts. If sample is 0 on McMaster’s, perform a Wisconsin Double Centrifugal Sugar Flotation.
- In 14-21 days collect follow-up fecal samples from the 15 animals with the highest eggs per gram from the previous sampling.
Best Management Practices: Fecal Sample Collection and Quantitative Egg Counts for Detecting Anthelmintic Resistance in Cattle

• Calculate the % fecal egg count reduction for each animal
  \[ \frac{\text{Sample 1 EPG} - \text{Sample 2 EPG}}{\text{Sample 1 EPG}} \times 100 = \% \text{ reduction in eggs per gram} \]

• Average the results

• Consider turning in pooled fecal samples pre and post treatment for parasite species identification via coproculture

• If submitting samples to a commercial lab for fecal egg counts, make sure to ask for the above techniques.
FECRT Summary

• Take as many fecals as possible
• Pick 15 animals with highest counts-repeat on same animals!
• Wait at least one month after start of grazing
Control in General

• Increase immunity
  – Protein
  – Newer research looking into delaying treatment to increase immunity and decreasing need for treatment later
  – Increase growth = increase need for forage = increase intake = increase exposure to larvae = increase immunity early (computer modeling)
Control in General

- Use cows as vacuum cleaners for calves
  - Also other grazing livestock species
    - Horses, goats
- Don’t buy resistant worms
  - Deworm with multiple classes on arrival
  - Drylot for 24-48 hours
  - Turnout onto contaminated pasture
- Cull poor doers
- USE HYBRID VIGOR!
Pasture Rotation for Parasite Control

• Pasture rotation is not necessarily for parasite control

• Rotate for pasture management & nutritional management
  
  • Sometimes it’s bad
    – “Bermudagrass was developed to propagate Haemonchus”
      Tom Craig, TAMU

• Can help control secondary effects of parasites
Clean vs. Contaminated Pasture

- **Cleaner**
  - Environment cleans
    - Ostertagia in summer
    - Cooperia in winter
  - Grazed by other species
  - Stocker pastures grazed by cows (cleaner)

- **Cleanest**
  - Tilled and planted
  - Used for hay

- **Contaminated**
  - Permanent pastures
  - Overseeded pastures
Rotation of Dewormers

• Pick the right product for the right time
  – Inhibited larva
  – Fly control benefits
• Don’t just use for fly control
Use products properly

- Use generics with data to back them up
- Use pour-ons sparingly
- Dose adult cows with dose for heaviest cow
- Dose calves based on actual weight or heaviest
- Don’t deworm in feed or mineral
- Store products properly
  - Not outside!
- Combos
Keeping Refugia

• Either on pasture, in animals, or both
  – If you have a clean pasture, you need some “dirty” animals
    • Don’t deworm all animals before turnout onto clean pastures
      – Especially with macrocyclic lactones and other long acting products
      – Most practical with cow-calf pairs
        » Don’t deworm cows 5 years and over-older cows then have refugia
        » Based on breed and locale
      – Avoid deworming cows going into summer in South-no Ostertagia refugia
  – If you want to have all clean animals (calves, stockers, replacement heifers) have “dirty” pasture or non-permanent pastures
    • Avoid keeping replacement heifers that have all been dewormed and then put on clean pasture for grazing
      – They will likely only have resistant parasites in the gut
      – If a must, treat like new arrivals (combo treat, drylot, turnout on contaminated pasture)
Keeping Refugia

• Targeted selective treatment of calves based on FEC
  – Hard sell to producers but best way to keep Cooperia refugia
  – Some initial studies indicate this can be done with little impact on production
  – Very dependant on situation

• Stockers from multiple sources
  – Source of cattle had the most influence on performance
  – Overshadowed parasite control differences
Keeping Refugia

• For replacement heifers where deworming the whole group may be desirable
  – Turn out onto contaminated pasture following deworming
• Avoid keeping replacement heifers that have all been dewormed and then put on clean pasture for grazing (ex, from stocker operation)
  – They will likely have only resistant parasites in the gut
  – If unavoidable, treat like new herd additions above
• Avoid using the same pastures for young stock year after year
  – For example, don’t raise replacement heifers in the same pasture year after year – move the “heifer pasture” around on the ranch
Keeping Refugia

• For stocker calves where deworming the whole group may be desirable
  – Avoid permanent pastures used only for young stock combined with long-acting products
  – This is certain to produce an almost pure anthelmintic resistant population of parasites over time

• If long-acting products are used, all stockers should go to feedyards for eventual harvest, and pastures should be tilled, used for hay or left fallow for several months
  – Even if you turn out onto contaminated pasture cattle act as vacuum cleaners and eliminate pasture contamination over time
  – Only thing left are resistant parasites in the animal
  – Will they prevent development of immunity?
Replace Refugia???

- Some studies show promise
  - Sheep
  - Cattle
Pitfalls

• Type II Ostertagiasis
  – If becomes a problem, may have to re-evaluate program

• Switch to more use of benzimidazoles may lead to resistance in that class
Alternative Controls

- Tannins in forage (fresh or hay/pellets) to decrease egg hatching and infective larvae development
  - *Sericea lespedeza*
Condensed Tannin Containing Plants

- Sericea lespedeza
  - Forage that grows relatively well in SE US
    - Weed ???
    - Establishment as pasture may fit some operations
    - Hay, meal, pellets, etc. may be suited for many other operations
  - Has effect on *Haemonchus*

- Plant extracts
  - Drench or in pelleted feed
Copper-oxide Wire Particles

- *Haemonchus* only
- Marketed for use in cattle (Copasure) where copper deficiency is common
- Appears to work better in sheep but potentially toxic
- May be worth a try in goats
  - Selective treatment for individuals (FAMACHA)
- Copper sulfate added to feed is not the same
  - Does not work
Worm-trapping Fungi

- *Duddingtonia flagrans*
  - Feed to animals, pass in feces, prevent larval development
  - Must be fed every day for 60 days
  - Works in other species also
  - Bolus being developed?
  - Affects all worm larvae in feces
  - Feed daily with supplement
  - Primary objective is to clean up pasture
  - Long term results (?, maybe 2-3 years)

https://www.youtube.com/watch?v=jOwCOLf0IRU
Vaccine

• Promising for *Haemonchus (Barbervax)*
  – Works well in sheep and goats
  – Drawback
    • 3 initial doses
    • Protection only lasts 6 weeks
  – Expensive to produce now
    • Genetically engineered product is under development
      – Cost will be acceptable if successful
Alternative Control

- Co-grazing with other livestock species
- Buy refugia?
- Breed selection?
  - Use resistant breeds for crossbreeding
    - Hybrid Vigor
- Other plants
  - Birdsfoot trefoil
- Vitamin E
- Immune modulating drugs
- Engineered probiotics Cry5B - protein made naturally by the soil bacterium *Bacillus thuringiensis*, which is harmless to higher animals but toxic to parasitic worms
- GMO worms and or GMA animals
- Integrated control programs
  - Sounds great BUT….
    - We don’t know yet what that actually entails
New Products?

- Resistance (~2 years) will outpace new drugs (decades)
- Monepantel (Zolvix®)
  - Amino-acetonitrile derivative (AAD)
  - US soon?
- Derquantel
  - Spiroindole (SI)
  - Sheep in Australia/NZ
    - Toxic to horses
    - Not likely to come to US
- “Worminator” system
  - New computer based technology for rapid screening of antiparasitic compounds
    - Looks at motility post treatment
    - Doesn’t work for ML well
Common Situations-Beef

• Assumptions
  – Early spring calving
  – Fall weaning
  – Retaining some replacements
  – Maybe keeping stockers
Common situations-Beef

- **Winter-with ryegrass**
  - High protein is good
  - But *Ostertagia* is happy
    - Pay close attention to deworming replacement heifers, young cows and bulls
  - Overseeded/drilled pastures that were recently grazed will likely be contaminated
    - Deworming all is probably ok but not always necessary
  - Prepared seedbed will likely have no refugia
    - Don’t deworm all right before turnout
    - Graze for a month then deworm all
Common situations-Beef

• Deworm in fall for flukes
  – Will affect other parasites also
  – Keep on contaminated pasture
  – Ivermectin + clorsulon-don’t treat all?
  – If severe problems requiring treatment of all ages consider albendazole?
  – Resistance in flukes?
Common Situations-Beef

• Winter-no ryegrass
  – Poor nutrition combined with permanent pastures during peak Ostertagia time spells potential disaster
    • Especially when combined with cold, wet, mud
  – Decision to deworm again depends on nutrition, BCS, diagnostics, previous deworming, etc.

• Spring
  – Deworm nursing calves based on fecals
  – Deworm replacements and bulls depending on winter deworming, fecal samples
Common Situations-Beef

• Summer
  – Deworm nursing calves based on fecal exams
  – Fall-born summer stockers
    • Most susceptible age for *Cooperia* going into peak *Cooperia* season
    • Best to treat with product selection based on diagnostics and based on fecal egg counts
      – >250 EPG = treat?
    • Consider combo treatments
      – Macrocyclic lactones plus a white dewormer (with levamisole also=best)
      – Need more research
        » All at once?
        » In series?
        » What order?
Common Situations-Dairy

- Calves in hutches-little risk
- Weaned from hutches-BIG RISK
  - The “heifer pasture”
    - Always same pasture(s)
    - Continuous use
- Milking-depends on management
  - Drylot-little risk
  - Grazing-evaluate situation and diagnostics
Common Situations-Zoo
Hoofstock

• Same issues with resistance
• Multi species exhibits?
• Evidence that integrated control strategies can reverse resistance (Disney Animal Kingdom)
Summary - What can we do now?

• Minimize other stressors
• Maximize nutrition
• Understand parasites in your locale
• Use best statistical analysis for FECRTs
• Think about refugia
• Think about pasture management
• Don’t buy resistant worms
• Proper product selection and use
• Cull poor-doers
Bottom Line

• Balancing Act
  – Short term economics
  – Long term sustainability
• Don’t know how much we can give up now vs. how much we will gain later
  – May never make up short term losses
• “The true meaning of life is to plant trees, under whose shade you do not expect to sit” Nelson Henderson
Refugia