Epidemiology and control of cystic echinococcosis

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Summary of talk

• Echinococcosis is a neglected disease
• Key epidemiological aspects, diagnosis and surveillance
• Basis for control of cystic echinococcosis
• Island and continental control programs
• Options, phases and structure of control
• Features of successful control programs
• Control in semi-nomadic communities
• Gaps and applied research needs
Public health and economic impact of cystic echinococcosis

• Human cystic echinococcosis results in 2-3 million lost DALYs per year globally

• 2 billion US$ in livestock production losses
  (est 2.5-20% reduction carcass wt)

• >50% of public health burden in China and Central Asia

• Cost of treatment Europe per patient 15,000-300,000 euros (surgery, chemotherapy)
Neglected Zoonotic Diseases (NZDs)


(Linked to **NTDs** 2011, 2015)

- Brucellosis
- Anthrax
- Leptospirosis
- Rabies
- Rift valley fever
- Zoonotic TB
- Echinococcosis
- Cysticercosis
- Fascioliasis
- Foodborne trematodiases
- Zoonotic trypanosomiases
- Zoonotic leishmaniases
Why is echinococcosis neglected?

- Chronic zoonotic disease
- Difficult to detect/diagnose, hospital records diverse
- Burden of disease hard to quantify
- Difficult to treat and follow-up in humans
- Human behavioural role, cultural aspects
- Occurs in rural, often marginalised, under-developed pastoral communities
- Human treatment does not affect transmission
- Dogs are main zoonotic reservoir (asymptomatic)
- Relative little significant economic loss in livestock
- Involves domestic animal hosts and possibly wildlife
- Control is difficult, expensive and.. very long-term
- Not sufficiently prioritised by either health or veterinary authorities, therefore..
- Lack of responsibility, advocacy, funding..
Distribution of *Echinococcus granulosus* s.l. (WHO, 2011)

**CE case hotspots**

CE case hotspots

**Ongoing, new or planned CE control programs (2016/17)**

- Sardinia
- Tunisia
- Rio Grande do Sol
- Uruguay
- Rio Negro
- Falkland Is.
- Chile
- Peru
- Kyrgyzstan
- W. China
Proposed revised species and genotypes (G1-G10)

“Echinococcus granulosus (sensu lato) complex”

- G1 sheep \( E.\text{granulosus} \)
- G2 sheep \( \text{(sensu stricto)} \)
- G3 buffalo
- G4 horse (equids) \( E.\text{equinus} \)
- G5 cattle \( E.\text{ortleppi} \)
- G6 camel (camelids)
- G7 pig
- G8 cervid (Canada) \( E.\text{canadensis} \)
- G9 Poland-pig
- G10 cervid-wolf (Finland)
- - lion \( E.\text{felidis} \)

Life-cycle of *Echinococcus granulosus* s.s.

**Main cycle**

- **tapeworm in dog gut** (42 d) (5-7mm)
- **protoscoleces** ingested-evaginate
- **oncosphere**
- **eggs** in faeces

**Hydatid cysts**

- in livestock liver/lungs 1-2 yrs

**Control:**
- reduce or eliminate **eggs**

**Human disease:**
- **cystic echinococcosis** (CE)
Community transmission of *Echinococcus granulosus* s.s.

- **Settled** rural livestock raising communities/farms
- **Semi-nomadic/transhumant** pastoral communities
- **Nomadic** pastoral communities
- **Peri-urban** communities
- **Urban** communities
Prevalence of human **cystic echinococcosis (CE)** in nomads: northwest Turkana (**Kenya**) and Shiqu, eastern Tibet, Sichuan (**China**)
2-9% human CE (female>male)

*E. granulosus*: 16-36% in dogs

100% of manyatta families owned 1- >10 dogs

Dogs < 5 yrs, ate offal, and free roam = higher risk (p< 0.05)

(after: PS Craig, CNL Macpherson, E Zeyhle, T Romig, I.Buishi, Prof GS Nelson)(Funded by AMREF-Kenya, MRC-UK)
Risk factors: role of dogs and *E. granulosus*: Shiqu County, Ganze Tibet Autonomous Prefecture, Sichuan Province, China-2000’s

Owned dogs-purge positive for *E. granulosus* = 8.2%; coproPCR DNA+ = 21%

82% of families owned 1-9 dogs
8% dog owners had CE vs 4.4% with no dogs (*p*<0.05)

(After: PS Craig, J Qiu, Q Wang, C. Budke, B. Boufana, J Moss, T Li)
### Risk factors for cystic echinococcosis in semi-nomadic or farming communities - China and Mongolia


<table>
<thead>
<tr>
<th>Risk Factor for CE</th>
<th>Popn Kazakhs (Xinjiang, China) -nomadic</th>
<th>(Region) Tibetan (Sichuan, China) -nomadic</th>
<th>Mongols (Mongolia, &amp; China) -nomadic</th>
<th>Hui (Ningxia, China) -farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex/age</td>
<td>age&gt;50y female</td>
<td>age &gt;20y female</td>
<td>age &gt;20y</td>
<td>age&gt;30y</td>
</tr>
<tr>
<td>Herding</td>
<td>p &lt; 0.05</td>
<td>p &lt; 0.05</td>
<td>p &lt; 0.01</td>
<td>not sig.</td>
</tr>
<tr>
<td>Home slaughter</td>
<td>p &lt; 0.05</td>
<td>p &lt; 0.05</td>
<td>p &lt; 0.01</td>
<td>not sig.</td>
</tr>
<tr>
<td>Dogs</td>
<td>not sig.</td>
<td>p &lt; 0.01</td>
<td>p &lt; 0.01</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Hygiene</td>
<td>ND</td>
<td>p &lt; 0.01</td>
<td>not sig.</td>
<td>P &lt; 0.05</td>
</tr>
<tr>
<td>Water source</td>
<td>ND</td>
<td>p &lt; 0.01</td>
<td>ND</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>Education</td>
<td>p &lt; 0.01</td>
<td>p &lt; 0.01</td>
<td>yes</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Domicile/environm</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>not sig.</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>ns (Kazak v Mongol)</td>
<td>_</td>
<td>yes</td>
<td>p &lt; 0.05</td>
</tr>
</tbody>
</table>
CE Emergence: Numbers of surgical cases of cystic echinococcosis
Kazakhstan 1984-2001

(After: P Torgerson et al)
Age-specific ultrasound prevalence of human CE and AE in a co-endemic area of Ningxia, NW China

(After: Y. Yang, Y. Wang, P. Craig unpublished)
Diagnosis of *E. granulosus* in animals: *problems*?

Sary Mogul, Alay Valley, Kyrgyzstan

- Asymptomatic in both dogs and livestock

- Surveillance is a key to assess control efficacy

Images: Philip Craig
**Taenia hydatigena**: the commonest *taeniid tapeworm* in dogs and sheep in rural areas

Dog *T. hydatigena* prevalence usually > 25%

Sheep infections—needs differential diagnosis with hydatidosis

Images: Philip Craig
Detection of *Echinococcus granulosus* (s.l) in dogs: necropsy, purgation and copro-ELISA/PCR

**Necropsy**
- 99-100% specific
- 90-100% sensitive

**Purgation (arecoline)**
- 99-100% specific
- 40-80% sensitive

**Copro-tests**
- Copro-ELISA: >95% specific (genus only)
- >70% sensitive (increased with worm burden)
- Copro-PCR: >99% species specific
- 40-80% sensitive
Detection of CE in livestock

meat inspection

microscopy

histology

PCR

serology

Figure: Representative results of the E. granulosus copro-polymerase chain reaction with faecal samples from positive coproantigen ELISA and controls. Lane 1, E. granulosus DNA; lane 2, negative control (no target DNA); lane 3-7, faecal samples from infected sheep DNA detected positive on coproantigen ELISA. Lane M, positions of the size marker bands. bp = basepairs.
Humans: mass screening by hepatic/abdominal ultrasound scan
(eg. northwest Sichuan Province, China)

Registration & questionnaire

Case detection

Age specific prevalence and incidence

Treatment approaches and follow-up: surgery, ABZ, PAIR, watch/wait

Portable ultrasound scan

Serology/blood screen, AgB, Em18 ELISA/blot; hospital records
Targeting dogs is the key to effective control of cystic echinococcosis...
Principles of cystic hydatid disease control
(E.granulosus) (after -Kuchenmeister, 1854; Krabbe, 1864; Gemmell 1987)

- Prevent dogs access to livestock offal
- Treat dogs with a purgative or anthelmintic
- Meat inspection and infected offal disposal
- Health education- parasite lifecycle, hygiene, dog contact, dog management
Control approaches for CE

**Target dogs**
- arecoline purgation (*efficiency problems*)
- praziquantel dosing (% *cover*, *specified frequency*)
- dog population management (*culling, impounding, sterilize, no offal*)
- Vaccination? of definitive hosts (experimental up to 2017)

*Surveillance* should also be required in *human, dog* and *livestock* populations in order to *measure impacts* and justify long-term expenditure...

**Integrated control**
- all of above measures; PZQ dog dosing *plus* EG95 vaccine sheep

(Craig et al., 2015, Vet Parasitol, 213, 132-148; Craig et al., 2017, Adv Parasit, Vol 95)
Five Island control programs-a success story (1863-2002)


Map source: WHO/OIE, 2001

After: Craig and Larrieu 2006
1. **Hydatid Control in Iceland (1863-1960)**

**The First and A Unique Experience**

- In mid-nineteenth century “1 of 6” Icelanders were infected at autopsy; 1932-1966 2.6% prevalence at autopsy; last pre-mortem CE case detected 1960 (23 yr female); 1863 28% dogs infected, 1950-60 prev 0% canine Eg; last infected sheep 1973.

**HOW WAS THIS ACHIEVED?**

- Prof. **Harald Krabbe** (1831-1917), Danish academic veterinarian advised Icelandic government on control (1860-1890)
  - Wrote 18pp booklet, free, translated into Icelandic
  - Introduced control of echinococcosis in 1869 (Law 1890)
    - Reduce numbers of dogs and contact; imposed dog tax
    - Required annual treatments of dogs (areca seed extract)
    - Village nominate a `dog cleaner` and cleaning house/kennels
    - Destruction of cyst infected offal
    - Change in husbandry practices- illegal to home-slaughter
    - Changed slaughter practices (lambs killed at 4-5 months vs 3-4 years)

- **Socioeconomic improvements** (*housing, urbanisation*)

- **Education and awareness** (*literate poor population, little reading material-all familiar with hydatids*) (P Schantz; Craig and Larrieu, 2006; Sigurdarson, 2010)
Five Island control programs—a success story (1863-2002)

Dog Dosing and testing- New Zealand (1960s)

Elimination of *E. granulosus* declared in 2002

Michael Gemmell
2. Experiences in control of cystic echinococcosis

New Zealand (1938-2002)

- *E. granulosus* introduced to NZ with sheep in late 18th Century
- CE made notifiable disease in 1873; 1% autopsy rate; 48% in sheep (most prevalent among indigenous Maori); human CE 4.5 per 100,000
- 1940 “Meat Act” made it illegal to feed raw offal to dogs
- 1938-58 Educational program encouraged “community participation” - largely unsuccessful (arecoline provided free)
- 1959 National Hydatids Eradication Council (NHEC)
  - Local committees apply day-to-day control funded through local dog tax.
    - Supervised dog registration
    - Arecoline supervised dosing for diagnosis up to 4x/yr (13 yrs)
- 1976 6-weekly supervised dog-dosing with praziquantel (19 yrs)
- 1991- Program converted to Ministry of Agriculture and entered “consolidation” phase (stopped dog treatments; NHEC disbanded)
- 1998- current: Maintenance of eradication phase
  - Permanent surveillance at meat inspection
  - Control of dog entry
  - After 1996 no hydatid cysts found in >25 million sheep
- 2002- Declared provisionally free of echinococcosis (43 yrs after start)

(After: MA Gemmell; PM Schantz; Craig and Larrieu, 2006)
3. **Tasmania CE control program (1964-1996)**

- Human CE $9.3 \times 10^5$ 1941-50; 50% sheep, 12% dogs
- Generally patterned by Dr **Trevor Beard** after New Zealand program

1963 **Educational program**—fostered local “community participation” (**Tasmanian Hydatids Eradication Council**)

1965-74 **Intervention Program** funded and applied by state **Ministry of Agriculture** with voluntary advisory committee involved **annual arecoline testing** of farm dogs with supervised **quarantine** of infected premises (**mobile testing units**)

1975-1996 **Consolidation phase**
- Supervision of farms with infected sheep detected at meat inspection with subsequent **trace-back**

1996 **Elimination declared**

1997- **Maintenance of eradication phase** reached in about 31 yrs
- 1997 two sheep farms quarantined (imported infected dog from mainland)
- 2013: 41 CE cases (youngest 44 yrs); **no new CE cases after 2002**

*After: PM Schantz; Craig and Larrieu 2006; O`Hern et al, 2013*
PHASES OF CE CONTROL

1. **PLANNING PHASE**
   identify authority and funding, baseline data, cost-benefit analysis, duration, education, operational research needs, logistics.

2. **ATTACK PHASE**
   measures applied, dog control, registration and testing/dosing, period (?)

3. **CONSOLIDATION PHASE**
   meat inspection, trace-back, quarantine, surveillance, dosing reduced/stopped

4. **MAINTENANCE PHASE**
   specific control stopped, meat inspection, trace-back, prevent out-breaks

*(after MA Gemmell, 1987; 1990)*
What about CE control in *continental* (non-island) programs?
OPTIONS FOR CE CONTROL

**OPTION 1**
(after Gemmell, 1990; Craig and Larrieu, 2006; Craig et al. 2017)
decision **not** to proceed

**OPTION 2**
long-term horizontal approach- education, meat inspection; 50-100 years (eg. *Iceland, NZ* before 1959)

**OPTION 3**
long-term vertical approach- education plus arecoline/PZQ; 15-30 years (eg. *NZ* after 1959, *Tasmania, FI, Uruguay*)

**OPTION 4**
short-term vertical approach-arecoline plus dog euthanasia; 10-15 years (eg. *Cyprus* after 1971)

**OPTION 5** (*most continental programs*)
short-term vertical approach- PZQ dosing at specified frequency 2-8 x pa; 10-15 years (eg. *Chile, Argentina, Brazil, Uruguay, Spain, Wales, China*)

**OPTION 6** (*not yet applied on large scale; pilots- Datangma, Rio Negro*)
PZQ dosing with livestock vaccination (1-2 per year) (duration 5-10 yrs ?)
# Successful control of human CE: four `continental` programs

*(CE cases per 100,000)*

<table>
<thead>
<tr>
<th>Country (Region)</th>
<th>Period (Years)</th>
<th>Pre-control incidence</th>
<th>Post-control incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chile</strong> (Reg. XII)</td>
<td>1979-1997 (18yrs)</td>
<td>38-80</td>
<td>6-11.8</td>
</tr>
<tr>
<td><strong>Argentina</strong> (Rio Negro)</td>
<td>1980-1997 (17yrs*)</td>
<td>73</td>
<td>&lt; 3</td>
</tr>
<tr>
<td><strong>Uruguay</strong> (National)</td>
<td>1994-2002** (8yrs*)</td>
<td>12.4</td>
<td>6.5</td>
</tr>
<tr>
<td><strong>Spain</strong> (La Rioja)</td>
<td>1986-2000 (14yrs)</td>
<td>19</td>
<td>4</td>
</tr>
</tbody>
</table>

* Ongoing 2015  **  1st program 1965-1990
<table>
<thead>
<tr>
<th>Region Program</th>
<th>Dates</th>
<th>Option</th>
<th>Main App</th>
<th>Dosing x / year</th>
<th>Main Screen</th>
<th>Outcome (%)</th>
<th>no. years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iceland</td>
<td>1863-1960</td>
<td>#2</td>
<td>Education</td>
<td></td>
<td>Autopsy</td>
<td>22</td>
<td>(5.9,1.5, 0)</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1959-1997</td>
<td>#2 #3</td>
<td>Educ, arec x4 PZQ x8</td>
<td>Ovine Dogs</td>
<td>48-58 04-15 1x10⁻⁶ 37 &lt;5 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tasmania</td>
<td>1965-1996</td>
<td>#3</td>
<td>Education, Arecoline x1</td>
<td>Ovine Dogs</td>
<td>52.2 8.7(83.3%) 0.6 0.0002 12.7 0.8(94%) 0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyprus</td>
<td>1971-1985</td>
<td>#4</td>
<td>Culling Arecoline x1</td>
<td>Ovine Dogs</td>
<td>66 0.9(98.6%) 0.014 6.8 0.02(99.7%) 0.17 2.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rioja Spain**

Ovine CE prevalence reduced: **64-78% in 10 years**

**Uruguay (national)**

Dog echinococcosis prevalence reduced: **81-97% in 10 years**

**Rio Negro Argentina**

**Region XII Chile**

**Rio Grande Brazil**

1983-2000 #5 PZQ x8 Ovine Dogs 26 3

28 9 (68%)

**Mid-Wales UK**

1983-1989 #5 PZQ x8 CoproAg Ovine Dogs 23.5 10.5 (55.3%) 4.6-25 0 (100%) 9 *
Consideration of CE control

- Considered a public health problem
- *Highly endemic?*
  - human incidence/prevalence $>1-5/10^5$ pa (<15 yrs age)
  - prev. in sheep $>20\%$
  - prev. in dogs $>5-10\%$
  -(WHO, 1st Report on NTDs, 2010)
- Economic impact - public health and livestock
- Administrative structures exist - Veterinary services/Min. of Agriculture/Min. of Health
- Availability of control tools and surveillance structures

**WHO 2011: CE Control defined as:**
- No human CE cases <15 years
- <0.1% CE in sheep <3 years age
- <0.01% dog infection with *E. granulosus*
`NEW` TOOLS FOR CE CONTROL since 1990s

Detection of infected dogs
- coproag ELISAs *Echinococcus* >80% sensitivity, >95% specificity [genus level]
- coproPCR tests > 80% sensitivity, 100% specific [-species specificity]

Screening for CE infection in rural human popn
- portable ultrasound (with serology), oral ABZ
  PAIR treatment

Animal vaccines
- EG95 rec oncosphere, >95% immunity, > 12m + colostral in sheep

Models for transmission, burden & cost benefit
- quantitative simulations for specific interventions and disease burden / economic impacts
CE Control simulation
vaccinate sheep (75%); 2x6m PZQ dogs

[after Torgerson and Heath, 2003]
Features of successful control?

CE is a *public health* problem...but *transmission* is only between *animals*...

..therefore the *control authority* is important...!
**CE CONTROL: LEGISLATIVE & OPERATIONAL AUTHORITIES**

-advantages *(problems)*

**MINISTRY OF AGRICULTURE/ VET SERVICE**

dog dosing and meat inspection, animal surveillance, manpower, rural out-reach *(problem: human data access, education)*

**MINISTRY OF HEALTH**

human CE rates, education, rural out-reach *(problem: dog control / dosing, livestock data)*

**SPECIAL COMMISSION / NGO**

local, separate funding, dog dosing, manpower *(problem: staff, out-reach, abattoir data, quarantine power)*

**MUNICIPALITY**

local, infrastructure, abattoirs, dog control *(problem: medical data, dog dosing)*
Features of successful CE control programs
based on control programs 1959-2000
(after: Craig and Larrieu, 2006)

• A public health priority
• Under a Ministry of Agriculture, Veterinary Services, or necessary veterinary linkage clear (ie. MoHealth and MoAgriculture)
• Awareness, participation and acceptance by target communities
• Supervised dog dosing; 4-8x per year
• Small stray dog population
• Good abattoir surveillance in livestock
• Good out-reach, accessible communities
• Political stability, advocacy and security
• Sufficient funding for >5 years in `attack` phase
Is control of echinococcosis feasible in endemic semi-nomadic populations in Asia and Africa?
Some probable reasons for failure or poor impact of Turkana, Kenya (1983-1997) and Tibet, China (1997-2005) pilot hydatid control programs

- Mobility of nomadic populations
- Poor access, difficult terrain, seasons
- Too few staff / technicians
- Financial constraints/budget management
- Illiterate populations
- Delivery and PZQ % cover of dogs dosed
- Sub-optimal surveillance of livestock/dogs
- Vaccine EG95 delivery/acceptance (Tibet)
- Sylvatic cycles for coendemic Em/AE (Tibet)
- Priority setting at provincial and national levels
National echinococcosis control program in China (2006-)
(After: Wang Qian Head Echino control Sichuan CDC)

• Funded from 2006/7 by central government, managed by Ministry of Health, includes vets but no direct involvement of livestock husbandry department.

• **2010**: included 170 counties in >8 provinces/regions- inc. Sichuan, Xinjiang, Inner Mongolia, Gansu, Qinghai, Ningxia Shaanxi and Tibet AR (> 5 million km²)

• Screen **1.23 million population** using ultrasound

• Provide **free treatment** for CE (ABZ, surgery); also % AE.

• Register all dogs in all endemic villages and aim for **monthly deworming** of **1.98 million dogs** using praziquantel

• Provide **1.9 million copro-ELISA tests** for dog infection surveillance.
CoproELISA for canine echinococcosis in Shiqu (Ganze Tibetan Prefecture, Sichuan, China) before (2006) and after (2013/14) PZQ (x4 pa) intervention (Salford coproELISA)

<table>
<thead>
<tr>
<th></th>
<th>Shiqu</th>
<th>n</th>
<th>Copro ELISA +</th>
<th>Copro PCR +</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2006</td>
<td>276</td>
<td>58 (21%)</td>
<td>3.6 % Eg</td>
<td>Moss et al, 2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.2% Em</td>
<td></td>
</tr>
<tr>
<td>Post-control</td>
<td>2013/14</td>
<td>339</td>
<td>4 (1.2%)</td>
<td>0.6% Eg</td>
<td>van Kesteren, Yu, Wang, Craig et al, unpub.</td>
</tr>
<tr>
<td>(7 yrs)</td>
<td></td>
<td></td>
<td></td>
<td>0.9% Em</td>
<td></td>
</tr>
</tbody>
</table>
Recommendations, gaps, challenges: epidemiology and control for cystic echinococcosis (2017)

- Vertical integrated control of CE using PZQ dosing dogs and EG95 livestock vaccine.
- Slow release PZQ for dogs?; dog vaccine research?
- Rapid /commercial diagnostic tests - canid coprotests; human serology; reliable livestock serology (?).
- Dog population management.
- Transmission models for planning optimal control.
- Molecular epidemiology approaches.
- Optimised setting-specific treatment for human CE (and AE) in resource-poor areas.
- Successful inter-sector (Med-Vet-VPH) collaboration.
- Multiple zoonoses control integration in rural areas, especially resource-poor communities (One Health)

P.S. Craig
THANK YOU, GRACIE, XIE XIE

Dedicated to:
Dr Mike Gemmell

1926-2003
Worm burden of *E. granulosus* in dogs against coproELISA OD value

Correlation with burden and sensitivity poor when worm intensity < 50-100

Jenkins et al, 2002

A. Mastin, F van Kesteren, PS Craig unpublished
# Coproantigen ELISAs for *E.granulosus* in dogs

<table>
<thead>
<tr>
<th>CoproELISA Antibodies</th>
<th>Standards exp, pm, purge</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Cross Reactions*</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>R anti Eg worm som.</td>
<td>n = 410 (exp, pm)</td>
<td>83</td>
<td>96</td>
<td><em>T.hydatigena</em></td>
<td>Allan et al 1992; Craig et al 1995; Buishi et al 2005</td>
</tr>
<tr>
<td>R anti-EgWES</td>
<td>n = 155 (exp, pm)</td>
<td>87</td>
<td>98</td>
<td><em>T.hydatigena</em></td>
<td>Deplazes et al 1992</td>
</tr>
<tr>
<td>Mab EgES &amp; EmA9</td>
<td>n = 13 (exp)</td>
<td>100</td>
<td>96</td>
<td><em>T.hydatigena</em> T.multiceps</td>
<td>Malgor et al 1997; Nonaka et al 2011</td>
</tr>
<tr>
<td>R anti EgPxES</td>
<td>n = 200 (pm)</td>
<td>78.4</td>
<td>93.3</td>
<td>Not specified</td>
<td>Benito &amp; Carmena 2005</td>
</tr>
<tr>
<td>Mab EgES EgC1/EgC3</td>
<td>n = 16 (exp.)</td>
<td>100</td>
<td>100</td>
<td><em>T.hydatigena</em></td>
<td>Casaravilla et al 2005</td>
</tr>
<tr>
<td>R anti EgWES,FT Sheep antisera</td>
<td>n = 55 (exp, pm)</td>
<td>92</td>
<td>80</td>
<td><em>Taenia spp</em></td>
<td>Huang et al 2008</td>
</tr>
<tr>
<td>R anti Eg worm</td>
<td>n = 411 (exp, purge)</td>
<td>92</td>
<td>86.5</td>
<td><em>Taenia spp</em></td>
<td>Pierangeli et al 2010</td>
</tr>
<tr>
<td>MabEg9 ES</td>
<td>n = 24 (exp, pm)</td>
<td>86.6</td>
<td>86.4</td>
<td><em>Taenia spp</em></td>
<td>Morel et al 2013</td>
</tr>
</tbody>
</table>
## Selected key studies for state-of-the-art diagnosis of *E. granulosus* in animals

<table>
<thead>
<tr>
<th>Test</th>
<th>Key reference</th>
</tr>
</thead>
</table>
5. **Cyprus CE control Program (1971-85)**

- Human CE 12.9 per $10^5$ in 1960s

1971  Control measures implemented and funded by Department of **Veterinary Services**, Ministry of Agriculture (*K.Polydorou*)
- Stray dog control (**euthanasia**)
- Dog tax (higher for unspayed animals)
- Obligatory “arecoline testing” of all dogs every 3 months
  - Euthanasia of all positive dogs
- Educational program
- Strict controls at slaughter houses and butcher shops

- **`Eradication`** thought to be achieved in 1985 with cessation of activities (NB. Island partitioned-1974)
4. CE control: Falkland Islands (FI) (1965-2014) (Las Malvinas)

- First report 1941 in sheep; 1969 sheep CE prevalence 59%; First human cases 1965 (~55 per 10^5), last 1992 (human pop.~ 2000, sheep ~700,000)
- 1965 Safe offal disposal, dog licence, annual arecoline treatment (Department of Veterinary Services)
- 1977-2014 PZQ dosing of dogs 6 weekly initially supervised; quarantine infected properties
- 1981-93 ovine CE reduced from 1.8% to 0.16%
- 2007, 2014 ovine CE 0.008%, 0.02%
- 1992/93 - dog coproELISA 1.7%
- 2010,2012 – dog coproELISA 3%,0%, 2014-1%
- 2015 Move to consolidation phase using abattoir and periodic coproELISA surveillance; treatment of imported dogs (Craig and Larrieu, 2006; Lembo et al, 2013; S.Pointing and B.Boufana Unpub)
## European CE control programs: mid-Wales (UK) (Ministry of Agriculture) 1983-1989

<table>
<thead>
<tr>
<th>Prev. % or incidence</th>
<th>1953-83 Pre-control</th>
<th>1983-89 Control measures applied</th>
<th>1990 7 yr post-start of control</th>
<th>1995-02 12-19 yrs post-start of control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dogs %</td>
<td>5-29</td>
<td>-</td>
<td>0-3.4 (cop-ELISA)</td>
<td>8 (cop-ELISA)</td>
</tr>
<tr>
<td>Sheep %</td>
<td>23.5</td>
<td>10.5</td>
<td>-</td>
<td>6 (sentinels)</td>
</tr>
<tr>
<td>Humans per 10^5 Hospital records</td>
<td>3.7-3.9</td>
<td>4.7-6.3</td>
<td>2.3</td>
<td>? sporadic cases</td>
</tr>
</tbody>
</table>
Control of cystic hydatidosis in Australasia
(Control authority: Special Commission/Ministry of Agriculture- New Zealand; Department of Agriculture- Tasmania)

<table>
<thead>
<tr>
<th></th>
<th>NEW ZEALAND (1959-1997)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dogs (%)</td>
<td>10</td>
<td>37</td>
<td>&lt; 5%</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sheep (%)</td>
<td>80</td>
<td>48-58</td>
<td>0.43-15.6</td>
<td>&lt;1 in 10^6</td>
<td></td>
</tr>
<tr>
<td>Humans Incidence</td>
<td>4.5</td>
<td>3.2</td>
<td>0.7</td>
<td>Last old cases</td>
<td>“eliminated” 2002</td>
</tr>
<tr>
<td>Incidence per 100,000 pa</td>
<td>9.3 x 10^5</td>
<td>28 cases</td>
<td>0 cases</td>
<td>“eliminated” 1996-97</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>TASMANIA (1965-1996)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dogs (%)</td>
<td>12.7</td>
<td>0.8</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sheep (%)</td>
<td>52.2</td>
<td>8.7</td>
<td>0.6</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>Humans Incidence</td>
<td>537 cases</td>
<td>28 cases</td>
<td>0 cases</td>
<td>“eliminated” 1996-97</td>
<td></td>
</tr>
</tbody>
</table>
APPROACH TO PLANNING FOR CE CONTROL

- Collect / review baseline data
- Public health priorities
- Assess economic losses
- Convince authorities-advantages
- Identify legislature
- Identify target region / districts
- Select control option, duration
- Funding & research needs
- Training requirements
- Quantify dog pop,% cover
- Dosing interval, teams
- Surveillance methods, abattoirs
- Health education, media
- Integrate livestock vaccination ?
Changes in prevalence of CE in humans, sheep and dogs during the control programs in New Zealand and Tasmania (Gemmell, 1990).