Host-parasite co-evolution in times of ecological globalization

Horst Taraschewski
Zoological Institute, Department of Ecology and Parasitology
Karlsruhe, Germany
Four categories of evolutionary events in a natural host-parasite association (Paterson and Gray, 1997)

Ecological globalization:

Rate of host-switching (capturing) increased

“Missing the boat” partly compensated by “taking the speed boat”

→ Accelerated evolution (contemporary, rapid evolution)
## Traits affected by accelerated evolution when parasites or hosts or both are aliens, chosen examples

<table>
<thead>
<tr>
<th>Trait</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture of novel hosts (parasite)</td>
<td>Acanthocephalans of the River Rhine</td>
</tr>
<tr>
<td>Development (parasite)</td>
<td>Anguillcula crassus</td>
</tr>
<tr>
<td>Morphology (parasite)</td>
<td>Anguillcula crassus</td>
</tr>
<tr>
<td>Resistance / tolerance (host)</td>
<td>Rainbow trout, <em>Myxobolus cerebralis</em></td>
</tr>
<tr>
<td>Parasite induced behavioural alterations (host-parasite)</td>
<td><em>Pomphorhynchus</em> spp., <em>Polymorphus</em> spp. in amphipods</td>
</tr>
<tr>
<td>Speciation (parasite)</td>
<td><em>Fasciola</em> spp.</td>
</tr>
</tbody>
</table>
Capture of novel intermediate hosts by indigenous acanthocephalans

- 1980s until mid-90s: native and alien gammarids co-existed in the river Rhine near Karlsruhe

- 1992: Inauguration of the Main/Rhein-Danube Canal
  - *Gammarus pulex, G. fossarum, G. roeseli* became very rare
  - *G. tigrinus*: up from 1998 only sporadic (*Paratenuisentis ambiguus* disappeared)
  - *Dikerogammarus villosus*: up from 1996, now dominant
  - *Echinogammarus ischnus*: up from 1998, low abundance
  - *Echinogammarus berilloni*: continuously present since 1968 (?) until 1996

Thielen et al. 2007 and own group (unpubl.)
Gammarid xenodiversity in the River Rhine

Lauter
Summer 2015
n = 273

Queich
Summer 2015
n = 134

Rhine Karlsruhe
Summer 2014
n = 290

Alb
Winter 2014
n = 503

- *Gammarus roeseli*: 55.3%
- *Gammarus pulex*: 44.7%
- *Gammarus fossarum*: 20.0%
- *Gammarus tigrinus*: 8.0%
- *C. robustum*: 0.3%
- *D. bispinosus*: 0.3%
- *D. haemobaphes*: 0.3%
- *G. pulex*: 20.0%
- *G. roeseli*: 17.7%
- *G. tigrinus*: 0.6%
- *O. cavimana*: 0.3%
- *E. ischnus*: 1.0%
- *E. trichiatus*: 0.1%
- *E. berilloni*: 25.4%
Capture of novel hosts

→ Dikerogammarus villosus
  ○ First records of acanthocephalan infection:
    ○ Pomphorhynchus spp.: 2008
    ○ Polymorphus spp.: 2014
    ○ Echinorhynchus truttae: 2011

→ Echinogammarus ischnus tributaries
  ○ First records of acanthocephalan infection:
    ○ Pomphorhynchus spp.: ---
    ○ Polymorphus spp.: 2015
    ○ Echinorhynchus truttae: ---

→ Echinogammarus berilloni tributaries
  ○ First records of acanthocephalan infection:
    ○ Pomphorhynchus spp.: 2014
    ○ Polymorphus spp.: ---
    ○ Echinorhynchus truttae: ---

Own group (unpubl.)


USA: Abundance (of the "Japanese strain") in Anguilla rostrata less than in Europe (Hein et al. 2014)

Germany: American and European eels equally infected (with the "Taiwanese strain"): Thieser et al. 2012

Italy (Lago di Bracciano): Anguillicola novaezelandiae genetically absorbed by A. crassus (Dangel et al. 2015)
Prevalences, intensities, body mass, reproductive capacity higher in the European eel

Opened swimbladder of the novel host A. anguilla (European Eel)

Opened swimbladder of the natural host A. japonica (Japanese Eel)
Collection of L₂ larvae

Experimental infections of intermediate hosts

Experimental infections of final hosts (L₃)

Dissection

L₂ Germany  L₂ Poland  L₂ Taiwan

Copepods

A. anguilla  A. japonica

Collection of nematodes after 25, 50, 100 and 150 days

Weclawski et al. 2013, 2014
A. crassus from Europe and Taiwan in European eels

25 years of divergent evolution: Worms from Europe develop faster!

Weclawski et al. 2013
Morphology (parasite)

Anguillicola crassus from 25 years of divergent evolution: Worms from Poland have a larger oesophagus and buccal capsule.

- n = 424 in European eels, n = 179 in Japanese eels
- n = 387 in European eels, n = 142 in Japanese eels
- n = 325 in European eels, n = 111 in Japanese eels

Weclawski et al. 2014
Resistance/tolerance (host)

- *Myxobolus cerebralis*
  - Natural tolerant host: *Salmo trutta* (Eurasia)
  - Susceptible novel hosts: *Oncorhynchus mykiss* (up from the late 1800s in Germany), salmonid fishes in North America (first record of the parasite 1958)

  ➔ Whirling disease: skeletal deformation, neurological impairment, mortality among offspring  (Sarker et al. 2015)
Comparative susceptibility to whirling disease (WD) among salmonid hosts of Myxobolus cerebralis, ascertained via laboratory or natural exposure to M. cerebralis at vulnerable life stages. 0 = resistant, no spores develop; 1 = partial resistance, clinical disease rare and develops only when exposed to very high parasite doses; 2 = susceptible, clinical disease common at high parasite doses or when very young, but greater resistance to disease at low doses; 3 = highly susceptible, clinical disease common.

Sarker et al. 2015
Resistance/tolerance (host)

- Germany: **110-120 years** after introduction of rainbow trout: 2 self-maintaining resistant populations discovered (El-Matbouli et al. 2005)

- USA: **50 years** of co-evolution: too short

- Resistance/tolerance: heritable trait on rainbow trout chromosome Omy9 (Baerwald 2011)
  - selective breeding programs

Sarker et al. 2015
Parasite induced behavioural alterations (host-parasite)

- *Pomphorhynchus laevis, Echinorhynchus truttae, Polymorphus minutus*
  - alteration of the host's phenotype (decamouflage)
  - alteration of its behaviour
  - elevated risk of predation (see Taraschewski 2000, Sures 2014)

- *P. laevis* in 3 natural hosts: hosts become photophilic (Bauer et al. 2000, Cézilly et al. 2000, Kaldonski et al. 2008), missing anti-predator behaviour, increased activity (Dianne et al. 2011)
  - In *G. roeseli* (~100 years in France): hosts remain photophobic, no change in activity (Bauer et al. 2000, Perrot-Minnot 2004, Tain et al. 2007)

- *P. minutus* in 2 natural hosts: these show avoidance of non-host predators (Cézilly et al. 2000, Bauer et al. 2005, Médoc et al. 2006)
  - In *E. berilloni*: host shows little avoidance (~100 years in France, Germany): “less sophisticated manipulation” (Ashgali Farahani et al. 2010, Jacquin et al. 2014)
  - In *G. roeseli*: non-host avoidance fully displayed (Médoc & Beisel 2008)
Speciation: *Fasciola* spp.

**Morphology:**
- High degree of host-mediated phenotypic plasticity: species not well distinguishable
- Worms from original versus introduced range: no pattern apparent, few data

**Biology:**
- Natural area: temperate Palaearctic (*F. hepatica*), Palaetropic (*F. gigantica*)
- Novel range: global (*F. hepatica*), partly sympatric, introgression
*Pseudosuccinea columella* proven to transmit *F. gigantica* (Grabner et al. 2014)
Genetics:

- Genome of *F. hepatica* large and polymorphic (worms from UK, USA, Uruguay) despite selfing (Walker et al. 2011, Cwiklinski et al. 2015)

- Hybrids between the two congeners in colonized areas: diploid, mixoploid or triploid, aspermic (partly also *F. hepatica*): parthenogenic reproduction common

- Walker et al. (2012): nuclear and mitochondrial genomes of worms from Europe, India, East Africa: 4 well separated clades:
  1. African *gigantica*-like flukes,
  2. Indian *gigantica*-like flukes,
  3. European *hepatica*-like flukes,
  4. African high-altitude *hepatica*-like flukes

- The 4 clades could be described as species (Birky et al. 2010), but ...

- Time scale of speciation: clade 1-3: large natural duration, clade 4: 150-200 years (Rapid evolution?)
Taxonomy based on the 3 major species concepts

- *Loxodonta africana* (African savanna elephant)
- *Loxodonta cyclotis* (African forest elephant)
- Morphological data available
- Biology: Small degree of hybridization, hybrids reproductively unsuccessful
- Genetics: Support by nuclear and mitochondrial DNA-patterns

Roca et al. 2015