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Fisheries and Marine Sciences

Genetic threats of liberated aquarium fish in Australia: is endemism the key?



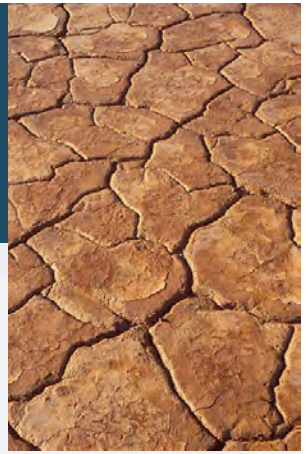


Science for decision makers



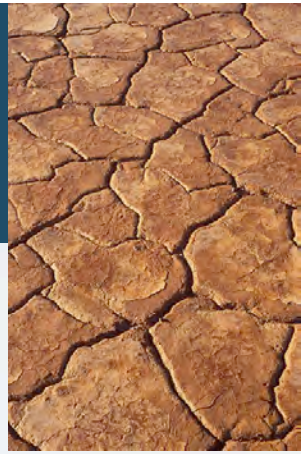


DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY



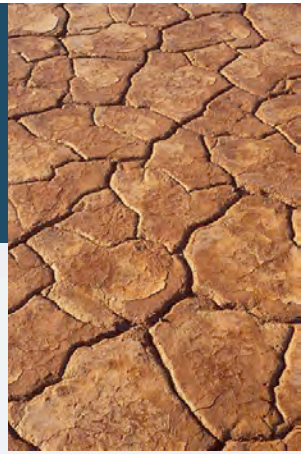
Aquarium industry in Australia

- 12 to14% of Australians are believed to keep aquaria
- Ornamental industry is valued at approximately $350 million
- Liberations pose a significant threat to biosecurity
- Introduced pests can have large and small-scale impacts



Exotic aquarium fish established in Australia

- 30 species in Australia, 5 families
- Not including gambusia, carp, roach, tench, redfin and trout
- All States and Territories
- Covering a wide range of freshwater habitat types
- Some species very centralised while others have vast ranges



Exotic aquarium fish established in Australia

Hybrid cichlid	Firemouth cichlid	Sailfin moly
Jewel cichlid	Banded cichlid	Guppy
Victoria Burton's haplochromis	Redhead cichlid	Caudo
Black mangrove cichlid	Red devil	Three-spot gourami
Redbelly tilapia	Midas cichlid	Oriental weatherloach
Blue tilapia	Convict cichlid	Goldfish
Mozambique tilapia	Green terror	Rosy barb
Oscar	Pearl cichlid	Sumatra barb
Three-spot cichlid	Green swordtail	White cloud mountain minnow
Jack Demsey	Platy	Blue acara

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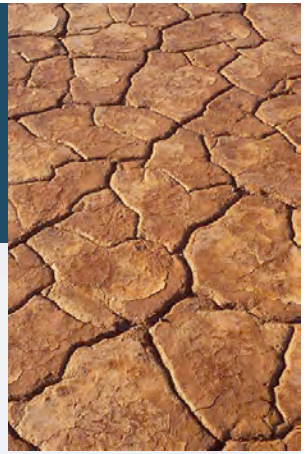
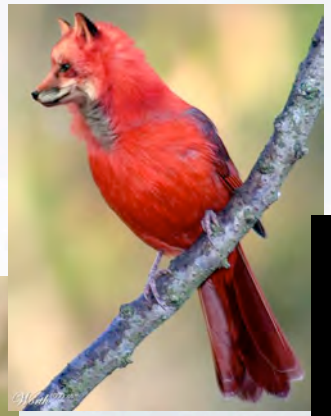
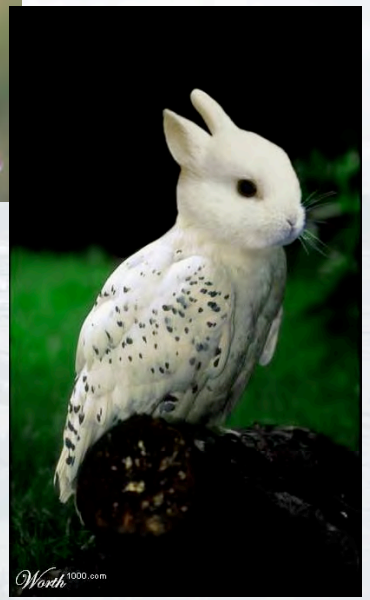
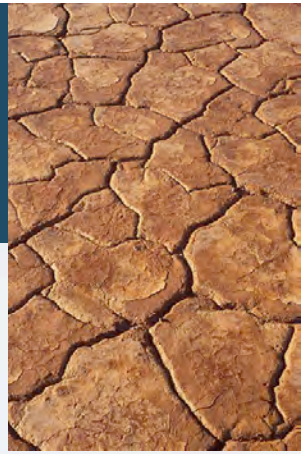


What kind of genetic threats could exotic aquarium fish pose?

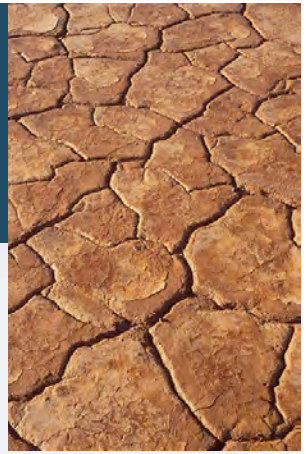






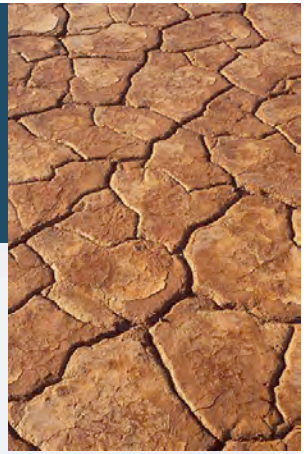
Likely genetic threats

1. Hybridisation and introgression with native species
2. Hybridisation and introgression between exotic species
3. Problems associated with demographic contractions and small population size as a result of deleterious ecological interactions and disease



Hybridisation and introgression

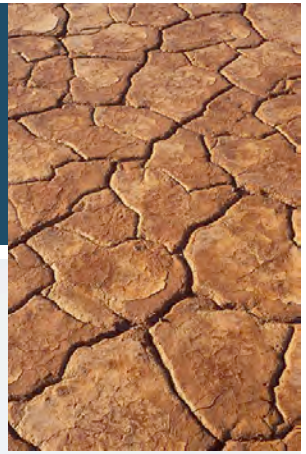
- Hybridisation is the crossing of two species, or populations
  - Does not align well with the biological species definition
  - Though common in plants, fish and invertebrates
  - Less common in other vertebrates
- Introgression is the movement of genetic material between two species or populations



What is the chance of hybridisation and introgression?

Three primary isolation mechanisms that limit hybridisation & introgression

1. Pre-mating isolation
2. Post-mating isolation
3. Post-zygotic isolation

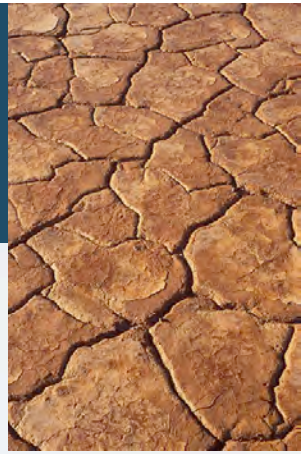


Pre-mating isolation mechanisms

Appearance

- Generally, the closer the evolutionary relationship, the more similar species will appear to be (exception of convergent evolution)
  - size and body shape

- Species have developed distinct cues to morphological characters for sexual selection
  - colour patterns, appendage shape

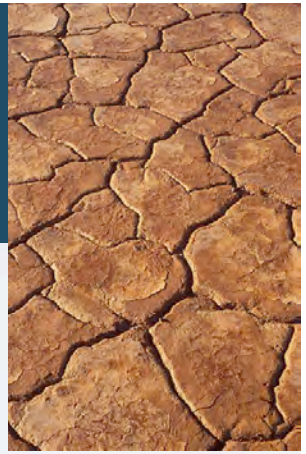


Pre-mating isolation mechanisms

For example

- Colour choice is the dominant factor in mate choice in tropical hamlets - 95% of spawning with the same colour pattern

- These small but distinct differences are an effective mechanism to maintain reproductive isolation and evolutionary distinction

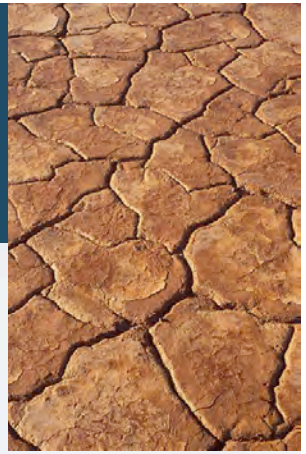


Pre-mating isolation mechanisms

Isolation in time

- For external, mass spawners like fish, corals, and sponges temporal spawning timing will play a significant role in separating gametes in time and space

- Temporal differences in mating systems are likely to be driven by environmental variability – eg. Temperature, food, flow conditions, etc.



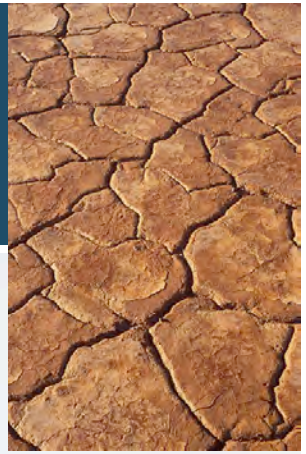
Pre-mating isolation mechanisms

Example

- Murray cod spawn spring/ early summer 15^{o}C to 23^{o}C
- Trout cod spawn earlier in the season at a slightly lower temperature

Hybrids?

- These preferences are likely separate the species during the spawning period

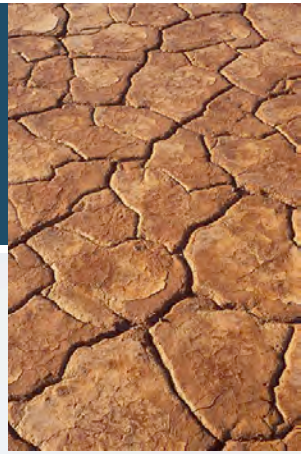


Pre-mating isolation mechanisms

Ecological isolation

- Species with non-overlapping distributions are unlikely to come into contact with closely related species

- For species with overlapping distributions, a spatial difference in spawning habitat or location is a primary isolation mechanism

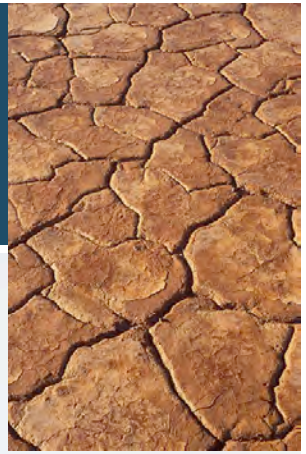


Pre-mating isolation mechanisms

Example

- Yellowfin bream spawn in river mouths and surf zones
- Black bream spawns well inside river systems

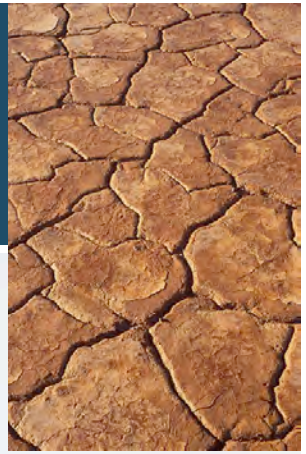
Hybrids?



Pre-mating isolation mechanisms

Ethological isolation

- Behavioural dissimilarities in mating between closely related species are likely to be a very strong isolating mechanism
- Many organisms have developed elaborate mating displays distinct to their individual species

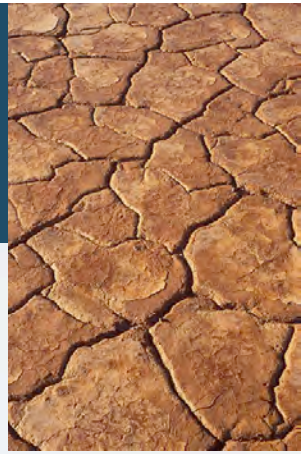


Pre-mating isolation mechanisms

Ethological isolation

Example

- Fiddler crabs engage in elaborate courtship displays in which males wave and rap their claw to attract partners



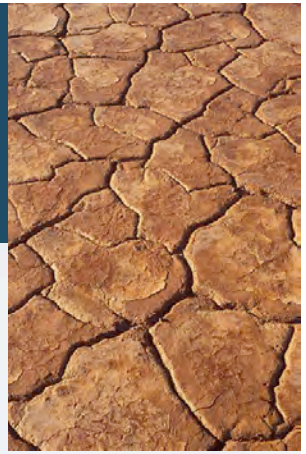
Post-mating isolation mechanisms

- Many groups, such as fish, sponges, corals, etc lack courtship behaviour

- Reproductive incompatibilities:

  - Self-incompatibility mechanisms that prevent fertilisation (S genes)

  - Number and compatibility of chromosomes, as are the size of germ-line cells – ie. Sperm/egg incompatibilities

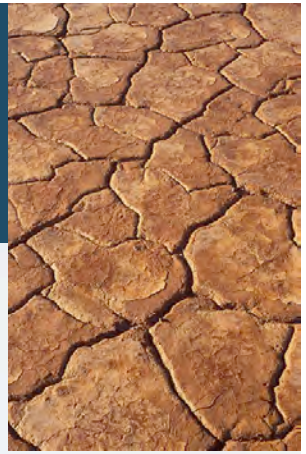


Post-mating isolation mechanisms

- Sperm/egg incompatibilities have been reported in sea urchins and polychaetes

Example

- Sea urchins, strong sperm/egg incompatibilities prohibit crossing despite:
  - Morphologically indistinguishable
  - Direct common ancestor

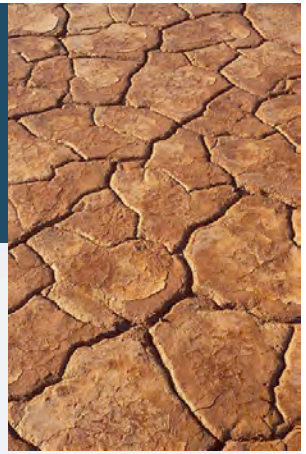


Post-zygotic isolating mechanisms

- Even after crossing
  - Sterile offspring - halting backcrosses
  - Fertile offspring - backcrosses prohibited by parent/hybrid incompatibilities

Example

- Brook trout/ bull trout crosses - 97% first generation hybrids

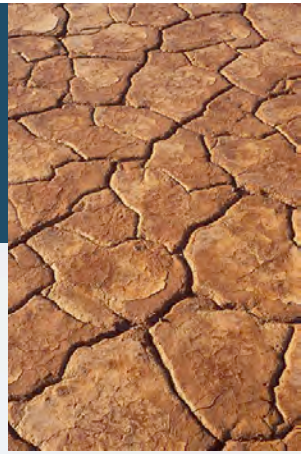


Post-zygotic isolating mechanisms

- Divergent selection on intermediates – less fit than either parental line

Example

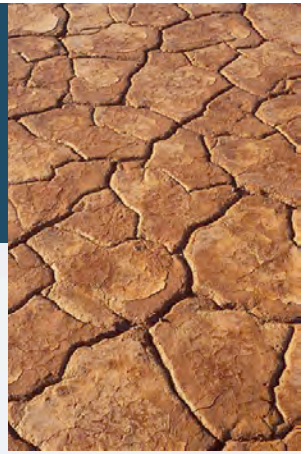
- Bottom and surface living sticklebacks



What is the level of risk of hybridisation between native and introduced fish?

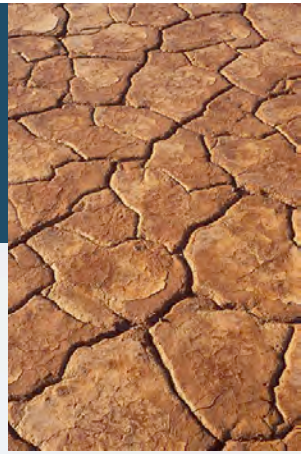
- What is the key factor?
- Relatedness
  - The closer the relatedness the higher the risk of hybridisation



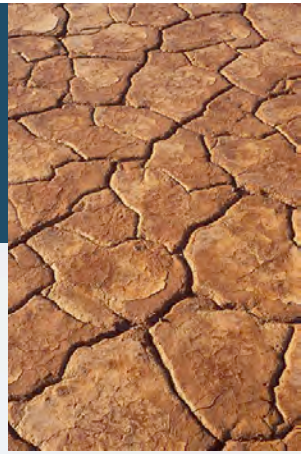
Endemism and Australian fauna

- Highly endemic wildlife
- Proportion of species (sp.) endemic to Australia
  - 90% marsupials
  - 88% rodents
  - 89% reptiles
  - 93% frogs
  - 98% Parastacid crayfish
- Australian native freshwater fish
  - Low overall diversity
    - 180-200sp. – Australia
    - 1500-2000sp. – Amazon
  - High levels of endemism



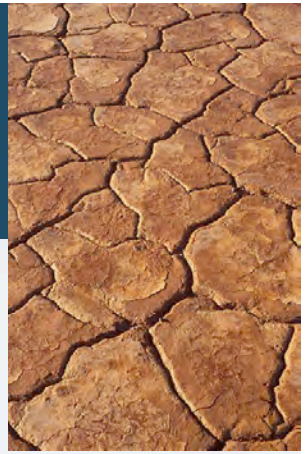
Freshwater fish families

Native to Australasia		Introduced aquarium
Percichthyidae	Anguillidae	Cyprinidae
Galaxiidae	Geotridae	Poecilidae
Retropinnidae	Eleotridae	Cichlidae
Plotosidae	Gobiidae	Cobitidae
Atherinidae	Pseudomugilidae	Osphronemidae
Melanotaeniidae	Belonidae	
Ambassidae	Megalopidae	
Terapontidae	Clupeidae	
Nannopercidae	Aplochitonidae	
Gadopsidae	Ariidae	
Bovichtidae	Hemiramphidae	
Ceratodidae	Centropomidae	
Osteoglossidae	Apogonidae	



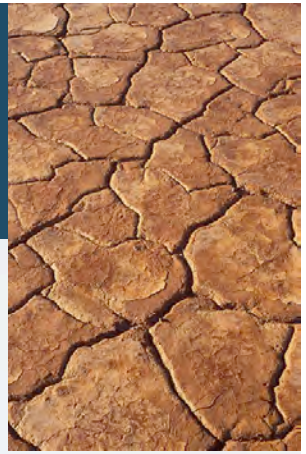
Hybridisation between native and introduced fish

- Is there any evidence for hybridisation and introgression between aquarium fish and native fish in Australia?
  - No
- Have we really looked?
  - No



Is endemism the key to genetic security for Australian freshwater fish?

- Partly
- Why?
  - Could be fish introduced from Australasia
  - Not the whole story



Indirect genetic threats

- Exotic species are know to harm native fish - reductions in population size & population fragmentation
  - Large stable populations = equilibrium
  - Small or contracting populations = non-equilibrium
- Therefore, small populations may suffer from inbreeding depression, and the loss of genetic diversity

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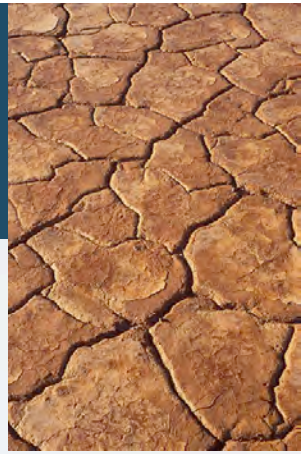
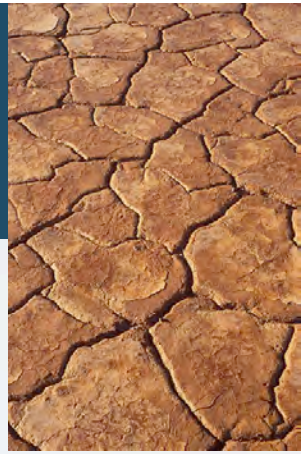
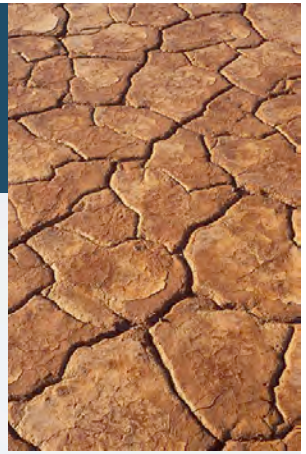




- As populations become fragmented and isolated they are likely to become genetically impoverished, less adaptable to change and more prone to extinction

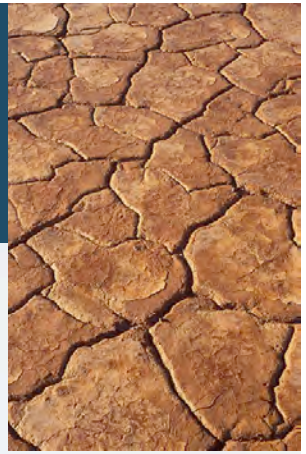


Hybridisation among introduced fish

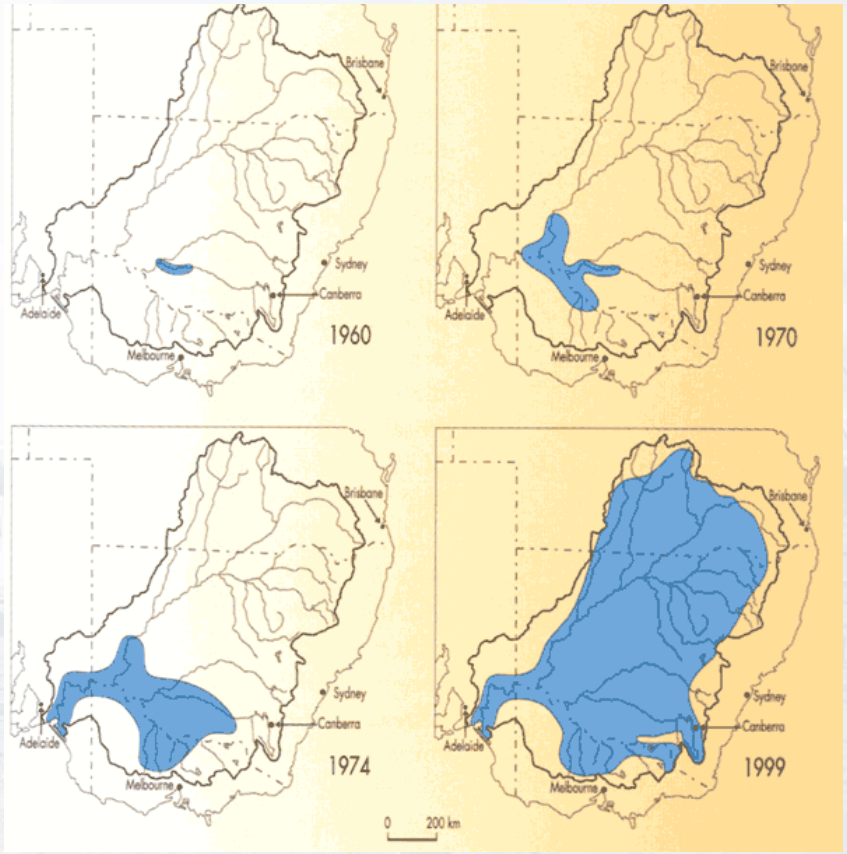
- Hybrid vigour
  - Increased adaptive potential (adaptive evolution)

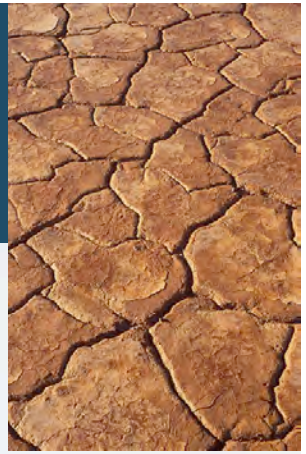
Example

- Boolara strain carp – hybrid appears to be a more aggressive coloniser than the wild type



Hybridisation among introduced fish

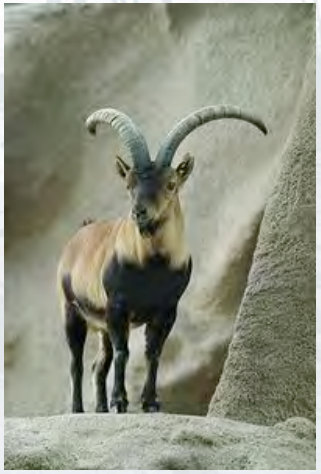




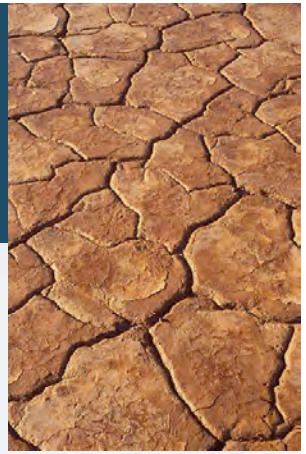
Hybridisation among introduced fish

- Lower reproductive success, reduction of fitness in intermediate forms & outbreeding depression

- Example - sunfish 95% sterile hybrids



- Example – Tatra mountain Ibex



Summary

- Endemism plays a large part – but not the whole answer
- Hybridisation and introgression with native species - low risk with current established aquarium species
- Demographic contractions and small population size – medium risk with current aquarium species
- Hybridisation within current established aquarium species – medium risk

Acknowledgements

DEW, NIWA, Prof. Peter Baverstock, and reviewers

- Corfield, J., Diggles, B., Jubb, C., McDowall, R. M., Moore, A., Richards, A. and Rowe, D. K. (2007). Review of the impacts of introduced aquarium fish species that have established wild populations in Australia