Evolution of Non-Diadromous Life Histories: Which Came First, the Fish or the Egg?

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SAPERE AUDE

Te Whare Wānanga o Otāgo

Amphidromy & Indo-Pacific Biodiversity

- **What is an amphidromous life history?**
  - Marine pelagic larval phase
  - Followed by growth to adult in freshwater
  - Reproduction in freshwater (or estuarine) habitat
  - Migration between pelagic larval rearing habitat & adult (mostly fluvial) habitat
- **Widespread life history pattern in Indo-Pacific region**
  - Significant contribution to regional freshwater biodiversity, particularly on oceanic islands

Amphidromy & Non-Diadromous Radiations

- **Evolution of non-amphidromous (mainly fluvial) species from amphidromous ancestors**
  - Significant contribution to regional biodiversity
  - Includes galaxiids, eleotrids, cottids, gobiids
- **Radiation of *Galaxias brevipinnis* in New Zealand & Australia**
  - At least 10 wholly freshwater species developed from amphidromous *G. brevipinnis*
  - Likely to increase with further taxonomic study of *Galaxias olidus* species complex in Australia

Adapting to a Non-Diadromous, Fluvial Life-History

- **Why Amphidromy?**
  - Characterised by pelagic larval phase
  - May occur in either marine or lake
- **Why pelagic environments important as larval rearing habitat?**
  - Abundant small prey items for gape-limited larvae
  - No strong currents to contend with
  - Avoids infection by snail-borne trematodes which can have devastating impact on growth of early larvae

Adapting to a Non-Diadromous, Fluvial Life-History

- **Streams as larval rearing habitat**
  - No opportunity for pelagic larval phase
  - Limited availability of small prey items
  - Strong currents to resist
  - High risk of infection from growth disrupting snail-borne trematode parasites
- **In fluvial habitats, bigger larvae likely to be favoured**
  - Capable of feeding on larger prey items & can tolerate longer periods of food deprivation
  - Better able to maintain position in currents
  - Adverse effects of parasitic infection on early development less severe
- **But a large larvae requires a large egg!**

Large Eggs & Loss of Diadromy

- **An original idea**……..**unfortunately no!**
- **McDowall**
  - Comments that larger eggs may be associated with loss of diadromy
- **Humphries**
  - Observed larger eggs in non-diadromous *G. truttaceus*
- **Goto & Japanese colleagues**
  - Recognised that large egg size characteristic of non-diadromous *Cottus & Rhinogobius* spp.
- **But no detailed analysis across taxa**

Methods

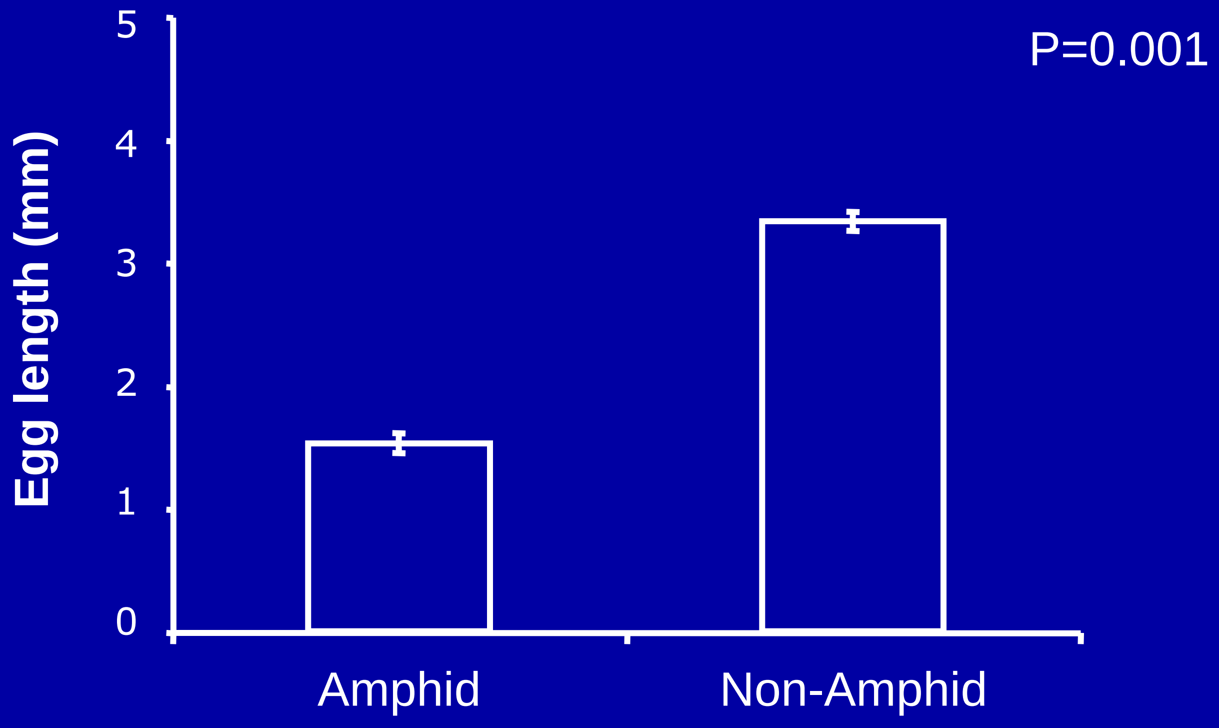
- **Compared egg size of non-diadromous species with (most likely) closest amphidromous relative**
  - Published phylogenies for galaxiids & some *Rhinogobius* spp.
  - Inferred likely phylogenetic relationships for *Gobiomorphus* & *Cottus*
- **Paired T-test**
  - Pairs comprise each amphidromous ancestral species & non-diadromous species

Egg Length Data Set

- **Galaxiids (*Galaxias & Neochanna*)**
  - 4 amphidromous, 13 non-amphidromous
  - New Zealand & Australia
- ***Gobiomorphus***
  - 1 amphidromous, 3 non-amphidromous
  - New Zealand
- ***Cottus***
  - 3 amphidromous, 6 non-amphidromous
  - Nth Am (egg weight) & Japan
- ***Rhinogobius***
  - 3 amphidromous, 5 non-amphidromous
  - Species not formerly described
  - Japan

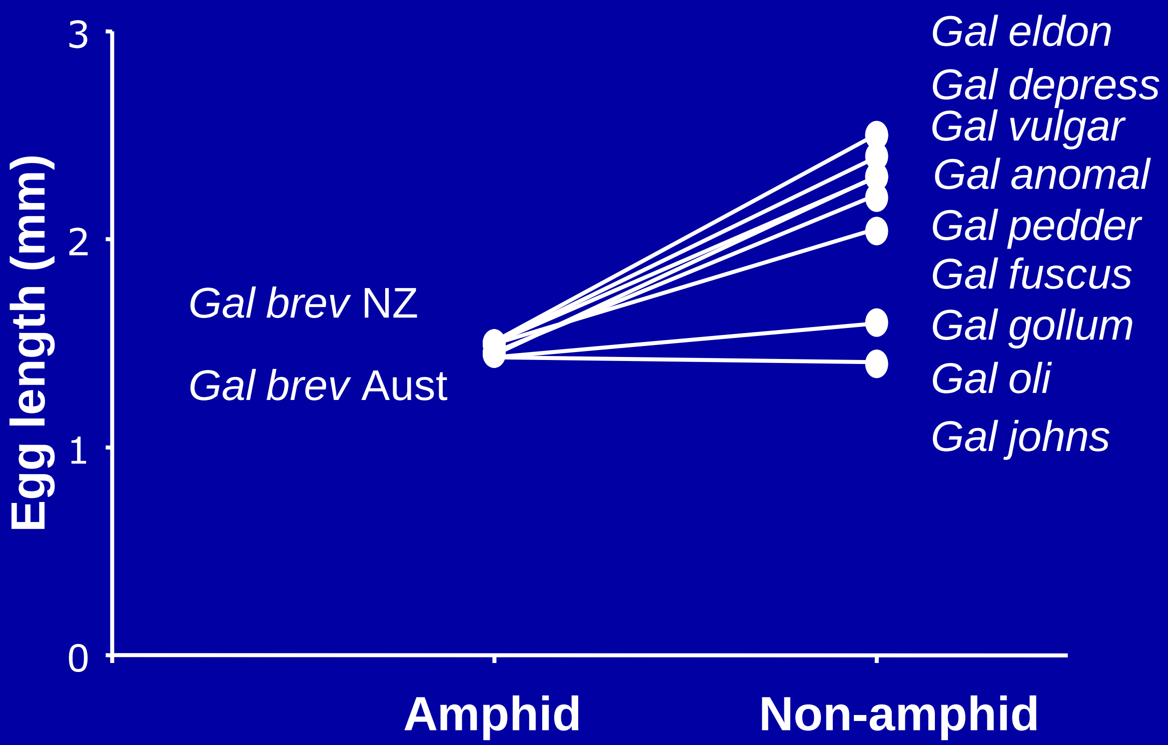
Mean Egg Length (±SE)

Amphidromous vrs Non-Amphid.

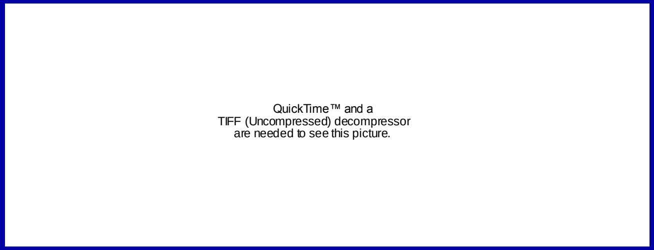


Galaxias brevipinnis grp.

Amphidromous vrs Non-Amphid.



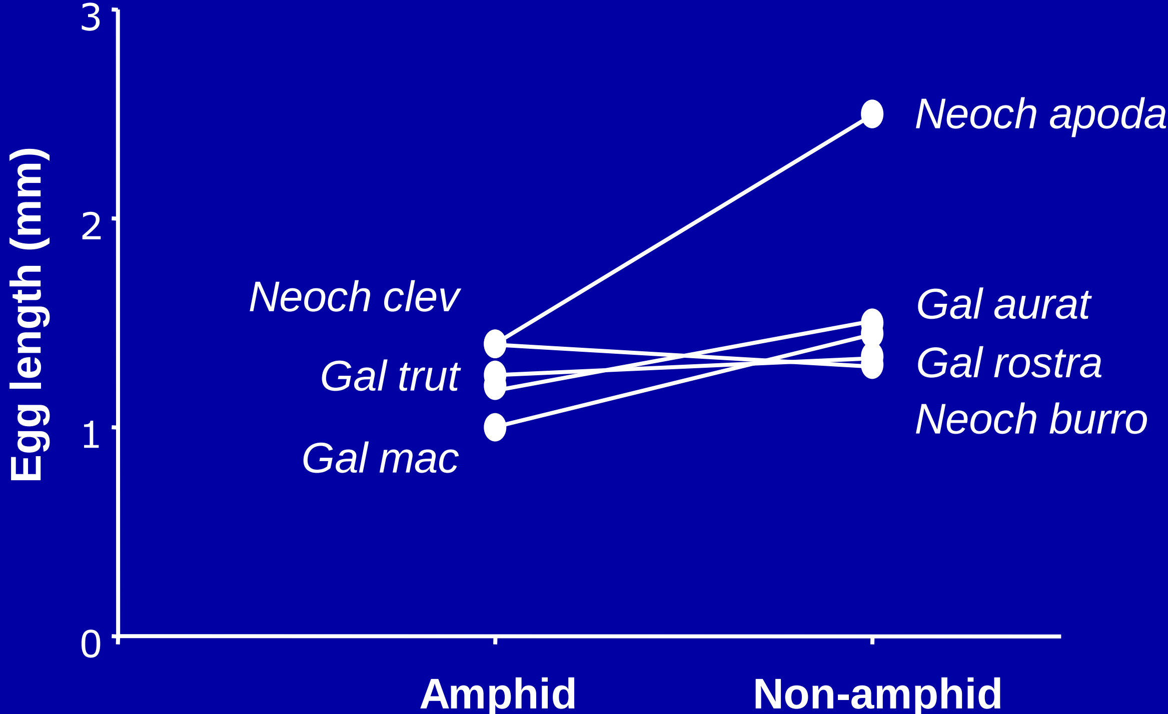
$P<0.001$
Incl. all galaxiids

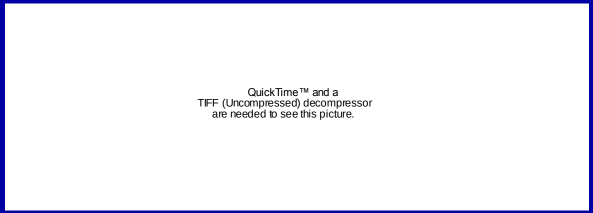


Galaxias brevipinnis
Source: Fishbase (McDowall, R.M.)

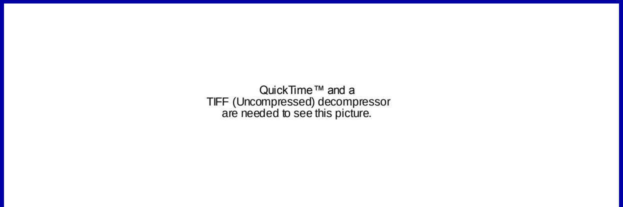
Other *Galaxias* & *Neochanna*

Amphidromous vrs Non-amphid





Neochanna burrowsius
Source: Fishbase (McDowall, R.M.)

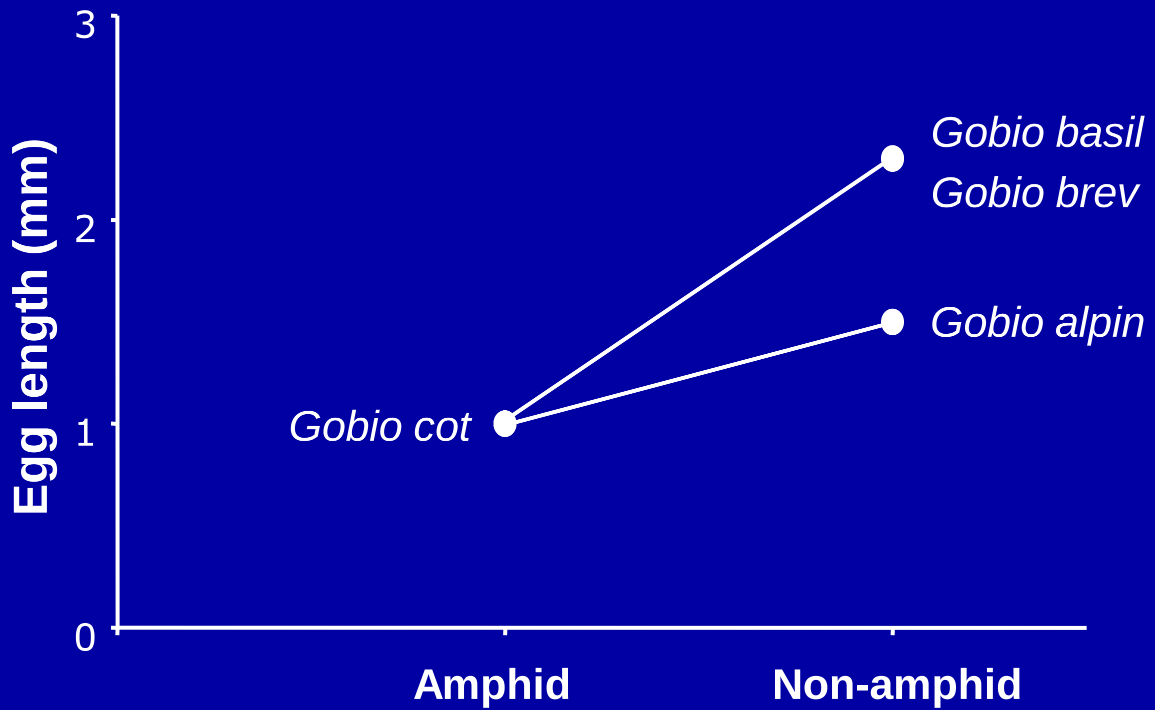


Galaxias maculatus
Source: Fishbase (McDowall, R.M.)

Gobiomorphus spp. (NZ)

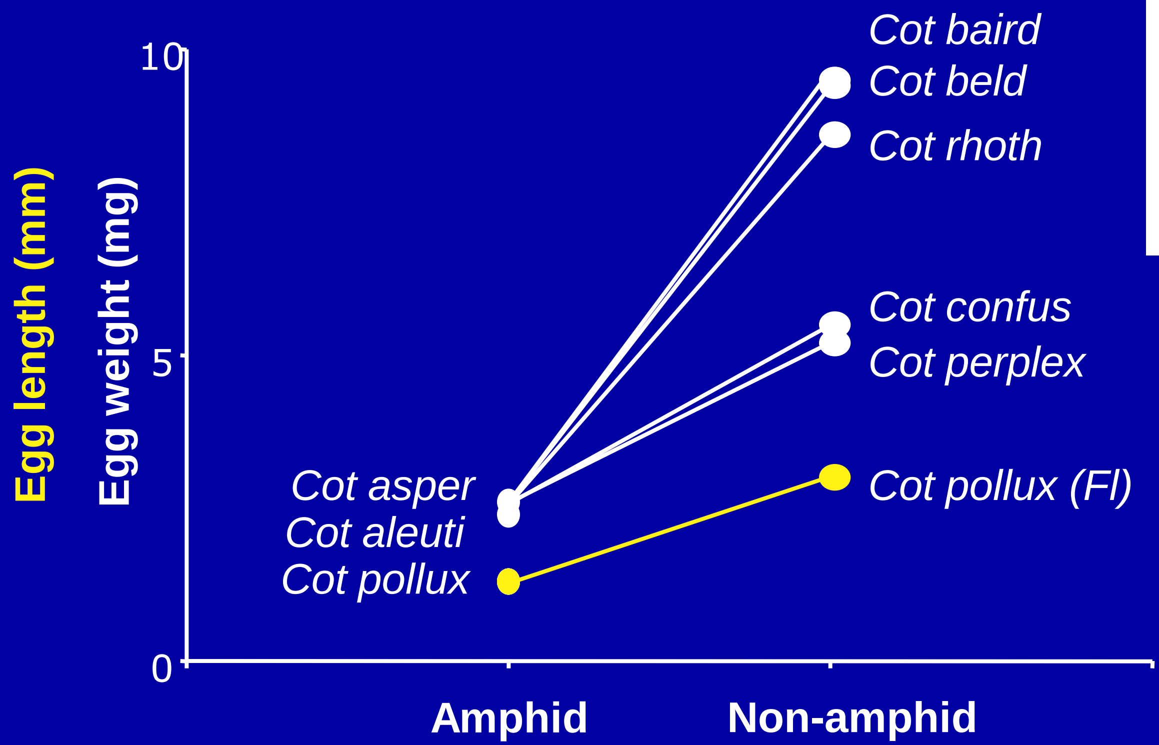
Amphidromous vrs Non-amphid

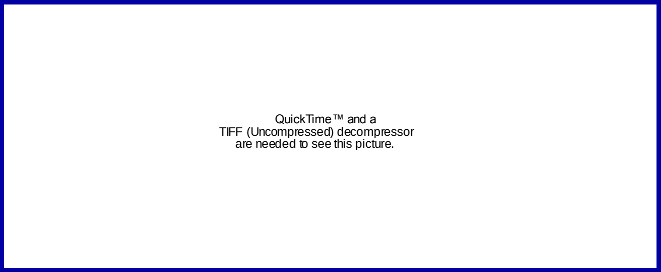
P=0.061



Gobiomorphus cotidianus
Source: Fishbase (McDowall, R.M.)

Cottus spp.
Amphidromous vrs Non-amphid

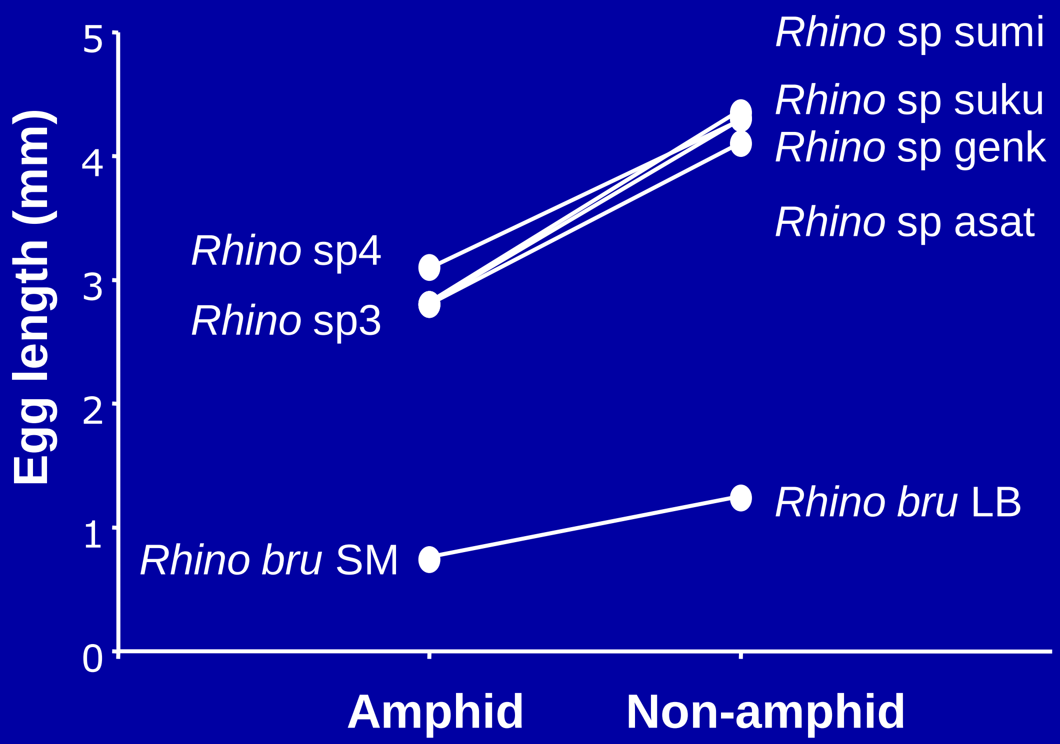




Cottus pollux
Source: Fishbase (Suzuki, T.)

P=0.003

Rhinogobius spp.
Amphidromous vrs Non-amphid



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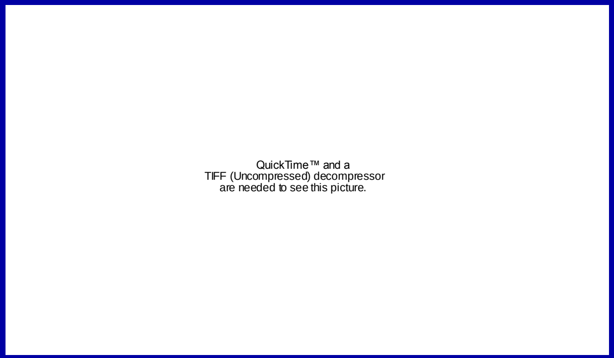

Rhinogobius brunneus
Source: Fishbase (Kim, I.-S.)

Results Summary

- **27 amphidromous / non-amphid pairs examined**
  - Only two non-amphidromous species have smaller eggs than (most likely) amphidromous ancestor
- **Increased egg size appears to have evolved multiple times**
  - At least five times in galaxiids
  - At least twice in *Gobiomorphus*
  - At least twice in *Cottus*
  - Potentially multiple times in *Rhinogobius*

Conclusions

- **Increased egg size is strongly associated with a non-diadromous life cycle**
- **Most radiations from amphidromous species are fluvial**
  - Requires completion of entire life cycle in streams
  - No pelagic rearing of larvae
- **But streams are difficult places to rear larvae**
  - Limited prey, strong currents, risk of parasitic infections
- **Potential benefits of a large egg**
  - Most obvious, a large larvae
  - Better able to access prey, tolerate food deprivation & parasitic infection, resist currents
  - No requirement for pelagic larval phase or risky migration
  - Occupation of upland streams remote from pelagic habitats

Conclusions

- **Cost of a non-amphidromous life history**
  - Most non-amphidromous species are small
  - No increase in adult size to compensate for production of larger egg
  - Hence, reduced fecundity relative to amphidromous ancestors
- **Potentially more vulnerable to stressors**
  - Witness severe impact of trout predation on non-diadromous galaxiid distribution & abundance

Thanks