FRANCESCA GHERARDI MEMORIAL AWARD
30TH MAY 2019

INVASIVE SPECIES: THE IMPORTANCE OF ENVIRONMENTAL CONTROLS

KATE MATHERS

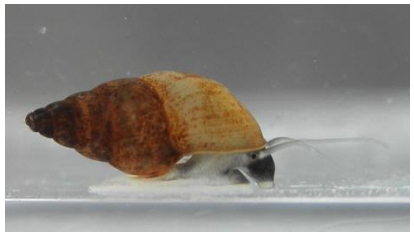
Invasive species

Chinese Mitten Crab

Killer, Demon and Crangonyx shrimp

Mysidae

Signal crayfish



New Zealand Mud Snail

Zebra and Quagga Mussels

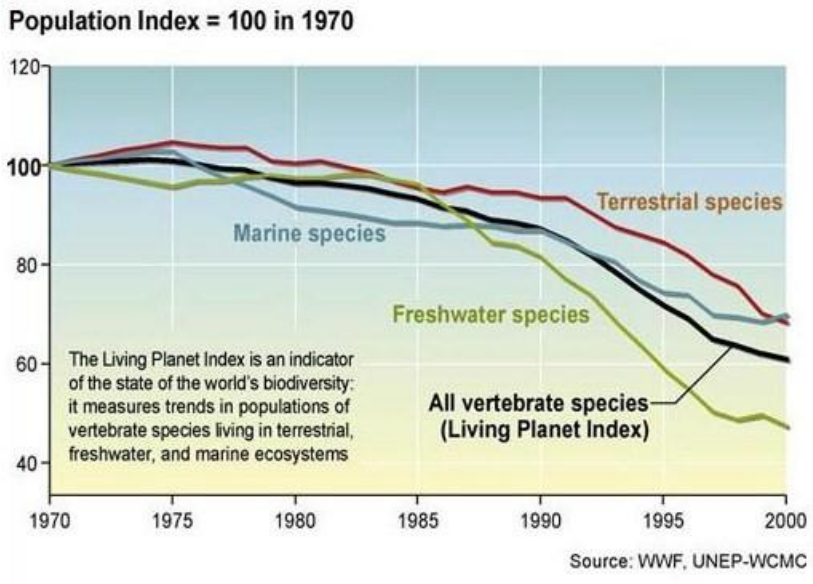
Himalayan Balsam

Harlequin ladybird

Biological invasions and the environment

1. Establishment and spread

2. Consequences for receiving ecosystem



STUDY ORGANISMS

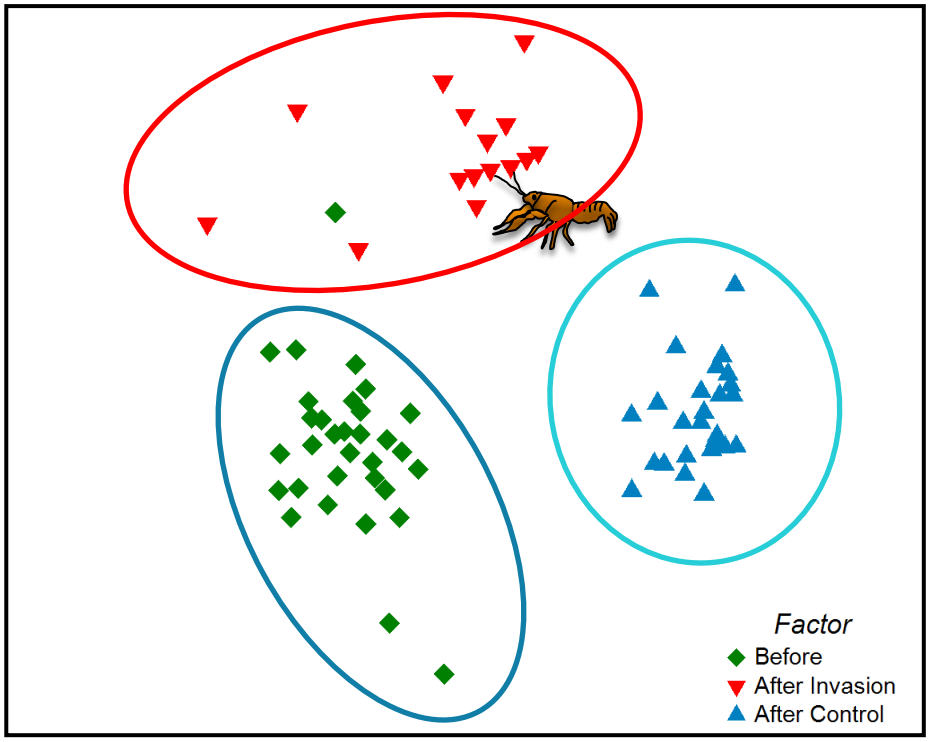
SIGNAL CRAYFISH (*PACIFASTACUS LENIUSCULUS*)

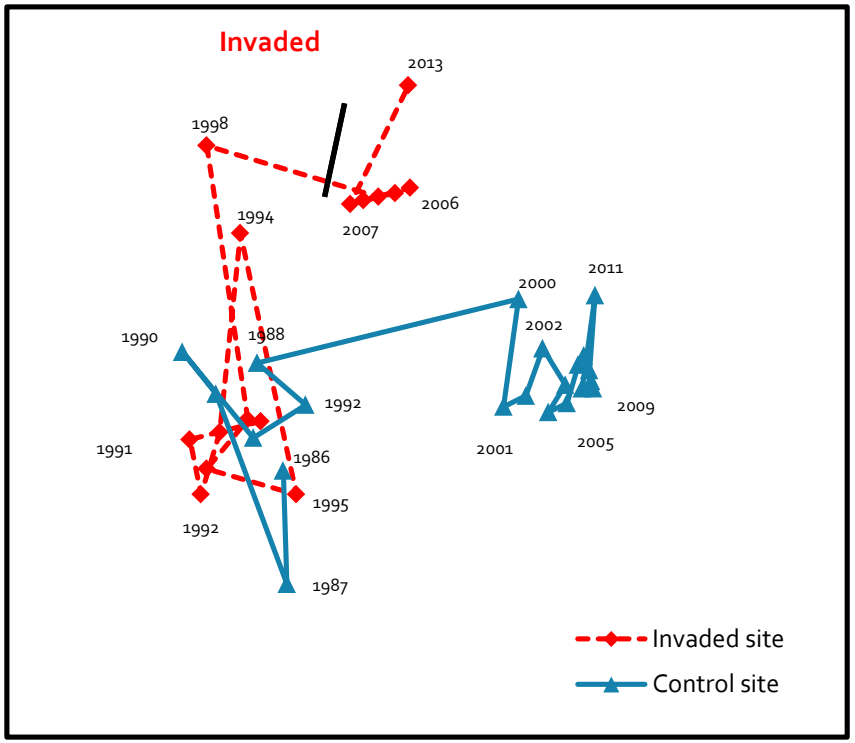
Signal crayfish (*Pacifastacus leniusculus*)

- Signal crayfish are one of the most prevalent non-native species and are continuing to spread (Holdich et al., 2014)
- Can reach large population densities
- Polytrophic feeding habits
- Considered to be keystone species

Signal crayfish (*Pacifastacus leniusculus*)

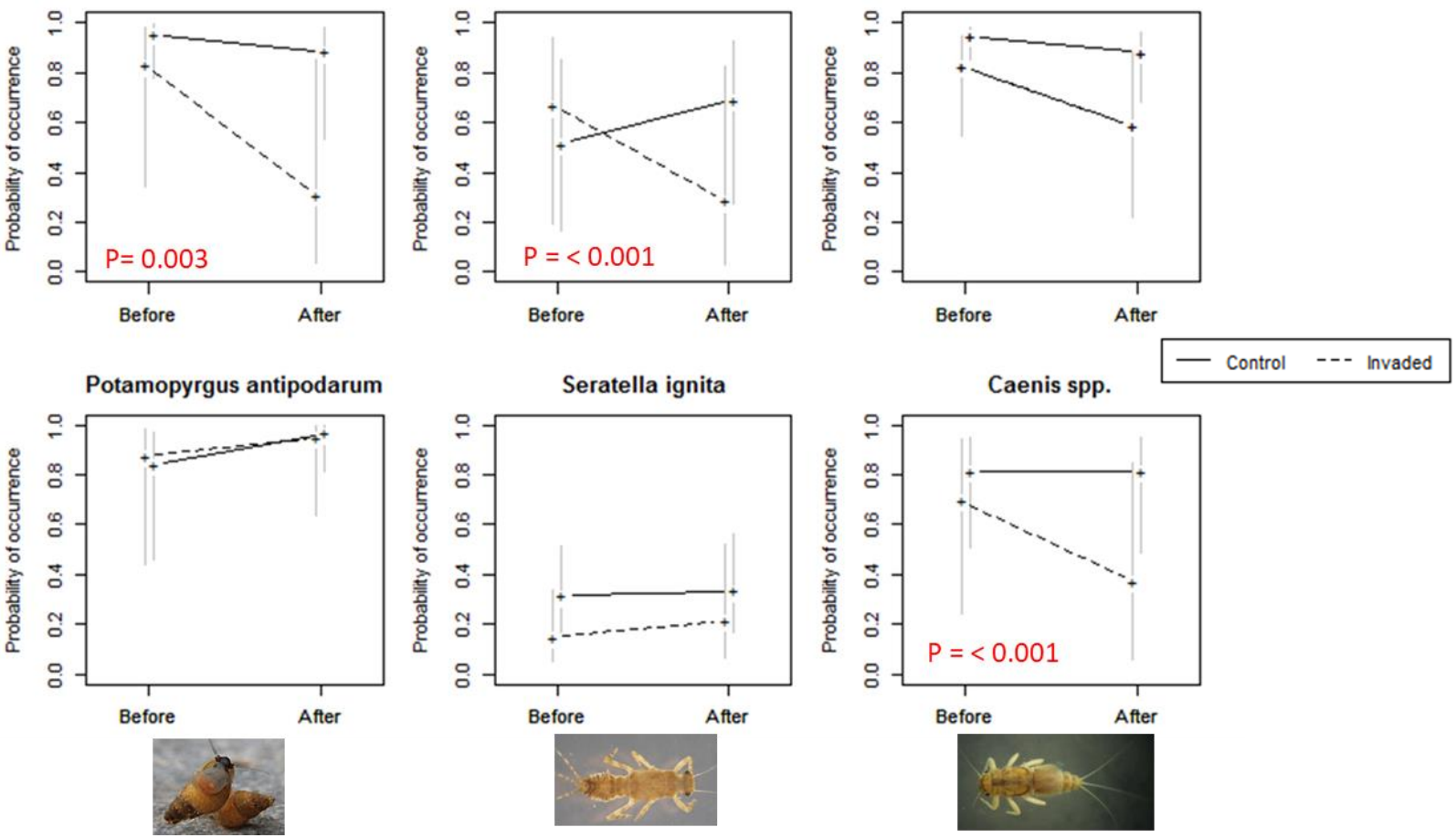
- Significant, irreversible long term effects for river macroinvertebrate communities (Mathers et al., 2017a)





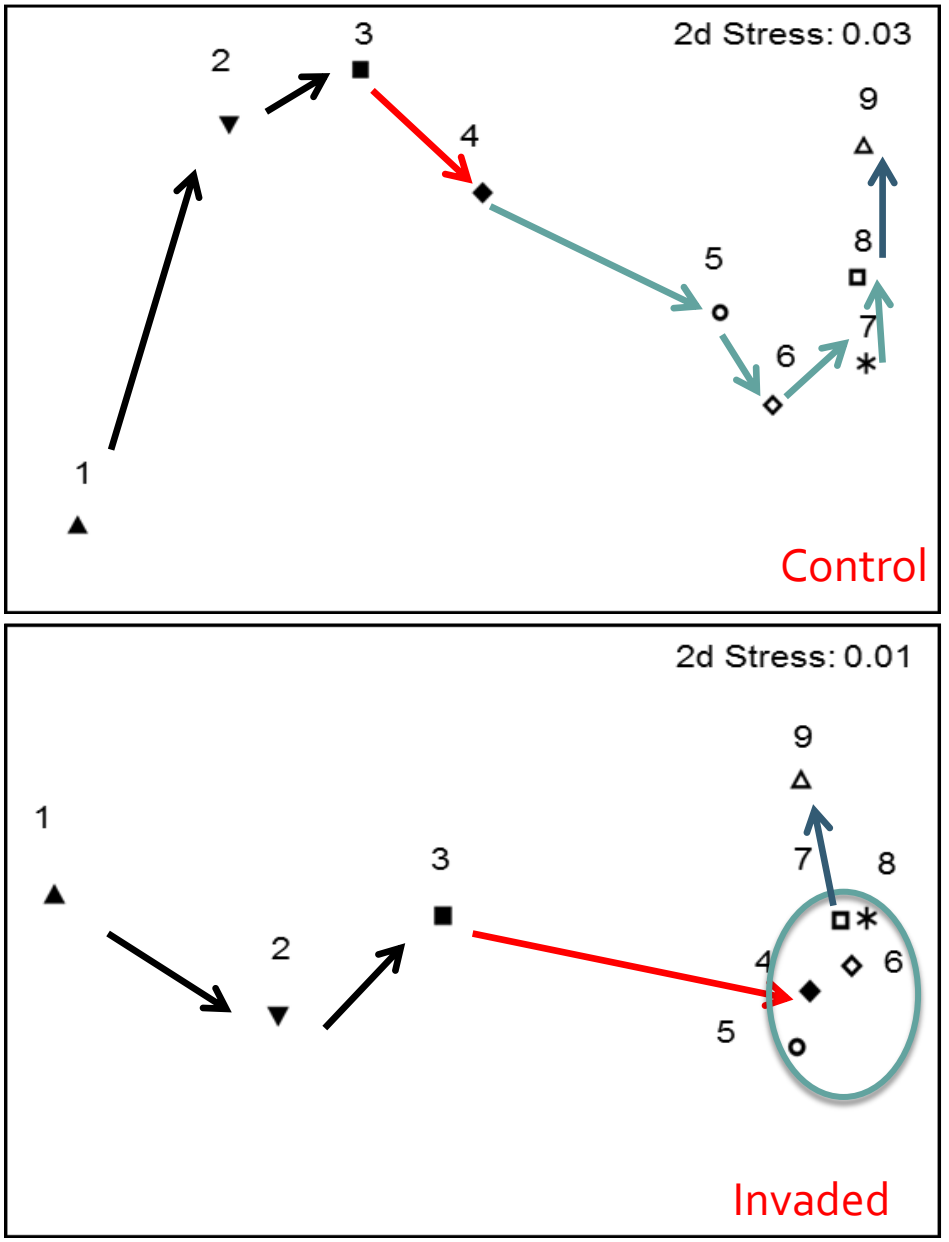
Signal crayfish (*Pacifastacus leniusculus*)

- Predominantly slow-moving taxa affected (i.e. snails, leeches)



Signal crayfish (*Pacifastacus leniusculus*)

- Temporally variable effects on macroinvertebrate communities over invasive crayfish season (Mathers et al., 2018)



Invasive crayfish: can modify the physical environment

- Burrowing activities introduce large quantities of fines to the river system (0.25 - 0.50 t km^{-1} yr^{-1})
- Crayfish bioturbation enhances sediment loads - 32% to monthly baseflow suspended sediment (0.21 to 0.66 t km^{-2} yr^{-1})

Rice et al., 2016, JGR-ES

DIKEROGAMMARUS

Dikerogammarus species

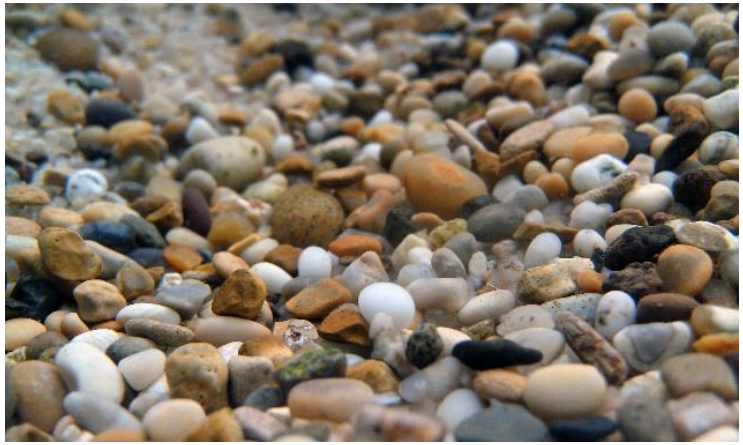
- Originate from Ponto-Caspian region (Dobson, 2013)
- Large environmental tolerance (water quality, thermal regime, habitat modifications)
- *Dikerogammarus haemobaphes* (demon shrimp) most widely distributed whilst *Dikerogammarus villosus* (killer shrimp) confined locations

Dikerogammarus species

- Replacement and extirpation of native and non-native congeners through inter-specific competition for refuges and resources (De Gelder et al., 2016)
- Killer shrimp regarded as one of the most dangerous invasive species across Europe (DAISE, 2019)

IMPORTANCE OF SUBSTRATE CONDITIONS

Biological invasions- substrate conditions



1. CRAYFISH MESOCOSM STUDY

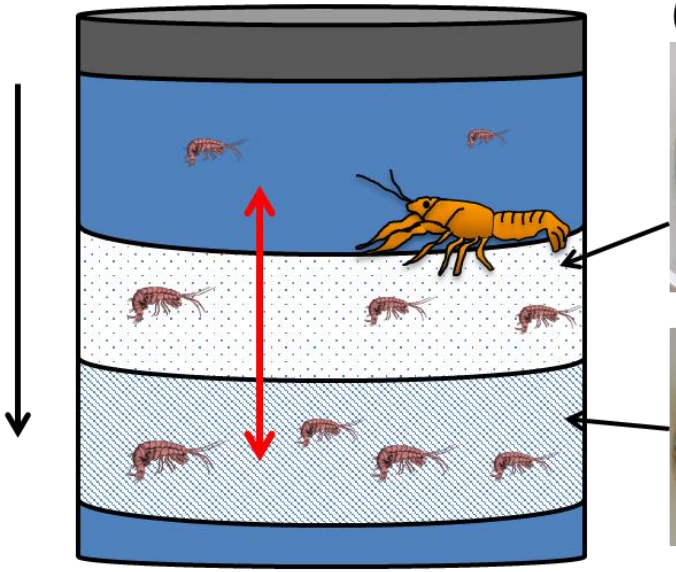
(MATHERS ET AL., 2019)

- Signal crayfish have direct implications for macroinvertebrate communities and fine sediment dynamics – inputs and mobilisation

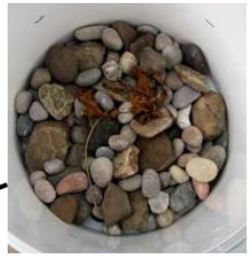


- BUT what are the interactions between fine sediment ingress and predator-prey relationships?

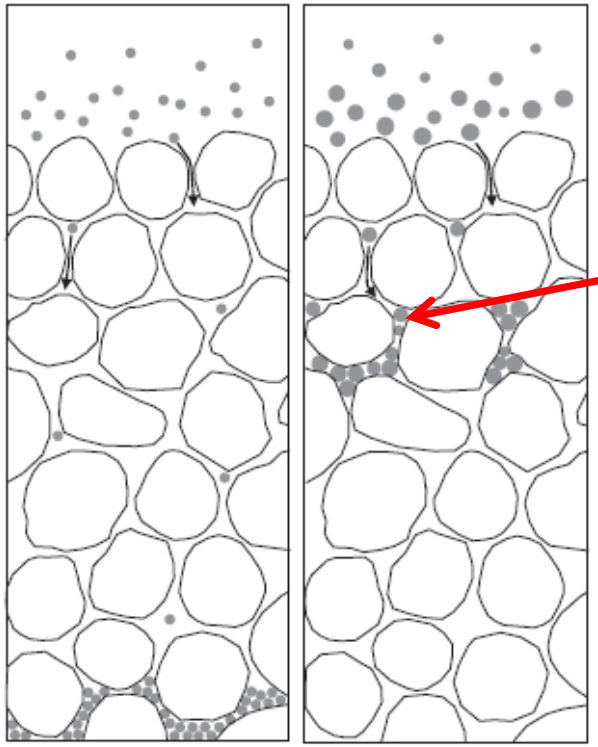
Crayfish and fine sediment



Coarse surface layer (50mm deep)



Finer sub-surface layer (50mm deep)

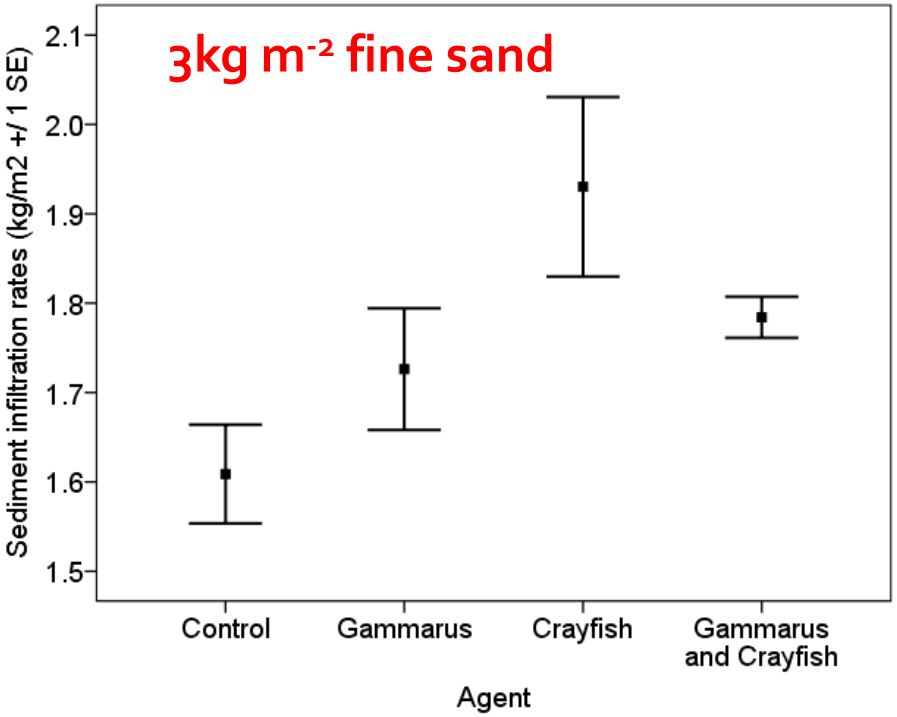


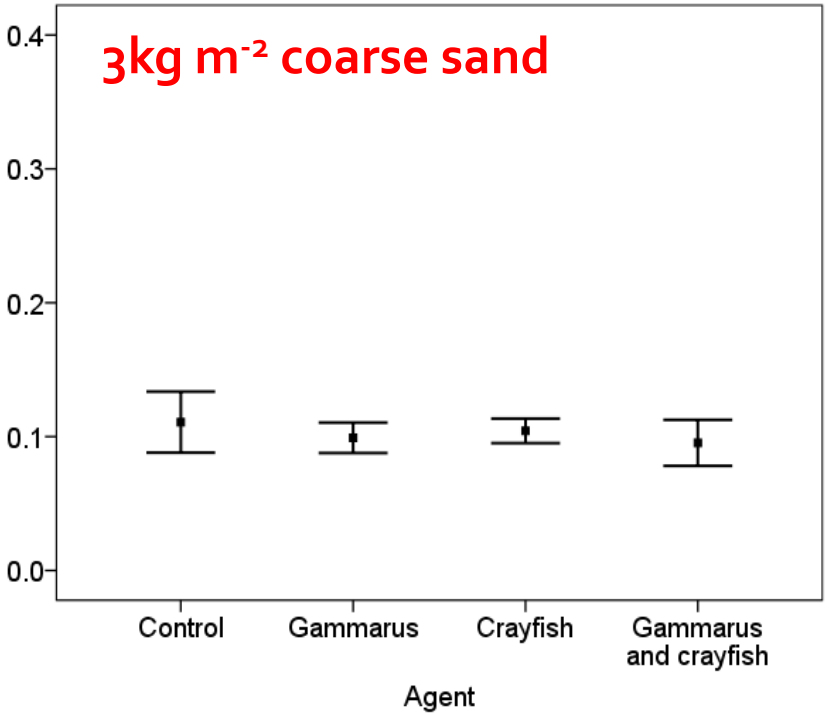
Colmation / clogging

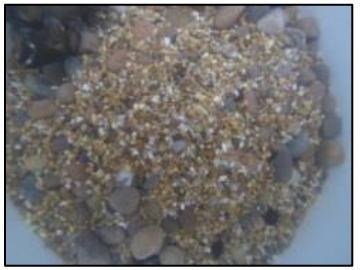
Gibson et al., 2009

“Bulldozing” effect to find food

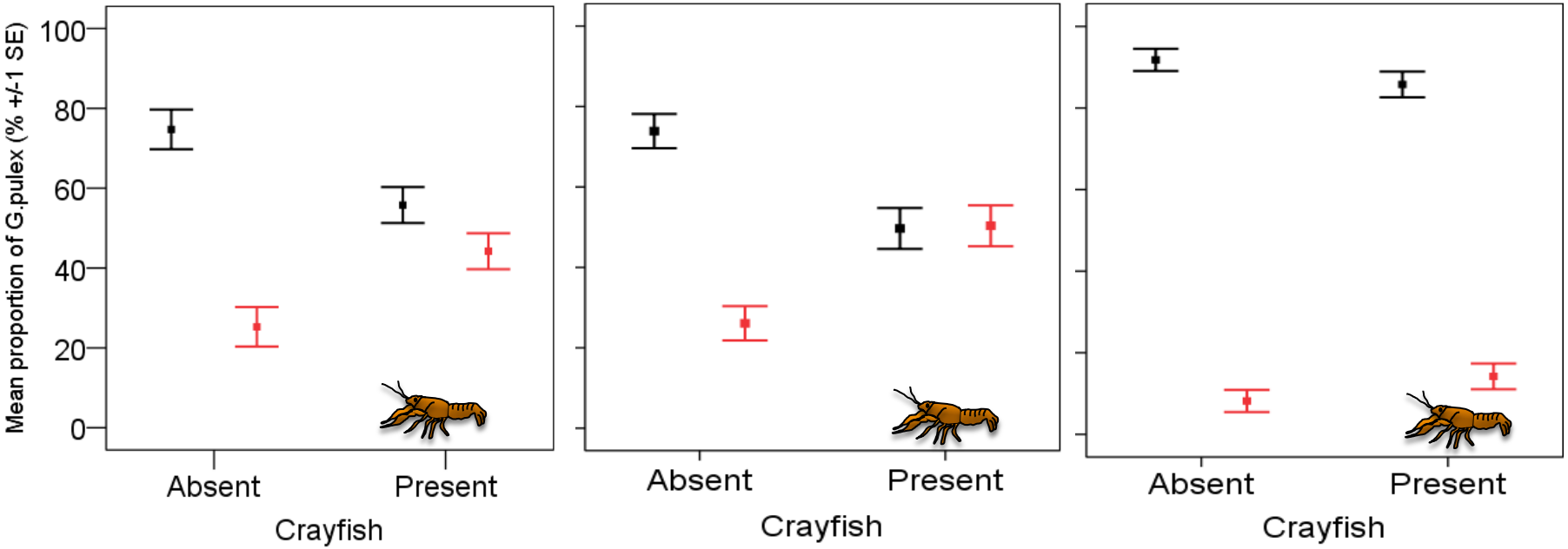
Fine sediment ingress rates







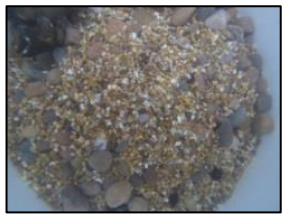
Prey avoidance behaviour



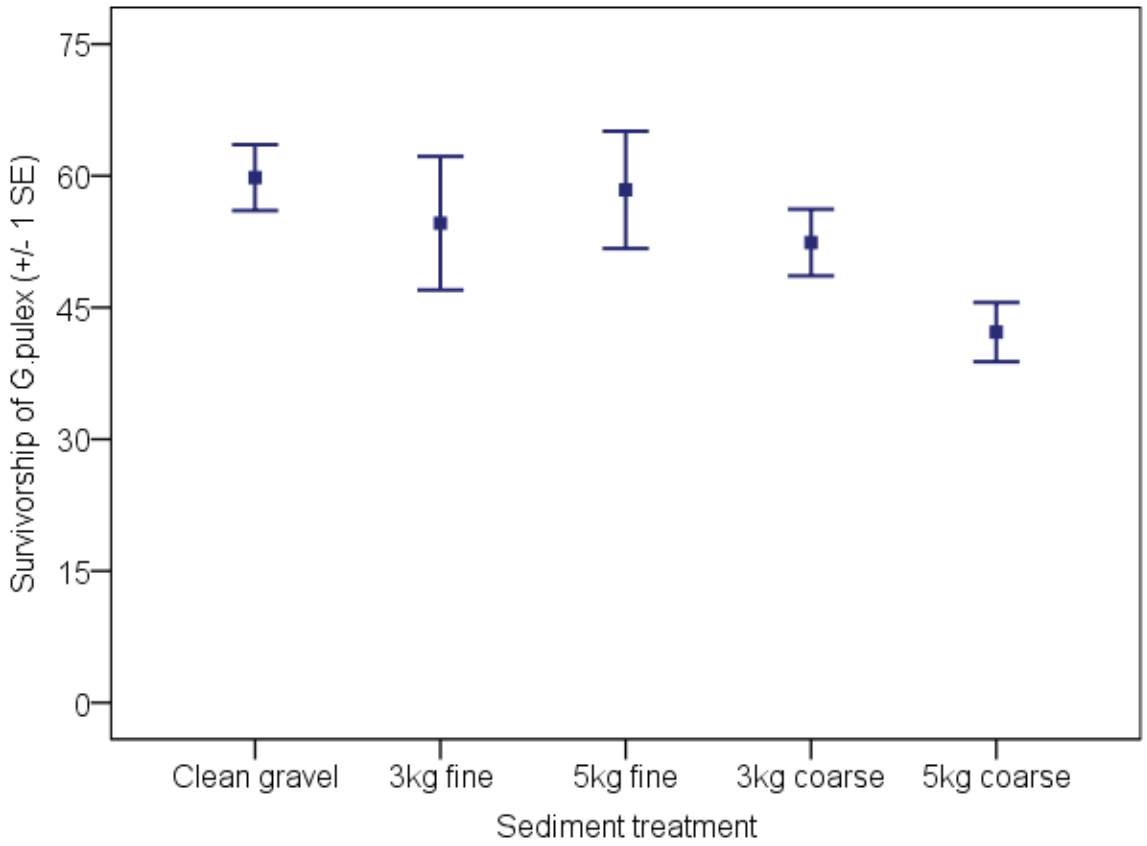
Control (clean open-framework gravel)

3 kgm^{-1} fine sand (low propensity to clog pores)

5 kgm^{-1} coarse sand (high propensity to clog pores)



Survivorship rates



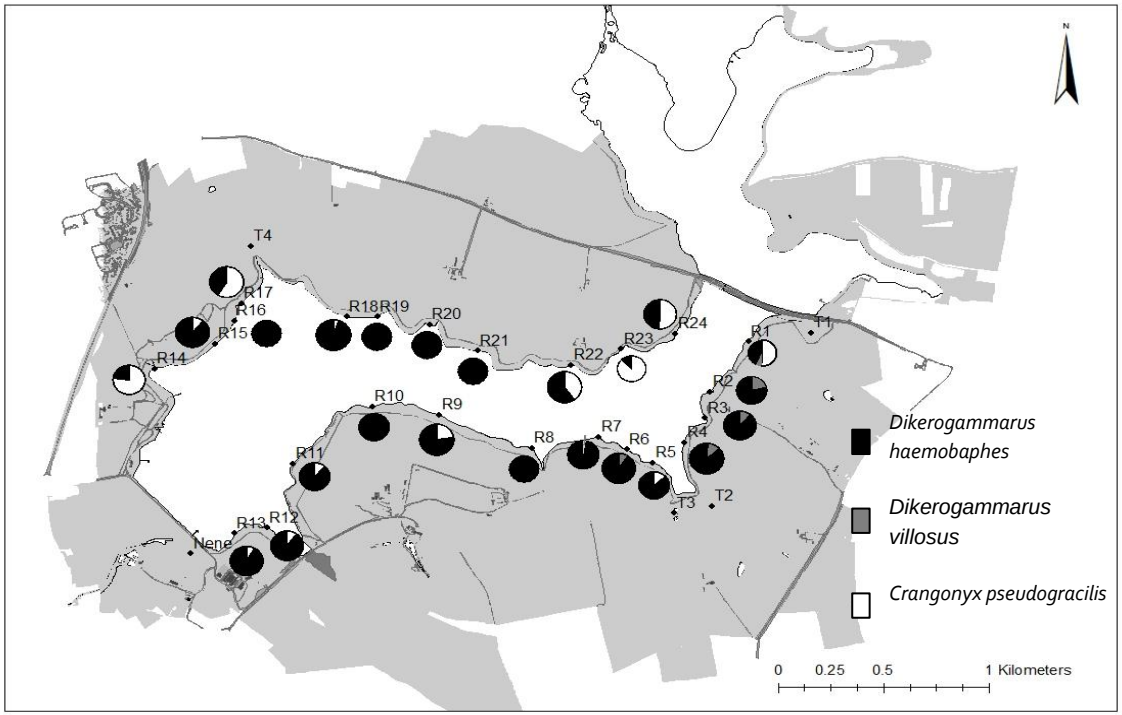
Summary

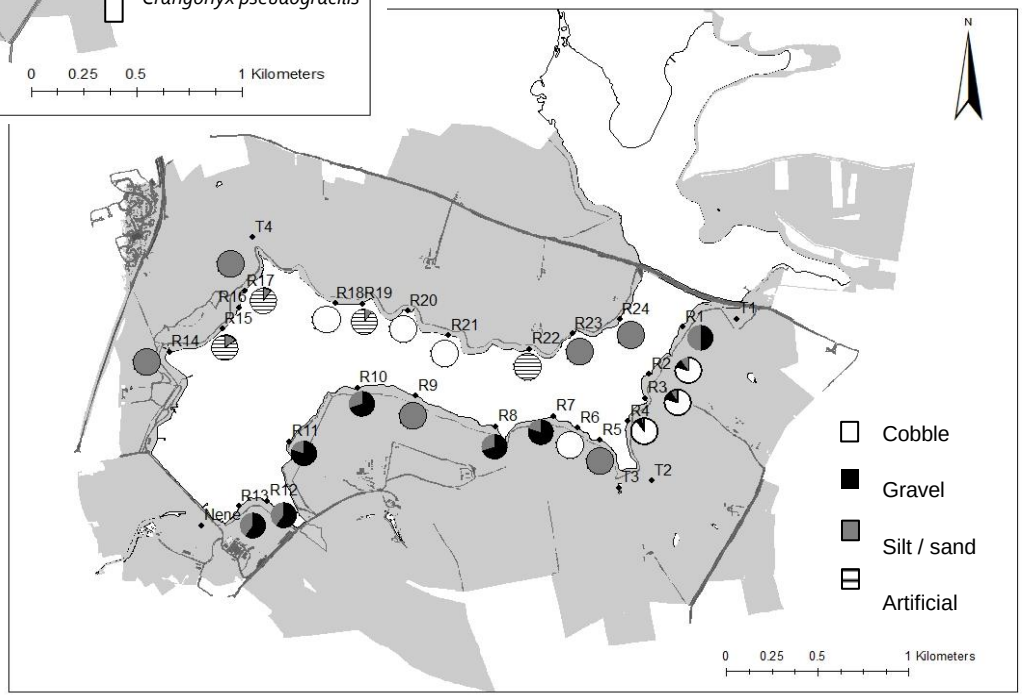
- Some taxa may utilize vertical migration into river bed to avoid predation
- Sedimentation limits refugia potential enhancing predation vulnerability
- Signal crayfish are able to modify their environment which may contribute to enhanced predation success in some rivers and possibly their invasion success?

2. INVASIVE AMPHIPODS SURVEY

(CLINTON ET AL., 2018; ONGOING)

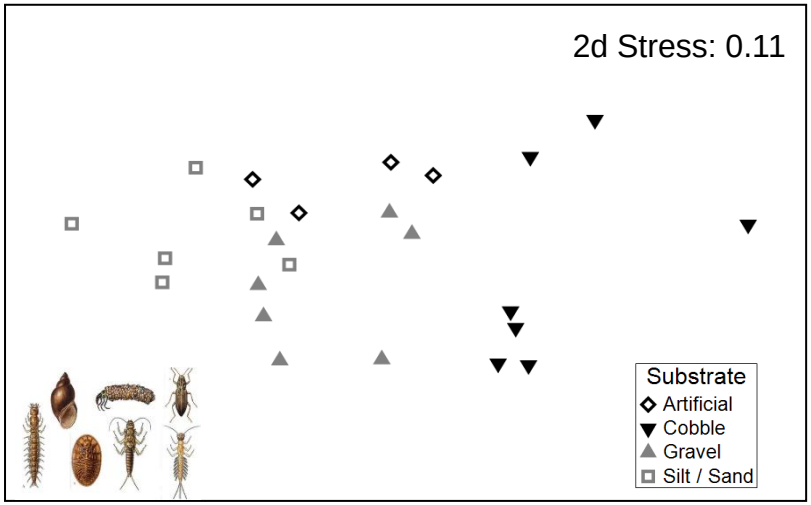
2016 field survey

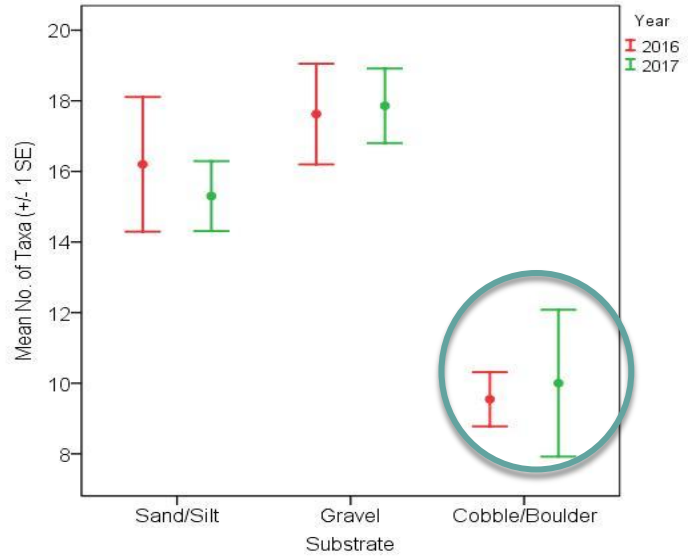




D. haemobaphes dominated the macroinvertebrate community within the reservoir and demonstrated a strong affinity for large cobble and artificial substrates.

Role of substrate characteristics for wider community



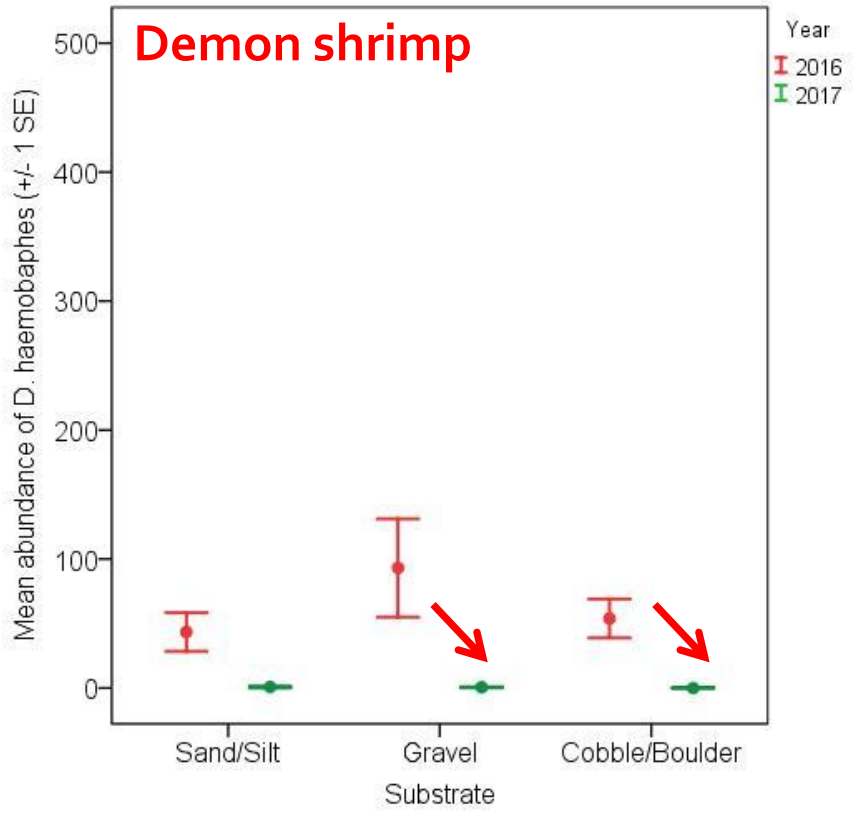


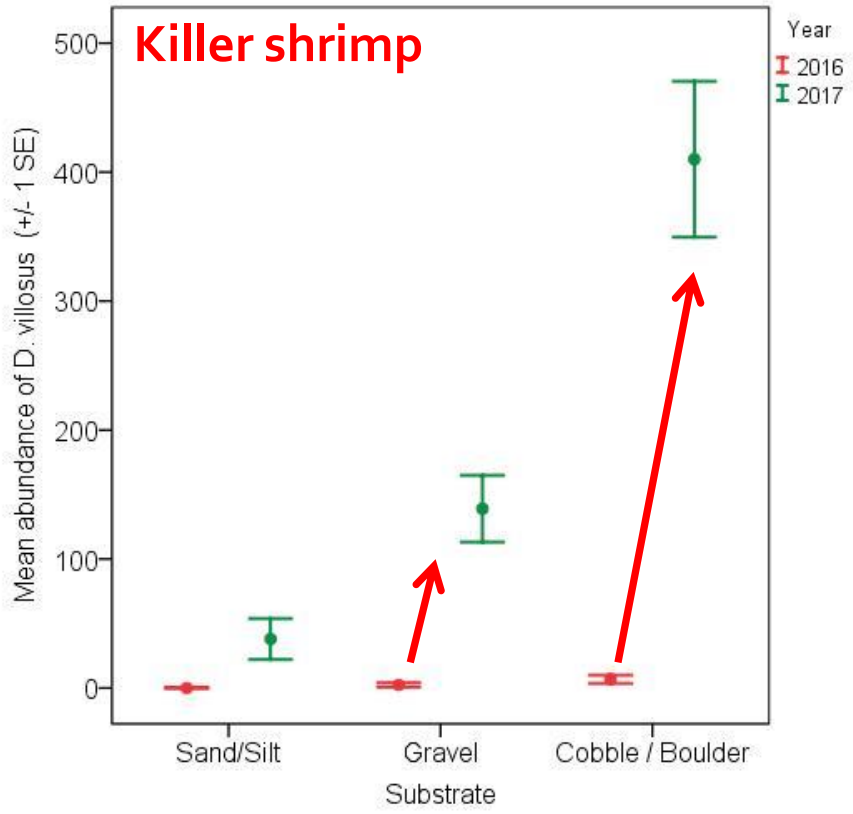
Presence of different habitats results in differential effects on wider native community composition of macroinvertebrates

Lack of other taxa present in 'preferred" *Dikerogammarus* habitat

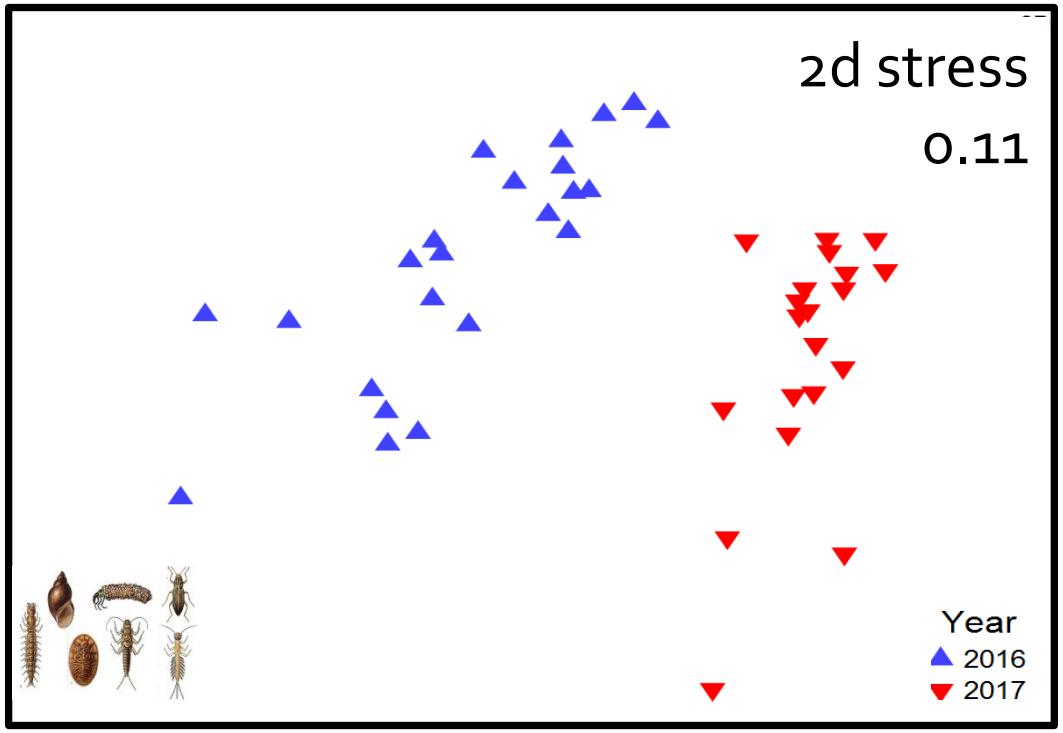
2017 follow-up field survey

Role of substrate characteristics for invasion dynamics





Role of substrate characteristics for invasion dynamics



Shift from demon to killer shrimp dominance altered wider community composition

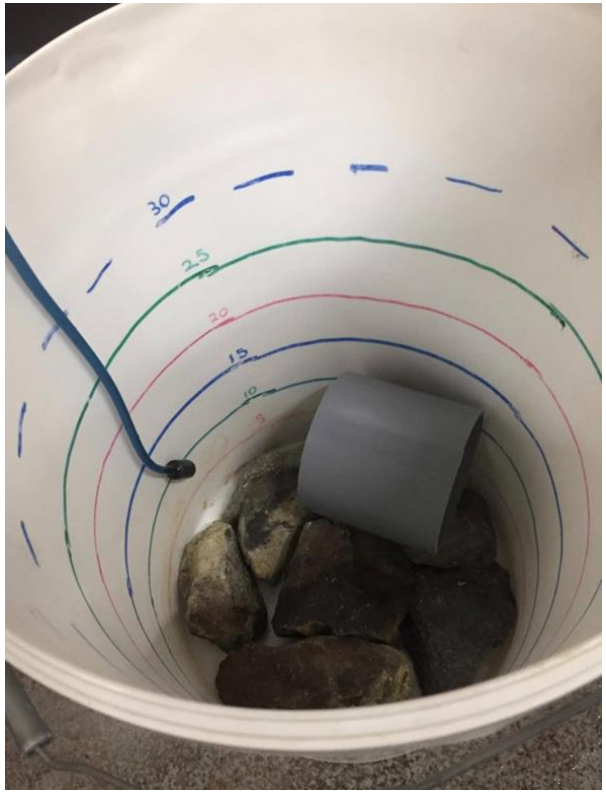
Summary

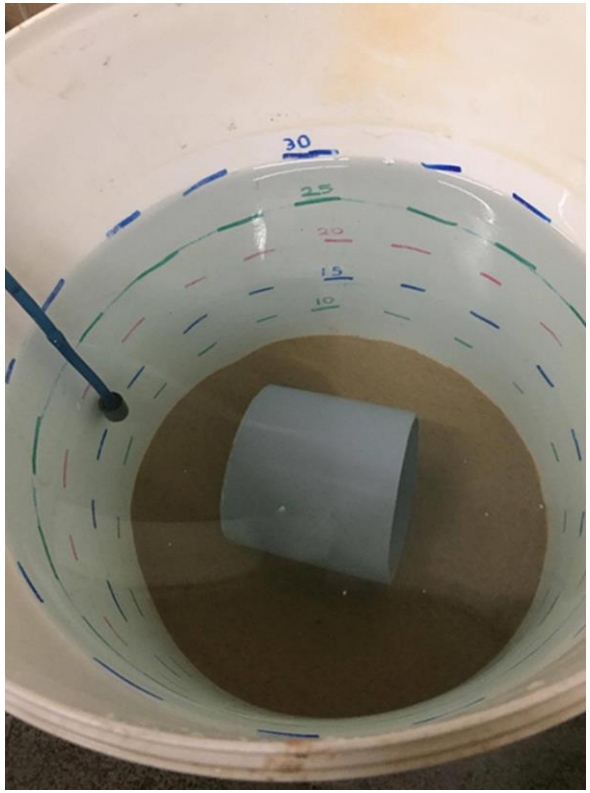
- Invasive *Dikerogammarus* prefer coarse substrates
- Native taxa and less competitive non-native amphipods displaced to less preferential habitats
- Heterogeneous habitats provide some ability for native taxa to actively avoid invaders

3. CRAYFISH & INVASIVE AMPHIPODS EXPERIMENT

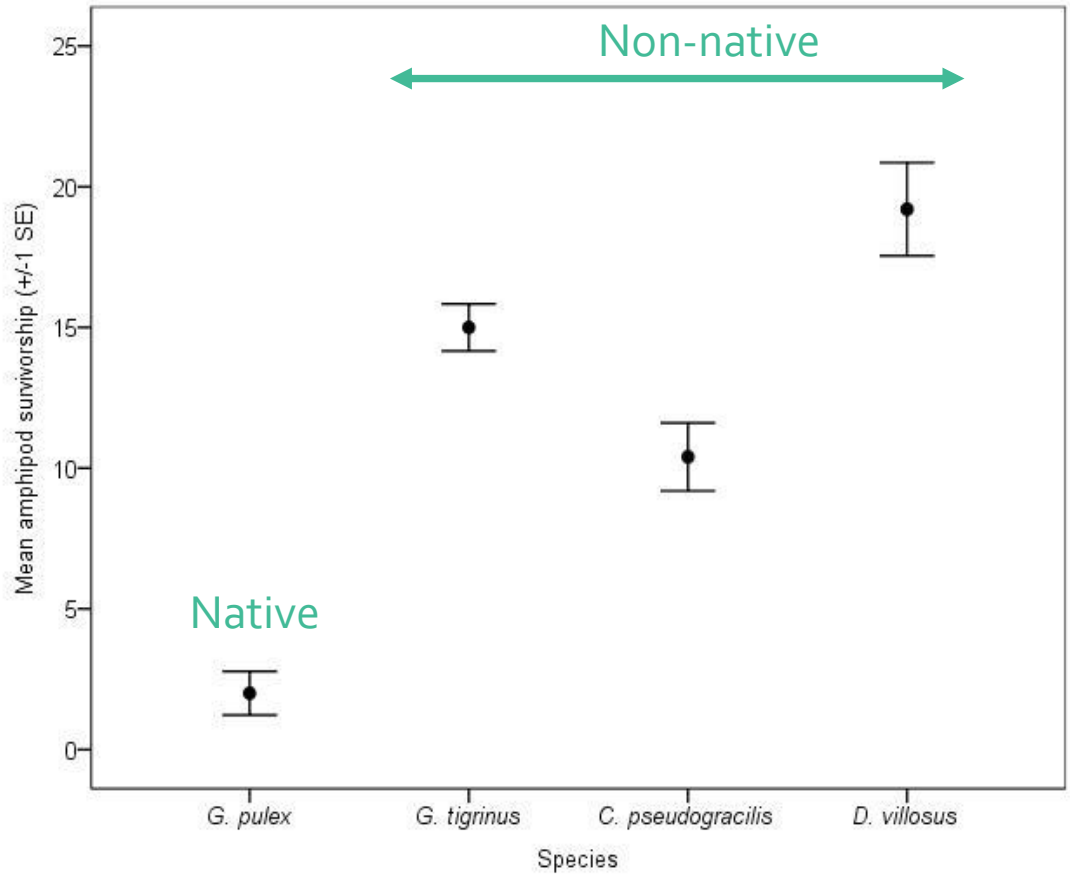
(BEATTY ET AL., IN PREP)

Invasive crayfish, amphipods and habitat suitability

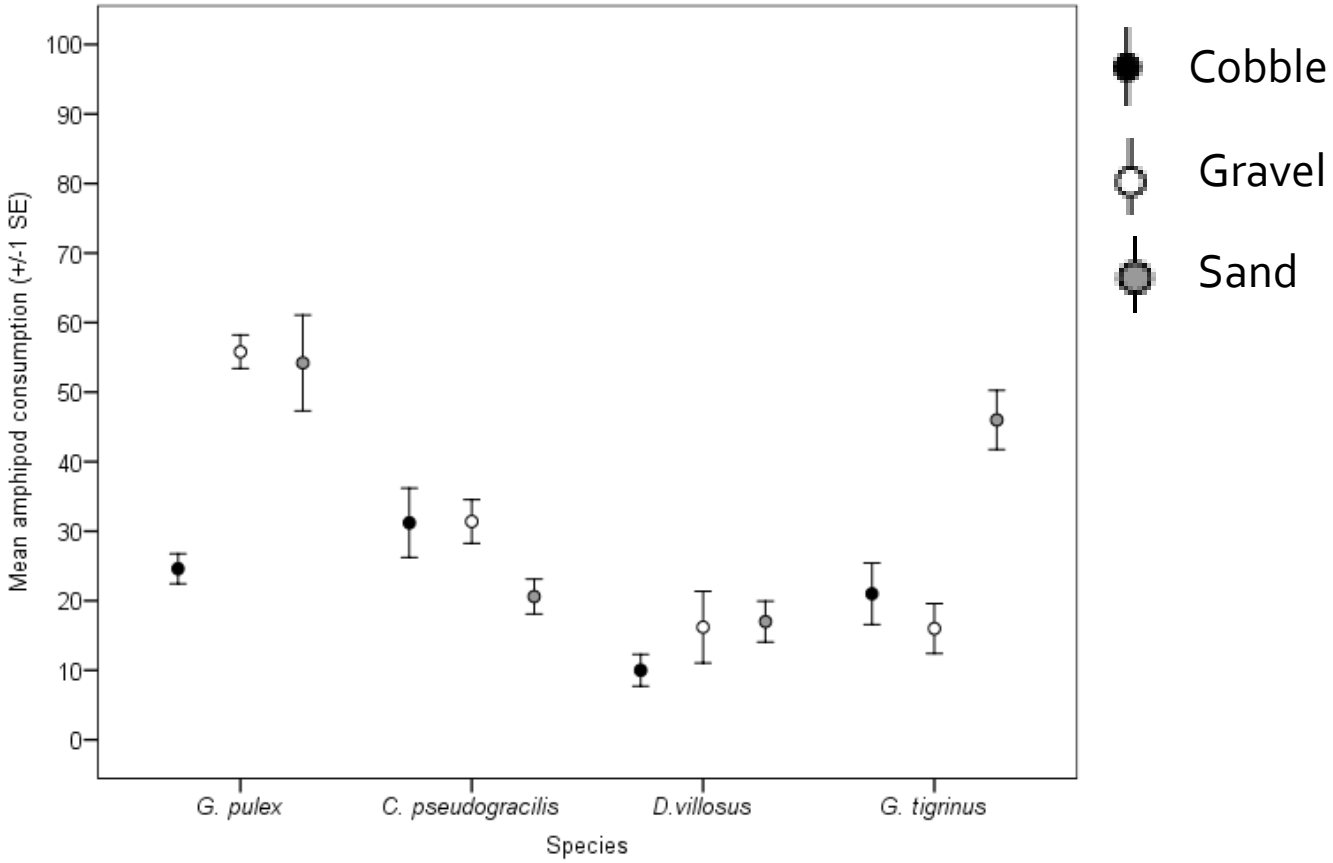




Invasive crayfish interaction with invasive and native amphipods



Invasive crayfish, amphipods and habitat suitability



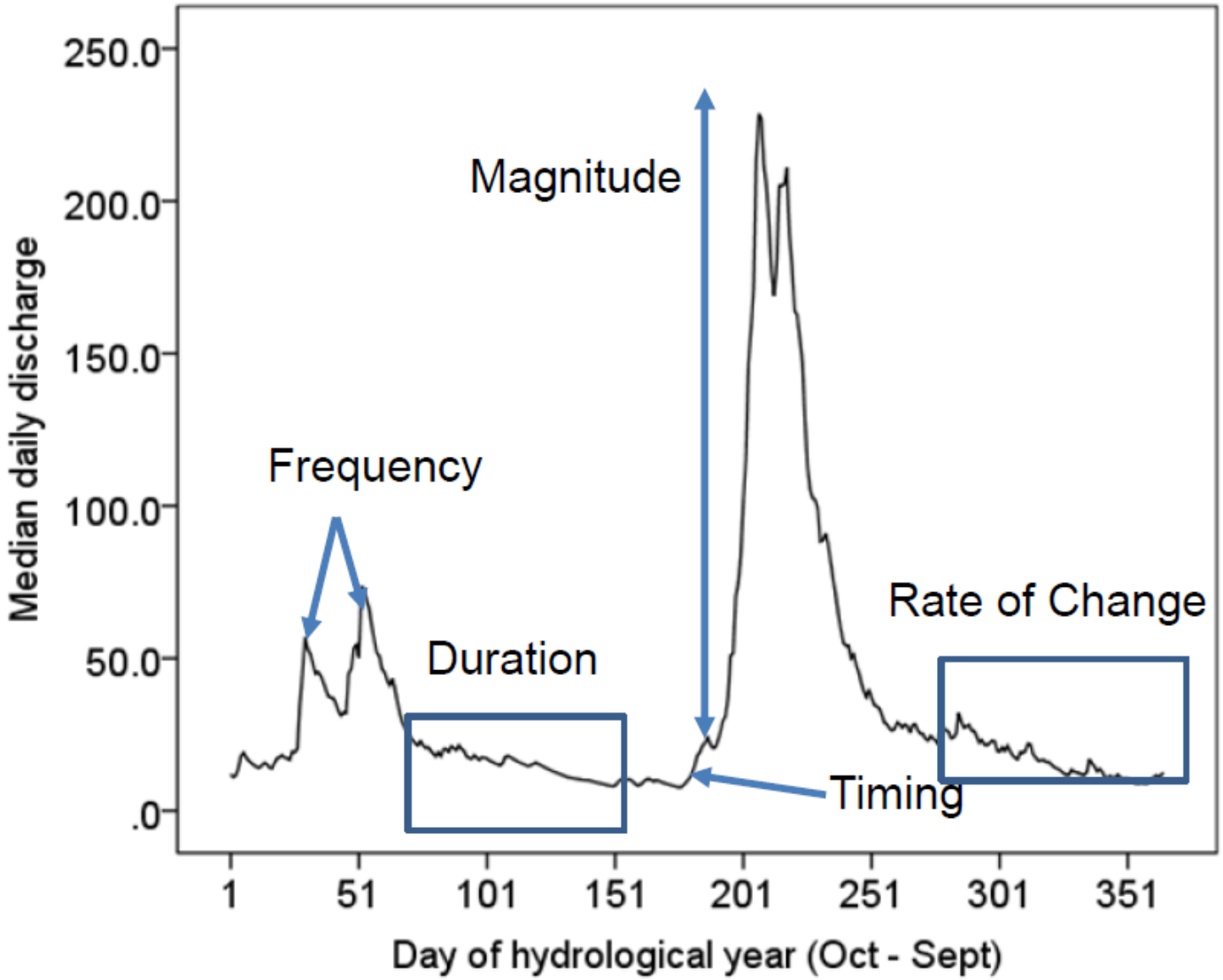
Summary

- Invasive amphipods demonstrate greater survivorship to invasive crayfish predation
- Substrate size has a significant effect on crayfish predation
- Larger substrates typically supported greater survivorship (except for *C. pseudogracilis*)
- Implications of habitat were taxa specific

IMPORTANCE OF HYDROLOGY

Biological invasions- hydrology

Biological invasions and hydrology

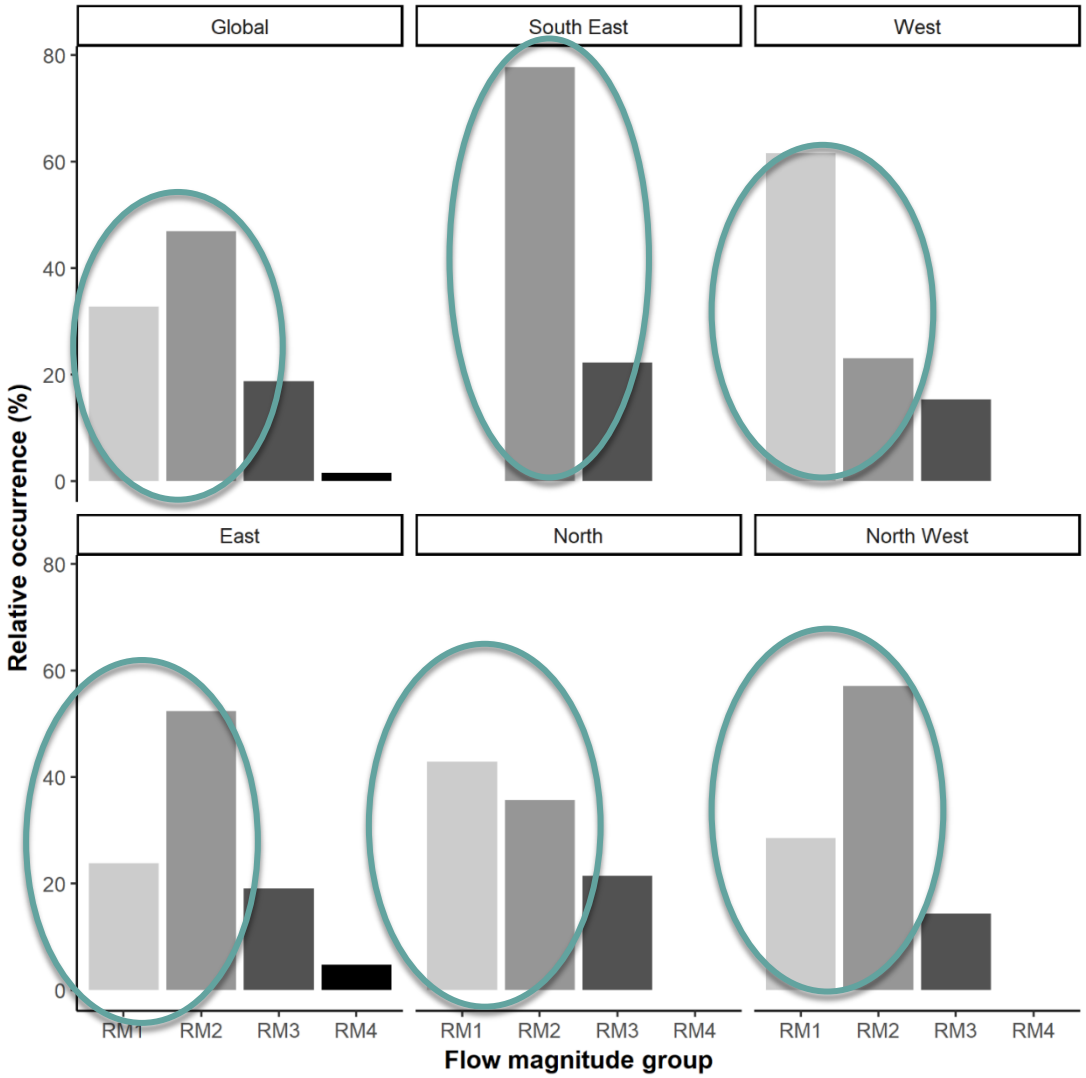


After (Richter et al., 1996; 1997)

1. CRAYFISH LONG TERM FIELD STUDY

(MATHERS ET AL., IN REVIEW)

Invasion dates of crayfish relative to river flow magnitude



Region wide flow magnitudes

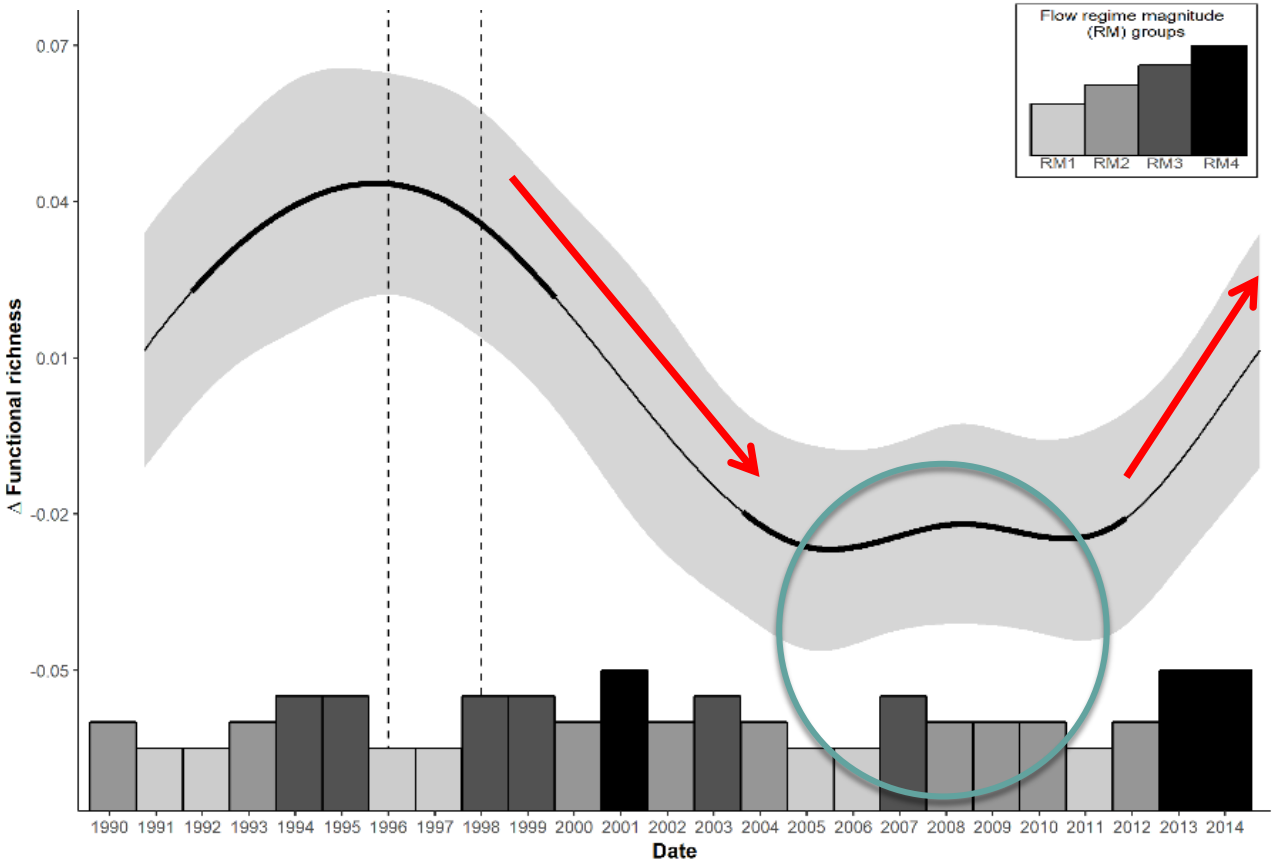
RM1 = low

RM2 = low-moderate

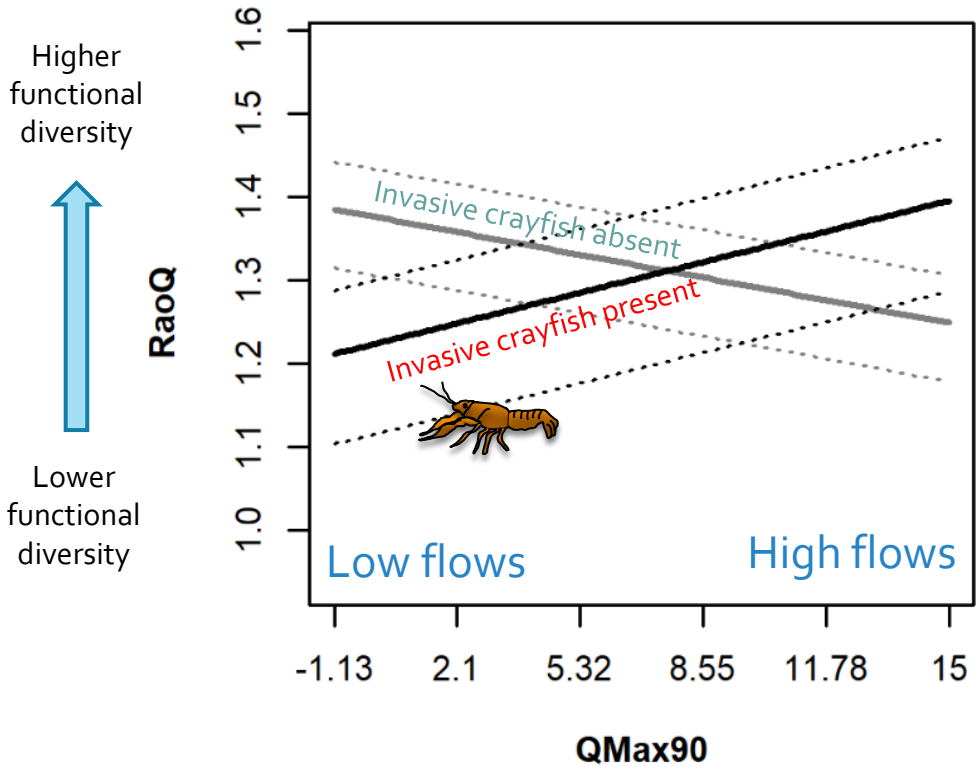
RM3 = moderate-high

RM4 = high

Crayfish invasion effects for receiving community associated with river flow magnitude

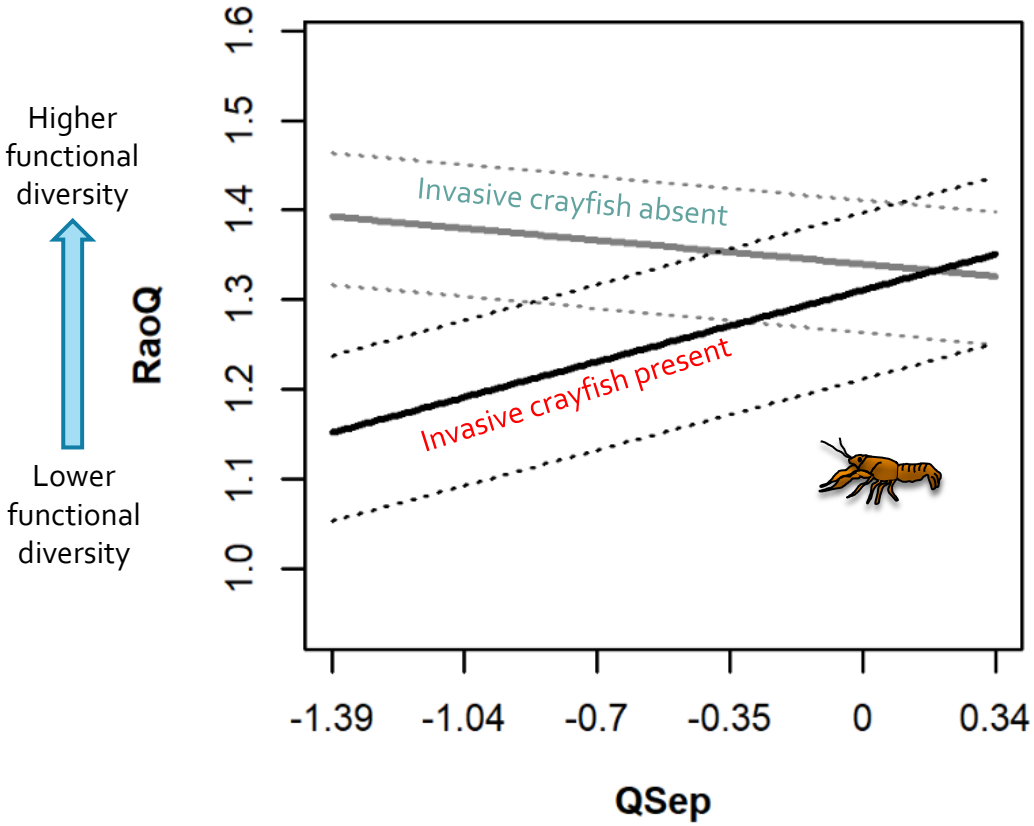


Crayfish invasion effects for receiving community associated with river flow variability



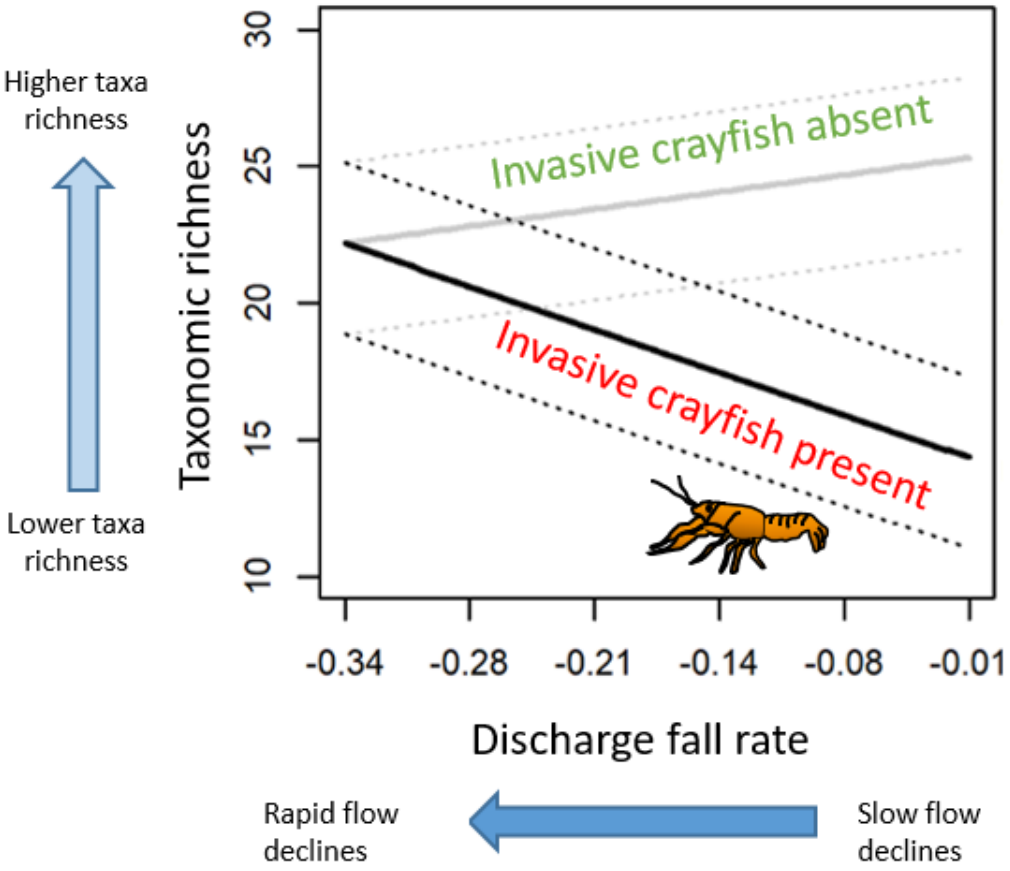
Magnitude of flow found to be a primary control

Crayfish invasion effects for receiving community associated with river flow variability



Timing of flow events a primary control

Crayfish invasion effects for receiving community associated with river flow variability

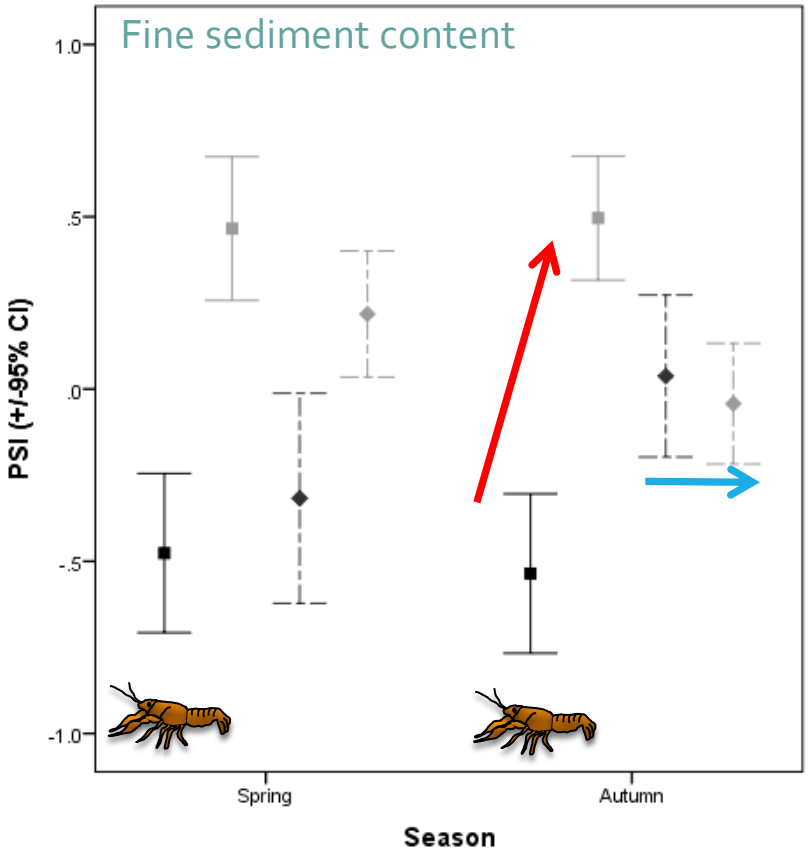


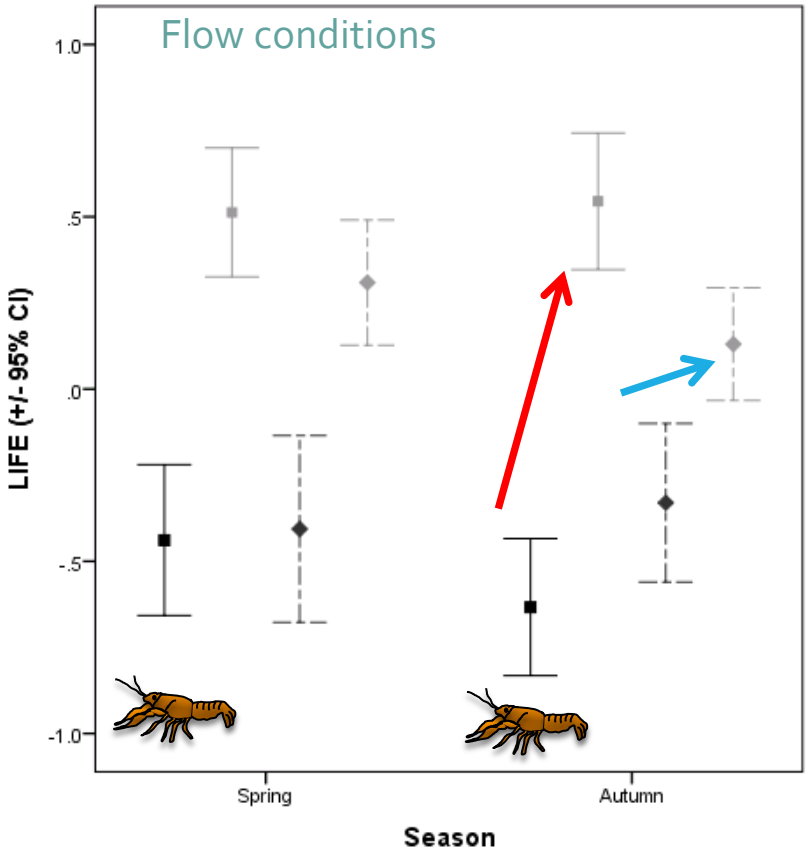
Summary

- Low-flow events were found to facilitate the invasion of signal crayfish and also corresponded with greater ecological effects for the receiving ecosystem
- High magnitude flow events provided some opportunity for the communities to recover and limited initial establishment of invasive crayfish
- Flow regime variability is critical in the prevention of INNS establishment, as well as the maintenance of structural and functional diversity of receiving ecosystems following biological invasions
- Magnitude and timing of flow events are primary controls in determining the ecological effects of signal crayfish

WIDER IMPLICATIONS OF INVASIVE SPECIES FOR MONITORING ENVIRONMENTAL CONDITIONS (MATHERS ET AL, 2017B)

Crayfish influence on monitoring environmental health





Crayfish invasion leads to inflated scores possibly not reflective of "real" conditions in autumn only following active summer period

SUMMARY

- Environmental controls are important in determining the establishment and subsequent ecological effects of invasive species
- BUT invasive species may alter environmental conditions (fine sediment) or may mask the actual health of ecosystems
- Environmental variability is key!
  - Heterogeneous habitats and flow regime variability mitigate some of the negative ecological effects of invasive species

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