High post-release survival of spot prawns (*Pandalus platyceros*) declines with long air exposure and high temperatures

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*Running headline: Spot prawn survival declines with air exposure and high temperature*

**ABSTRACT**

*Prawns like to be cold*

*Release them lickety split*

*Back to life at depth*

**KEY WORDS**

fisheries management, spot prawn, post-release survival, population dynamics

**INTRODUCTION**

* Big picture background on the increasing focus on evaluating the effectiveness of fisheries management interventions.
* Specific background on post-release survival evaluation.
* Life history & local fishery context of spot prawns in BC.
* Knowledge gap and framing of research question and approach.

**MATERIALS AND METHODS**

EXPERIMENT SET-UP

A given experimental trial consisted of three components conducted over three days: setting traps for field collection, collecting prawns and conducting the experimental treatment, and processing prawns at the end of the experiment to assess survival and condition. Each trial took 3-4 days to complete (the string of traps to initially collect prawns soaked for 24-48 hours) and we conducted trials between May XX, 2023 and Jun XX, 2023.

To collect prawns for a given trial, we set a string of 10 prawn traps (insert technical specs) baited with pellets (insert technical specs) within a target depth range (30-60 fathoms) that aligns with the approximate depth range targeted by commercial and recreational fisheries. Depending on weather conditions and logistics, the string of traps soaked for 24-48 hours before we hauled the traps and began the experimental trial. On the day the trial began, at the trap setting site, we collected air temperature, water temperature (at 0 m and 10 m depths), and water salinity (at 0 m and 10 m depths) using a YSI (insert technical details). During some of the trials, the YSI was broken, and we collected temperature and salinity data using a thermometer and refractometer respectively. We hauled the string of traps using hydraulic pot hauler (insert technical details). During trap hauling, as each trap came on the boat, we removed any bycatch and emptied the remaining prawns into a small square white bin (10 L) with drilled holes that allowed water to flow through. We placed each white bin in a large fish tote (insert technical specs) filled with seawater (XX L). This method insured that until the trial began, prawns experienced minimal air exposure (10-15 seconds as trap was emptied into white bin). After we finished hauling all traps, we assessed determined how many prawns we would assign to each treatment (minimum 35 per treatment, maximum 70 per treatment to minimise density-dependent effects). We haphazardly assigned prawns to one of four or five treatments: ‘immediate release’ or air exposures of 30, 60, 90, or 120 minutes. In circumstances where numbers of prawns was a limiting factor, we did not include the 120 minute treatment. To implement the ‘immediate release’ treatment in an experimentally tractable manner, we hung prawns off the boat in a mesh drawstring bag (insert mesh specs) approximately 20 m below the surface of the water. This mimicked quick release (insert evidence that it is reasonable to assume 10 fathoms is similar to bottom depth conditions) while still allowing for the experimental ‘release’ of prawns from all treatments together in one string of traps. To minimise air exposure, we emptied the prawns of one of the white bins into a solid white bin filled with seawater. We counted out the appropriate number of individuals, using a forceps to place a coloured orthodontic elastic band (insert technical specs) on the base of the rostrum (Figure X), and placing each prawn in the mesh bag which was submerged in a 20 L bucket of seawater. Once all prawns had been banded for the ‘immediate release’ treatment, we cinched the mesh bag and attached it to a weighted line hanging off the boat to a depth of 20 m. To begin the air exposure treatments, we removed the remaining white bins from the fish tote at the same time such that all prawns hit the air together. We started a timer for the first treatment (30 minutes) and began to distribute the appropriate number of prawns to each bin, distributing haphazardly by size. For trials with fewer prawns, we allotted one bin for treatment (e.g., 35 prawns per bin) and for trials with more prawns, we allotted two bins per treatment (e.g., two bins, each with 35 prawns). For the duration of the treatment time, we kept the bins under the canopy of the boat such that they received no direct sun exposure or direct precipitation. The spatial arrangement of the bins was haphazard with respect to treatment. Choosing different colours for different treatments (the exact colour varied trial to trial), we applied coloured bands to the rostrum of each individual prawn. As the timer for a given treatment went off, we emptied the prawns of a certain band colour into a weighted mesh bag and clipped it to the hanging line such that it descended to hang with the other treatment bags at ~20 m. At the end of the final treatment (90 minutes or 120 minutes), we placed the final group of prawns in a mesh bag hung off the side of the boat such that all treatments experienced the process of being lowered and raised in a mesh bag. Finally, we raised all the bags at the same time and distributed the prawns from all treatments across six baited prawn traps with the tunnels tied shut such that prawns could not escape. To avoid confounding treatment effect with trap effect, we distributed some prawns from each treatment to each trap such that traps contained a mix of all treatments (the coloured bands facilitated mixing prawns without losing information on treatment). Once prawns had been distributed, we closed the traps and reset the string of six traps in the same location and depth they had been hauled from initially. For each trial, we timed the length of time it took from the trial ending (mesh bags coming out of water) to the final trap hitting the water during re-setting.

EXPERIMENT WRAP-UP

Approximately 24 hours after we conducted the experimental treatment, we returned to the re-set string of traps to end the trial. We followed the same procedure as at the beginning of the experiment, collecting temperature and salinity measurements before re-hauling the string and placing the contents of each trap into a white square bin which we kept in the seawater-filled fish tote.

After re-hauling the string, we emptied one square bin (i.e., one trap’s worth of prawns) at a time into a sampling tray and collected the end-of-trial data. For each individual prawn, we recorded their band colour, stage (juvenile, male, transitional, female, egged female, or spent female), and their carapace length as well as whether they were alive, dead, or scavenged. We considered a prawn dead if their gill filaments were not moving at all (i.e., the individual was no longer breathing). A ‘scavenged’ prawn referred to an individual that was dead and missing some body parts. We returned dead and scavenged prawns to the ocean. As they were counted and measured, alive prawns were transferred from the sampling tray to a mesh bag submerged in a 20 L bucket of seawater. After processing a single trap, the mesh bag of live prawns was hung off the boat at 20 m to maintain the prawns as close to their initial condition as possible.

After collecting survival data for all traps, we assay each live prawn for a suite of ten reflex behaviours, based on the approach outlined in Stoner (2012) that developed a set of ten reflex behaviours in spot prawns that cumulatively predicted long term survival in the lab. Processing one trap’s worth of prawns at a time, we assessed each prawn for how many of the reflex behaviours they displayed, resulting in a cumulative score that could range from 0-10. Here, a score of zero indicates a prawn that is alive but displays no other behaviours (poor condition) and a score of ten indicates a prawn that is alive and displays all assessed reflex behaviours (good condition). After we finish assessing the reflexes of the live prawns, we remove their nose band and return them to the ocean.

STATISTICAL ANALYSIS

[insert from Jacob – should have model fitting and model selection sections]

**RESULTS**

* Basic summary statistics:
  + number of trials, number of individuals per trial/treatment
  + summary of temperature and salinity
  + summary of prawn composition: stage distributions, length distributions
  + summary of length of end-of-trial period (how long from water to back down in trap)
* Summary of model selection results
* Summary of best model predictions & uncertainty

**DISCUSSION**

* Discussion of the physiological mechanisms for death and how we expect air exposure/temperature to affect that process
  + Acknowledge lack of consideration of density-dependence
  + Discuss possible dynamics re: temperature differential (per Dylan’s comments, cite sea lice research?)
* Discussion of limitations & considerations
  + Lost prawns
  + Issues comparing to ‘real world’ (if anything, we might be underestimating survival in some respects)
  + Accounting for predation (is there literature on this?)
* Discussion of implications for management:
  + Commercial license requirements and enforcement
  + Informing recreational fishers
  + Evidence that it is worth making the effort
  + Temperature matters

**CONTRIBUTIONS**

**REFERENCES**