A large proportion of trap-captured spot prawns returned to the ocean near immediately survived the physiological process of being captured and released – we estimated survival probabilities greater than 70% across the range of carapace lengths and air temperatures encompassed by our field experiment. The 24-hour survival probability declined with increasing length of air exposure and the rate at which survival declined with increasing time out of water depended strongly on air temperature. In cool weather, we estimated a probability of survival just under 40% but this dropped quickly with increasing warmth and no prawns survived two hours of air exposure in >25oC weather. Although we did not track survival longer than 24-hours post release, our assessment of reflex behaviours suggests that the majority of surviving prawns were in good condition, indicating likely longer-term survival. Although discard mortality in fisheries is an increasingly acknowledged and investigated uncertainty (CITE), it is relatively less well understood for fished invertebrates and, as far as we are aware, this is the first assessment of post-release survival of spot prawns. The broad results of our experiment are generally consistent with previous studies on the discard mortality of other marine invertebrates, including the strong influences of air exposure and temperature on post-release survival. While we expected that spot prawns would fair less well out of water for long periods of time in hot weather, we were surprised by the relatively high survival of individuals released immediately and the high reflex scores for surviving prawns, regardless of air exposure treatment.

Handling, physiological, and environmental factors contribute to the observed patterns in post-release survival of spot prawns. Most of the existing research investigating post-release survival for invertebrate fisheries focuses on invertebrate trawl fisheries and while there is variability in the exact methods and survival estimates, survival estimates tend to be lower for trawl-caught invertebrates than trap-caught. In a paper investigating the survival of mantis shrimp, Lorenzon et al. 2013 documented 100% survival of individuals caught by trap in October compared to 0% survival for those caught by trawl at the same time of year. Other trawl-based survival estimates are more optimistic including ~50% survival of mantis shrimp exposed on deck for 10 minutes after a 30 minute trawl (Hill and Wassenberg, 1990) and 37-51% survival of Norway lobster subjected to different sorting methods (Merillet et al. 2018). Within trap-based fisheries, there is evidence that slower hauling speeds contribute to higher survival rates (Basti et al. 2010). Invertebrate species, such as Dungeness crab, which experience intertidal environments during their lives appear to survive at higher rates after release (e.g., Yochum et al. 2017). Physiological considerations, including tolerance to significance changes in depth and the metabolic effects of desiccation, influence spot prawns’ ability to survive capture and release.

Although spot prawns are not adapted to direct air exposure as for sub-tidal crustaceans like crab, they settle as juveniles in shallow water (Marliave and Roth, 1994) and are known to make nightly diel vertical migrations throughout the water column (Barr, 1970). These migrations may confer a baseline physiological tolerance for a wide range of depths. Furthermore, spot prawns and other fished invertebrates do not have swim bladders and thus do not suffer the same barotrauma experienced by, for example, rockfish (CITE). Multiple studies have investigated the metabolic responses of fished invertebrates to capture and air exposure, primarily focusing on desiccation and its associated impacts (e.g., Vermeer 1986, CITE…). Because spot prawns and other crustaceans require water flow across their gill filaments for proper respiration, desiccation through air exposure leads to a number of metabolic impacts including a shift to anaerobic respiration and the accumulation of toxic metabolites (Vermeer, 1986). While we did not directly measure the metabolic response of spot prawns in this experiment, declining metabolic function is the likely path to mortality for individuals in the longer air exposure treatments. The large negative effect of air temperature on survival is most clearly explained by the increase in desiccation rates of exposed prawns, emphasizing the influence of seasonality and other environmental factors on post-release survival.

Air temperature was a covariate in the five top models comprising 100% of the cumulative model support by AIC (Table 2) and had the strongest effect on the shape of the drop-off in survival with increasing air exposure (Figure 6). On the hottest days (23.5oC), survival dropped off quickly with air exposure, falling to ~10% estimated probability of survival after an hour out water compared to ~80% estimated probability of survival on a cool day (11oC). This result is consistent with previous studies that have found a strong effect of seasonality (e.g., Lorenzon et al. 2013, Giomi et al. 2008, Merillet et al. 2018) and intuitive given influence of heat on desiccation rate and associated metabolic function. Although we expected that smaller prawns would survive less well than larger prawns due to their higher relative surface area and possible higher desiccation rates (as in Vermeer, 1986), survival was higher at smaller sizes and our top model included a negative interaction effect between temperature and carapace length. While this might be a true ecological effect, it is possible that the difference in survival across size is at least in part an artifact of the experiment itself.

Although a field experiment provides a more realistic setting to evaluate post-release survival than in the lab, there were still several factors we were unable to account for including mechanical damage from handling and from descending in traps, post-release mortality due to predation, and longer term sublethal effects. The relatively higher survival of smaller prawns might be explained by lower susceptibility to injury from handling and from mechanical damage in the traps post-treatment during descent and ascent at the end of the trial. Larger prawns would be subject to higher drag during the hauling process and might have been more likely to get pushed against the sides of traps. Alternatively, despite a lower surface area to volume ratio, larger prawns might have higher absolute metabolic demands that could lead to higher post-release mortality. Further investigation is necessary to understand size-based trends in post-release mortality and the results from this experiment should be interpreted cautiously. To evaluate post-release survival of prawns without needing to recapture released prawns (and the additional complexity of recapture rates) we ‘released’ prawns in traps with the openings closed and thus did not account for additional mortality due to predation. Post-release mortality due to predation is difficult to measure and likely varies depending on predator abundance, descent speed of released individuals, and impairment of predator escape behaviour. There is evidence that air exposure affects the response behaviour of crustaceans including their ability to evade predators at least in the short term (Brown and Caputi 1983, Haupt et al. 2006, Vermeer 1987). Past research has estimated it takes 9-10 seconds for released crustaceans to sink below 1 m (relevant for predation from birds) and found that over 80% of bait set on a vertical drop line were intact of recovery (Hill and Wassenberg 1990). Nonetheless, it is likely that some proportion of released prawns would succumb to predation and further research would be necessary to incorporate this component of post-release mortality. We do not expect that this impacts our estimates of *relative* survival with increasing air exposure and temperature, but the absolute survival probability should be considered as a ‘best case’ estimate. Finally, it is possible that additional mortality would occur beyond the experimental period considered here. We did not track survival after 24 hours but were able to estimate long-term survival based on an established relationship between reflex behaviour and long-term mortality (Stoner 2012). We estimated that additional long-term mortality of surviving prawns ranged from just over 5% to just under 15% depending on air exposure (Figure 5). While uncertainty remains regarding the precise estimate of post-release survival for spot prawns captured by trap, our results suggest that potential survival could be relatively high given the right handling and environmental conditions. [TRANSITION]

Commercial and recreational fisheries as well as scientific surveys can maximise post-release survival by keeping air exposure brief and taking seasonality into account. The license conditions for the commercial spot prawn fishery specifies that traps must be sorted individually as they are hauled and non-target individuals (under-sized males and egged females) must be released immediately. Compliance with these conditions is likely to minimise mortality due to air exposure and likely also increases the probability that released prawns return to suitable habitat from where they were captured. Compliance and enforcement of this management measure is variable (Coady Webb, personal communication) and our results underline its importance. The progression of the commercial season typically leads to higher catches of under-sized males as the larger females are fished down (CITE? FIGURE?) and this often coincides with warmer air temperatures in June and July. Releasing under-sized males promptly may be critical to maintaining a healthy population that will subsequently transition and represent the following season’s females. While we did not investigate the influence of salinity in our analysis (all included trials occurred in high salinity conditions), there is evidence that post-release survival declines when release occurs through low salinity layers (Harris and Ulmestrand 2004), which is consistent with our anecdotal observations. Accounting for salinity will be important for commercial fishing that occurs in the heads of fjord systems where there can be a significant low salinity layer. In contrast to the specific license conditions for the commercial fishery, there are no strict regulations for size limits or sorting practices in the recreational fishery, which has grown substantially in recent years. This study suggests that recreational fishers can maximise survival of released egged females and small males through efficient sorting and consideration of warm weather.

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