

Paralysis and heart failure precede ion balance disruption in heat-stressed European green crabs

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Introduction

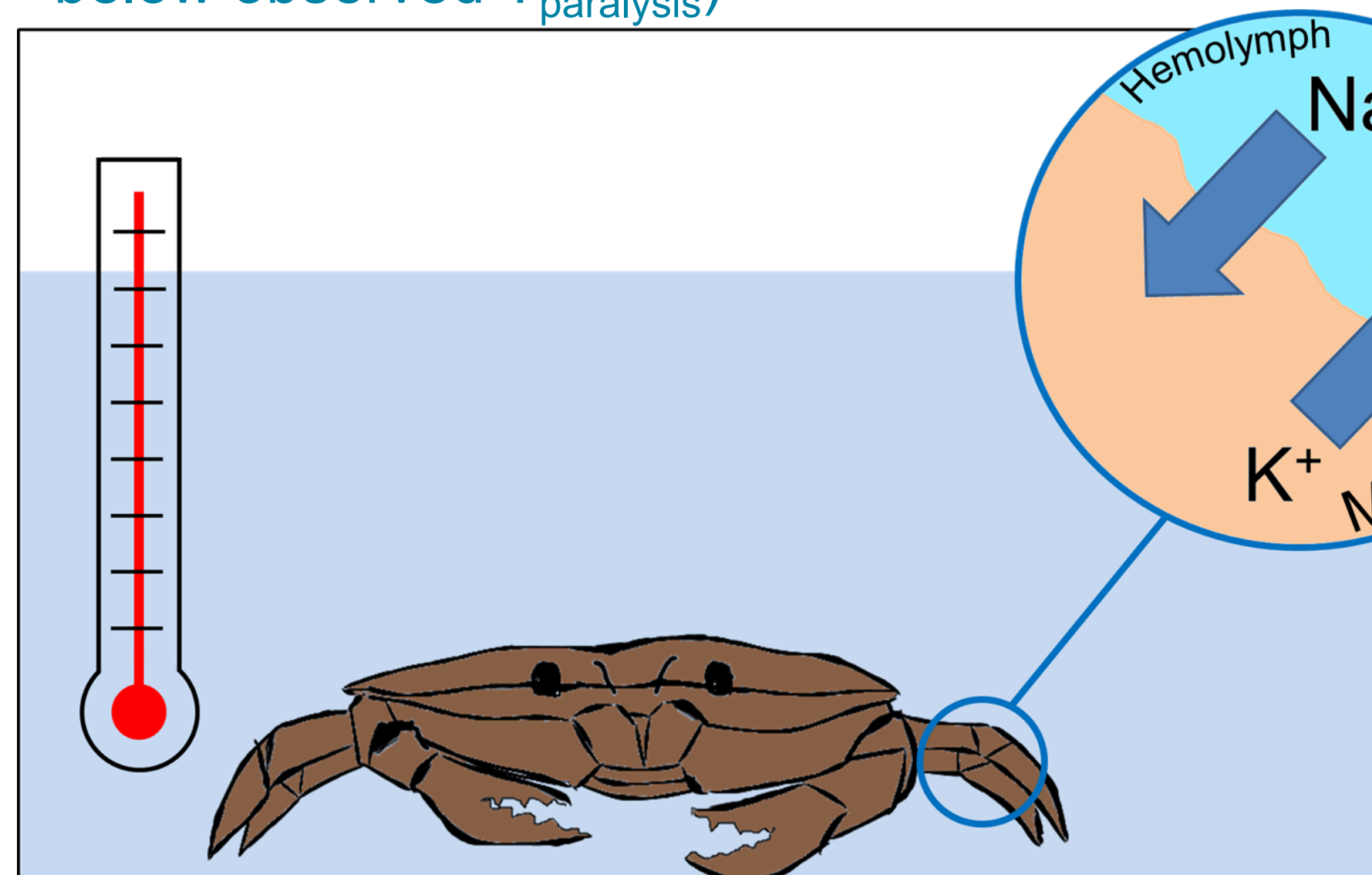
- Acute exposure to heat causes heat injury and death, which has been associated with impaired oxygen delivery (OCLTT)
- Heat stress has been shown to disrupt ion balance in a species of freshwater crayfish¹
- In part because of its role in oxygen delivery, the temperature of heart failure is a common measure of the critical thermal maximum in crustaceans²
- Here we examine whether heat stress causes a disruption of ion balance in a marine crustacean, and if so, whether it precedes or follows heart failure

Research question A

- Does exposure to heat stress cause a loss of ion balance in a marine crab?

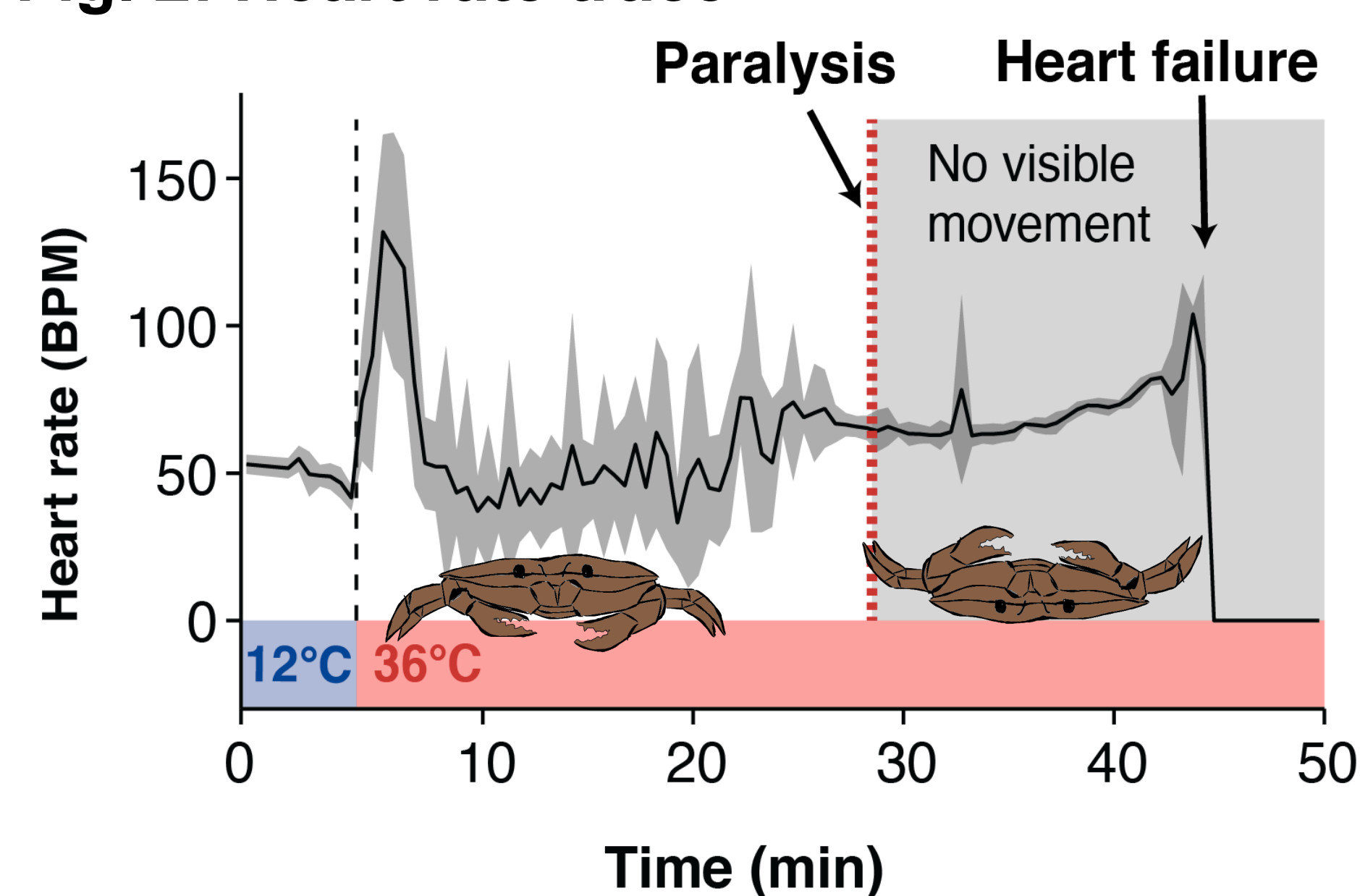
Methods A

- Pilot studies showed that marine crabs exposed to increasing temperatures experience muscle spasms and paralysis, and we chose 34 and 36°C as our acute heat exposure temperatures (just below observed $T_{paralysis}$)



- Muscle and hemolymph were taken from crabs (*Carcinus maenas*) held at 34°C and 36°C, and ion concentrations were measured to assess a change in Na^+/K^+ equilibrium potential
- Na^+/K^+ equilibrium potentials were subsequently divided into two categories; alive and dead, based on the responsiveness of the crab at sampling time

Fig. 2: Heart rate trace



References and funding

- Gladwell *et al* (1975) J Thermal Biology 1 pp.79-94
- Stillman, J. H. (2003) Science 301, 65.

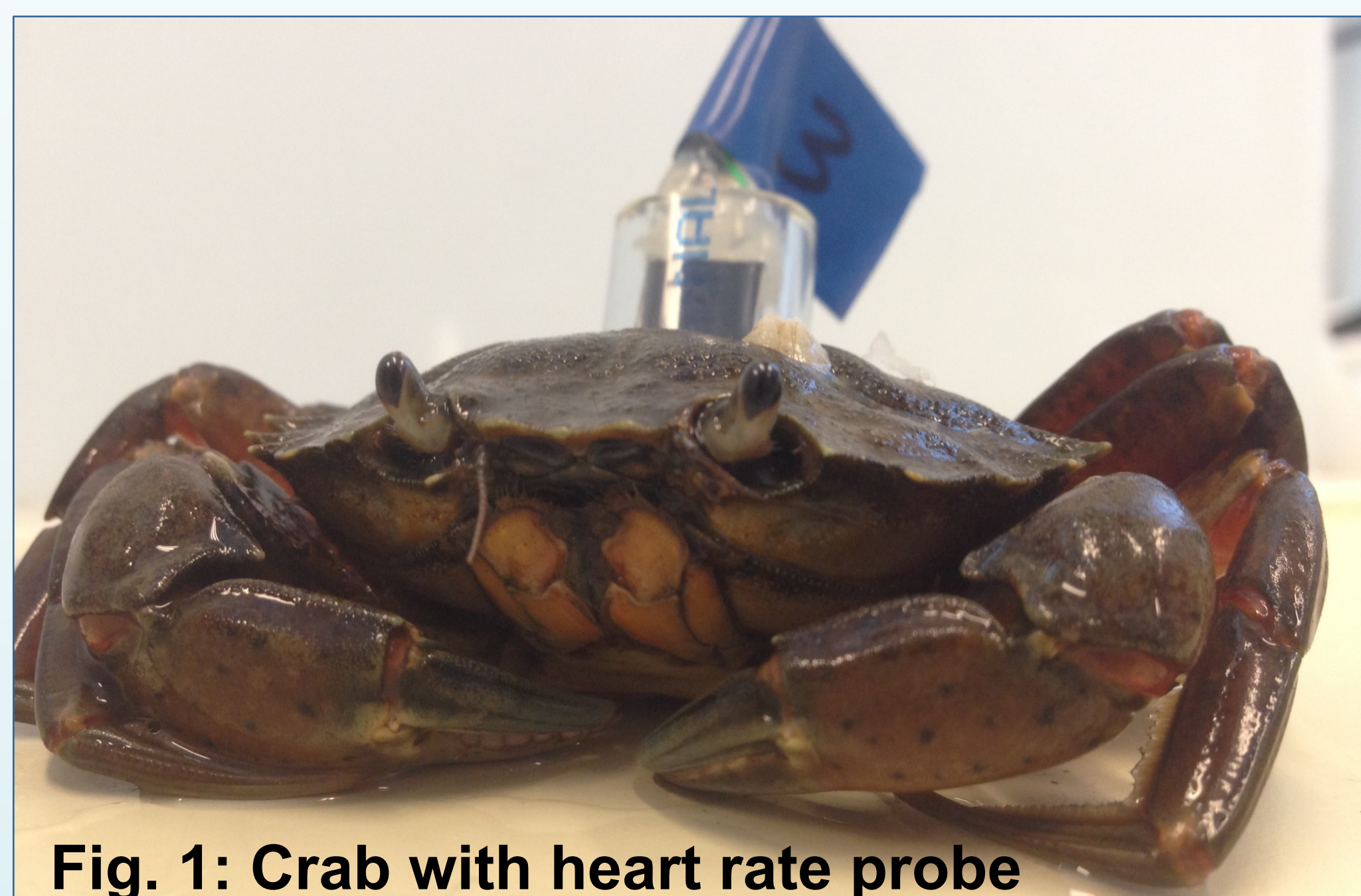
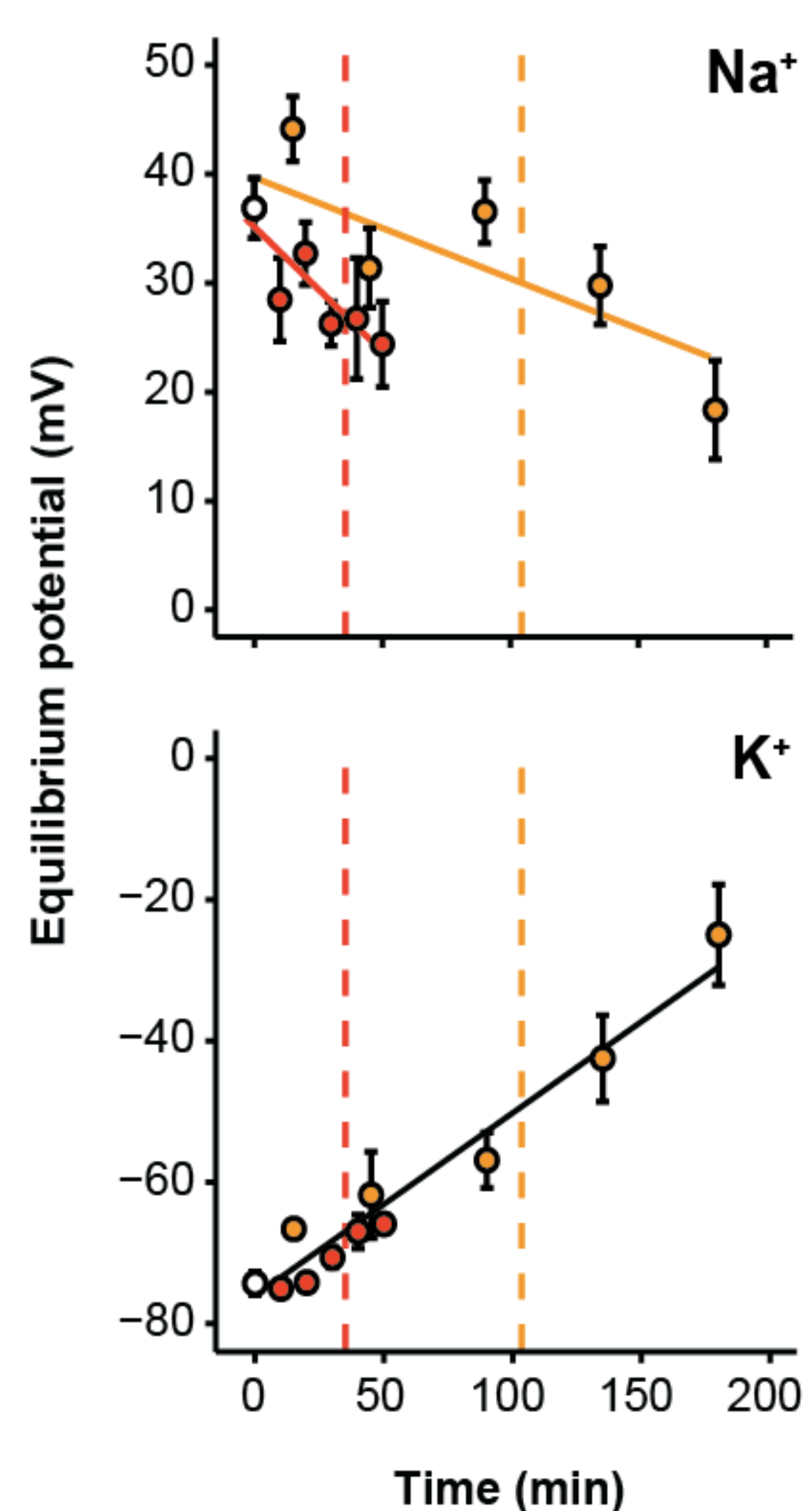


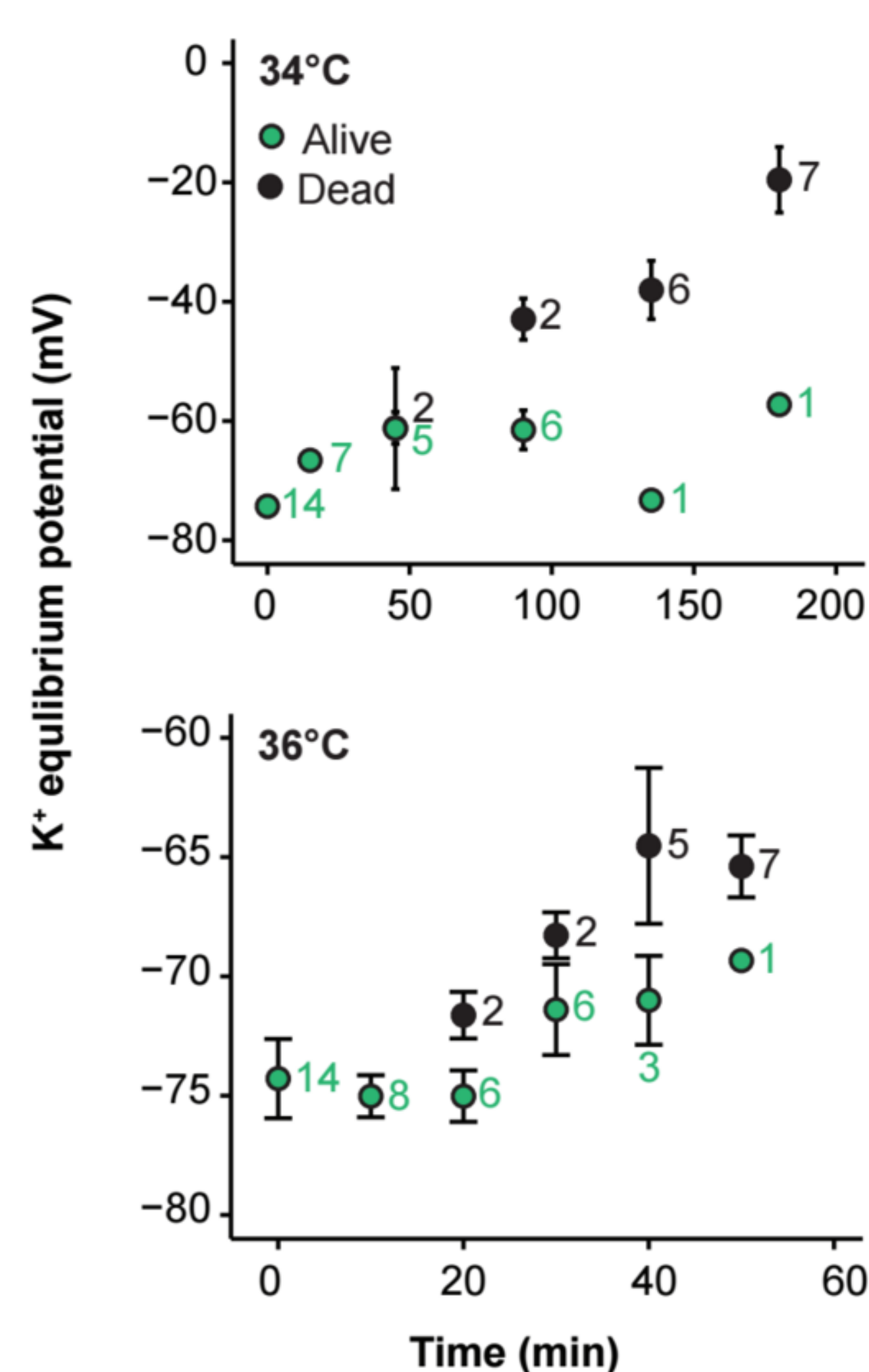
Fig. 1: Crab with heart rate probe

Results A

○ Control ○ 34°C ● 36°C



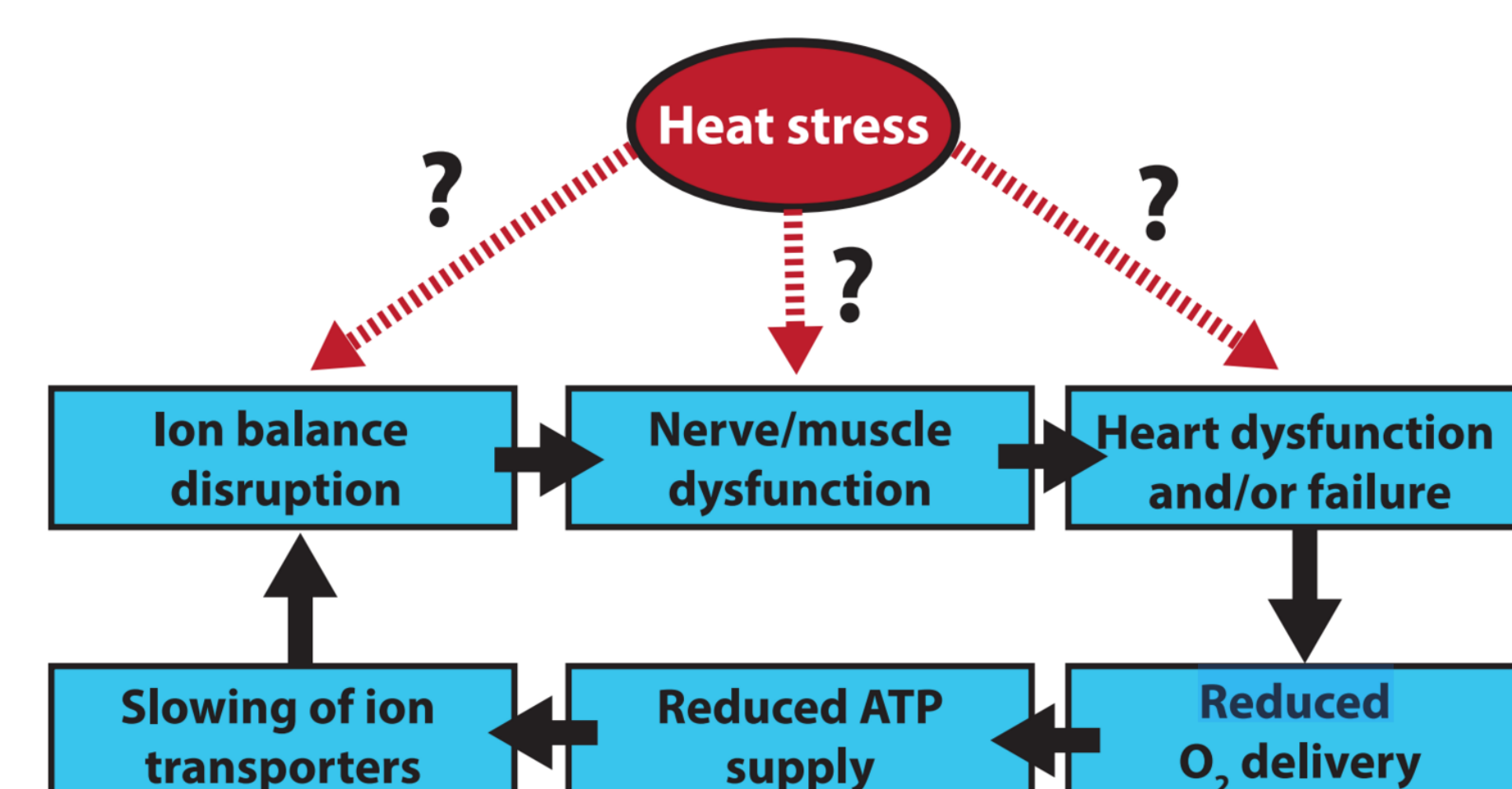
(Dashed lines represent mean time to paralysis)



(Numbers denote number of crabs)

Research question B

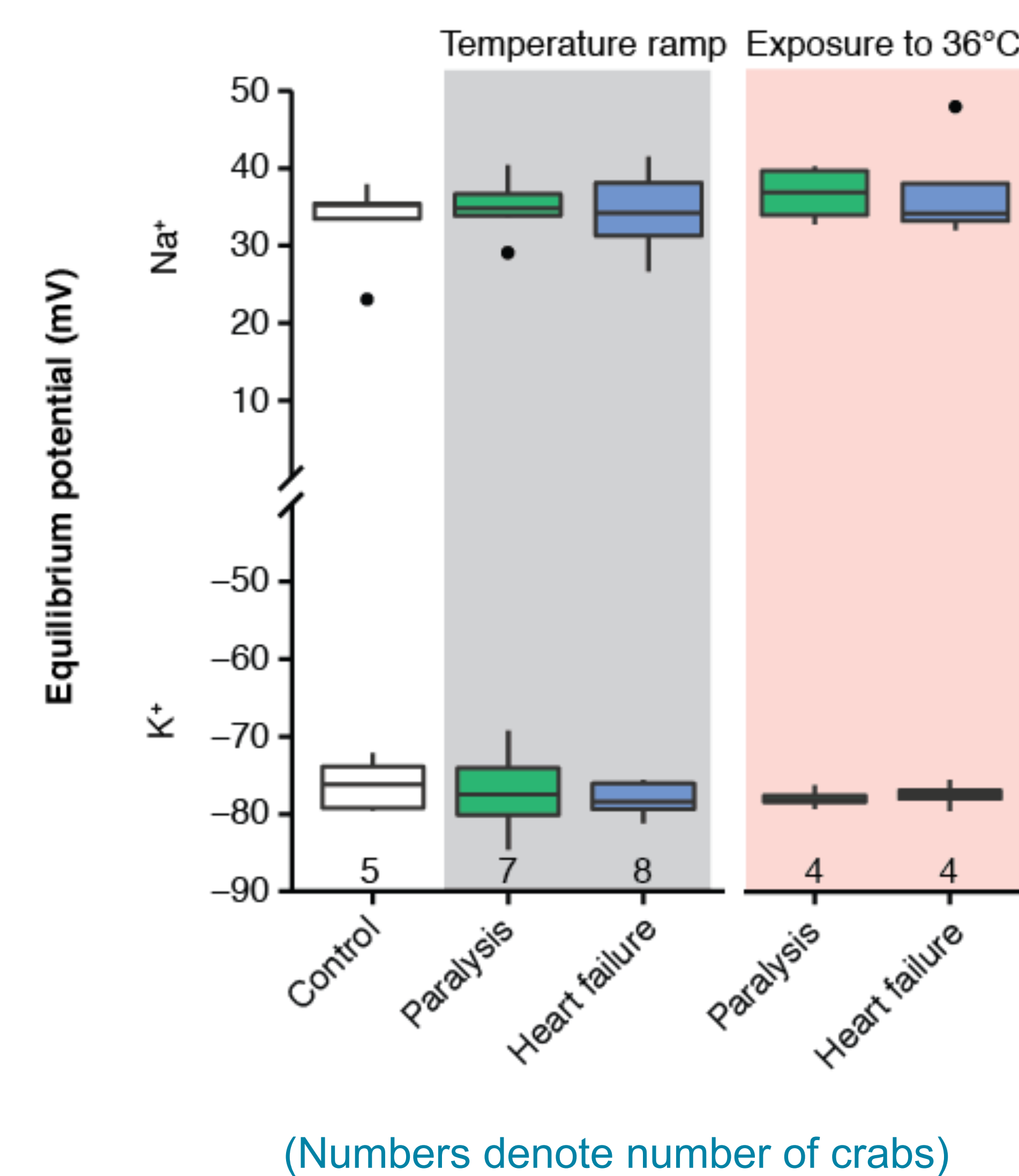
- The crabs experience loss of ion balance when exposed to temperatures near their upper thermal limit (see Research question A)
- So heat exposure causes a loss of ion balance but *is it a cause or consequence of a failure to deliver oxygen?*



- Which happens first? Heart failure, ion balance disruption or paralysis?

Methods & Results B

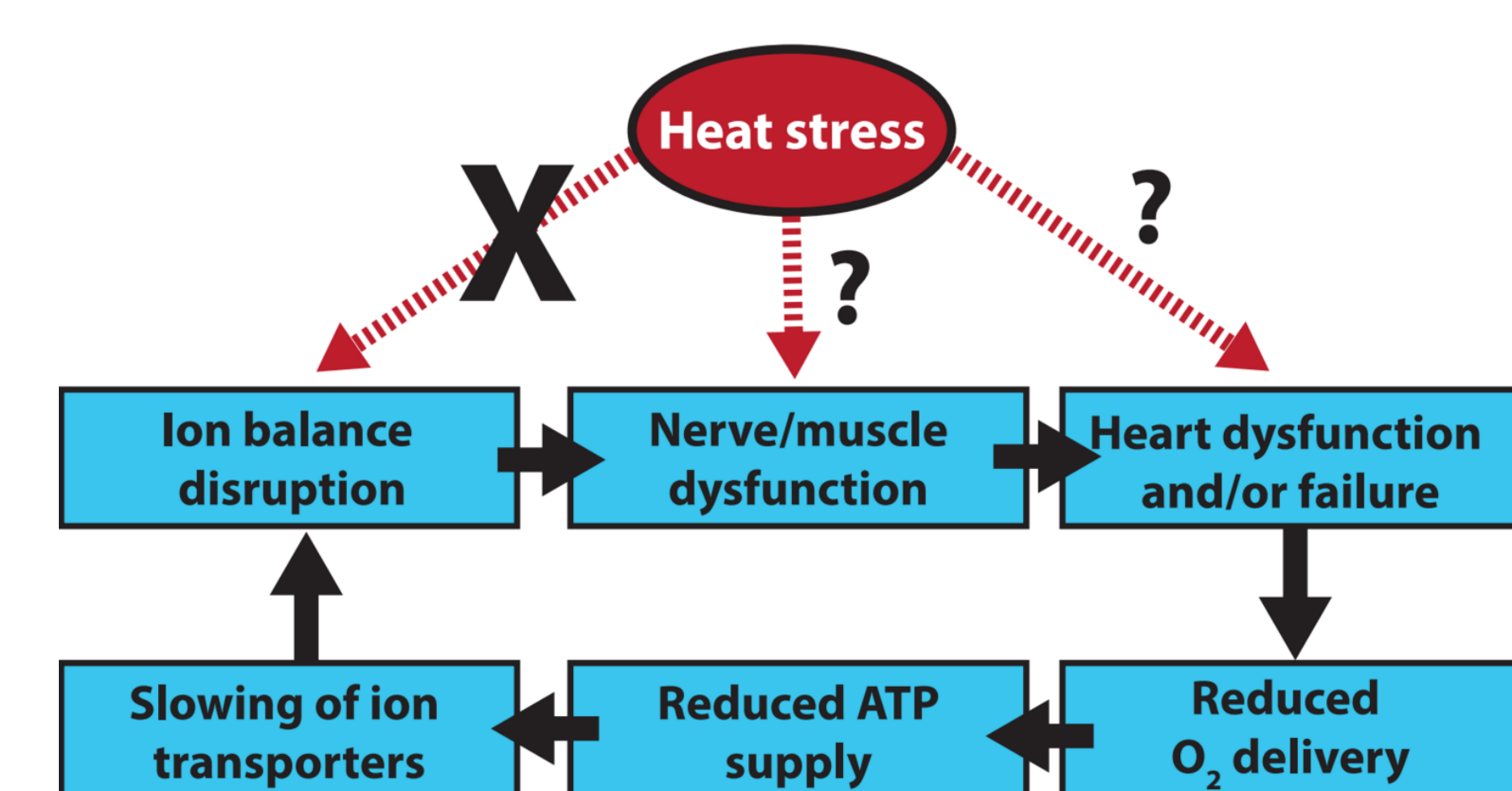
- Cessation of the heart was assessed from heart rate measurements performed with an infra red probe, as seen in Fig. 1
- In 20/22 cases paralysis precedes cessation of the heart, example trace seen in Fig. 2
- Muscle and hemolymph were sampled at time of paralysis and heart failure (in separate crabs), and Na^+/K^+ equilibrium potentials were calculated



(Numbers denote number of crabs)

Conclusions

- Ion balance is not disturbed until *after* paralysis and heart failure have occurred
- Disruption of ion balance is likely a consequence, rather than a cause, of neuromuscular and/or metabolic failure.



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