

Parasympathetic activity and heart rate in hibernating black bears

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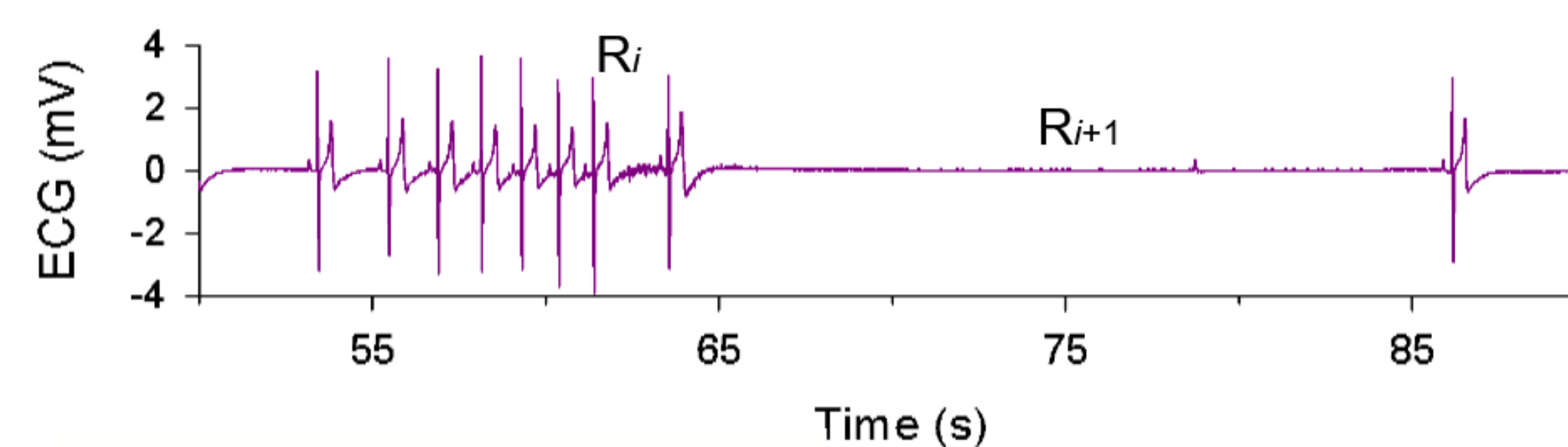
BACKGROUND

- During hibernation, American black bears (*Ursus americanus*) suppress metabolism by 75% with a body temperature (T_b) reduction of only 5.5°C. [1]
- Heart rate falls on average from 55 beats per min in summer to just 14.4 beats per min in mid-hibernation.
- Profound sinus arrhythmia permits depression of HR, with groups of rapid beats followed by extended R-R intervals throughout the breathing cycle. [Fig. 1]
- This unique mechanism of hibernation in bears stands to be of great interest for metabolic research.

METHODS

- This project is based on metabolic and biotelemetry data collected from three hibernating black bears monitored between 2008-2009.
- Study bears were nuisance animals captured and transported to the Institute of Arctic Biology at the University of Alaska Fairbanks; two of the bears were captured in Interior Alaska and one in Southeast Alaska. [Fig. 5]
- Bears were kept in artificial dens and fitted with telemetry devices to monitor T_b , ECG, EMG, EEG, and blood pressure. [2]
- These produced 24-hour continuous recordings which we examined in *EDFbrowser* for average heart rate, parasympathetic activity (measured as RMSSD/RR), and maximum R-R interval. [Fig. 1]

RMSSD → root mean square of successive RR interval differences, which estimates vagal contributions to HRV (Kleiger et al 1992, Shaffer et al. 2020)



$$RMSSD = \sqrt{\frac{\sum_{i=1}^{n-1} (RR_i - RR_{i+1})^2}{n-1}}$$

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Compensation for HR differences : Normalized by dividing by mean R-R interval: RMSSD/RR

Figure 1. Standard ECG pattern in hibernating bears and formula for RMSSD. RMSSD is used as an indicator of parasympathetic activity. [3]

RESULTS

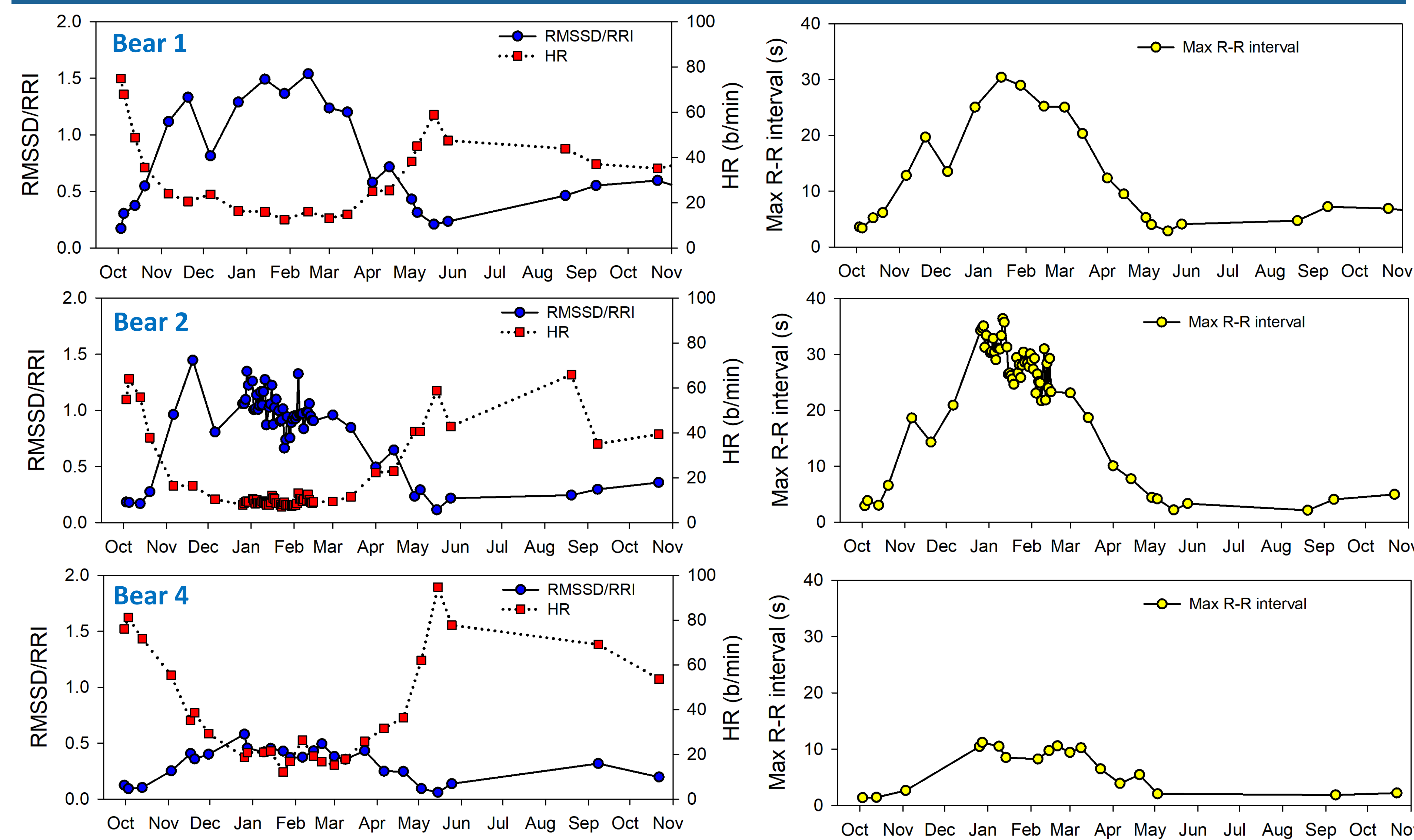


Figure 2. Time series comparisons of heart rate (b/min), parasympathetic activity (RMSSD/RR), and maximum R-R interval between three black bears between October 2008 and November 2009. Increased parasympathetic activity and depressed heart rate (HR) correspond to hibernating months. Bears 1 and 2 were captured in Anchorage and Bear 4 in Juneau. We recorded the longest maximum R-R intervals between December and February, with the longest overall R-R interval recorded from Bear 2 on 1/11/2009, lasting 36.4 seconds.

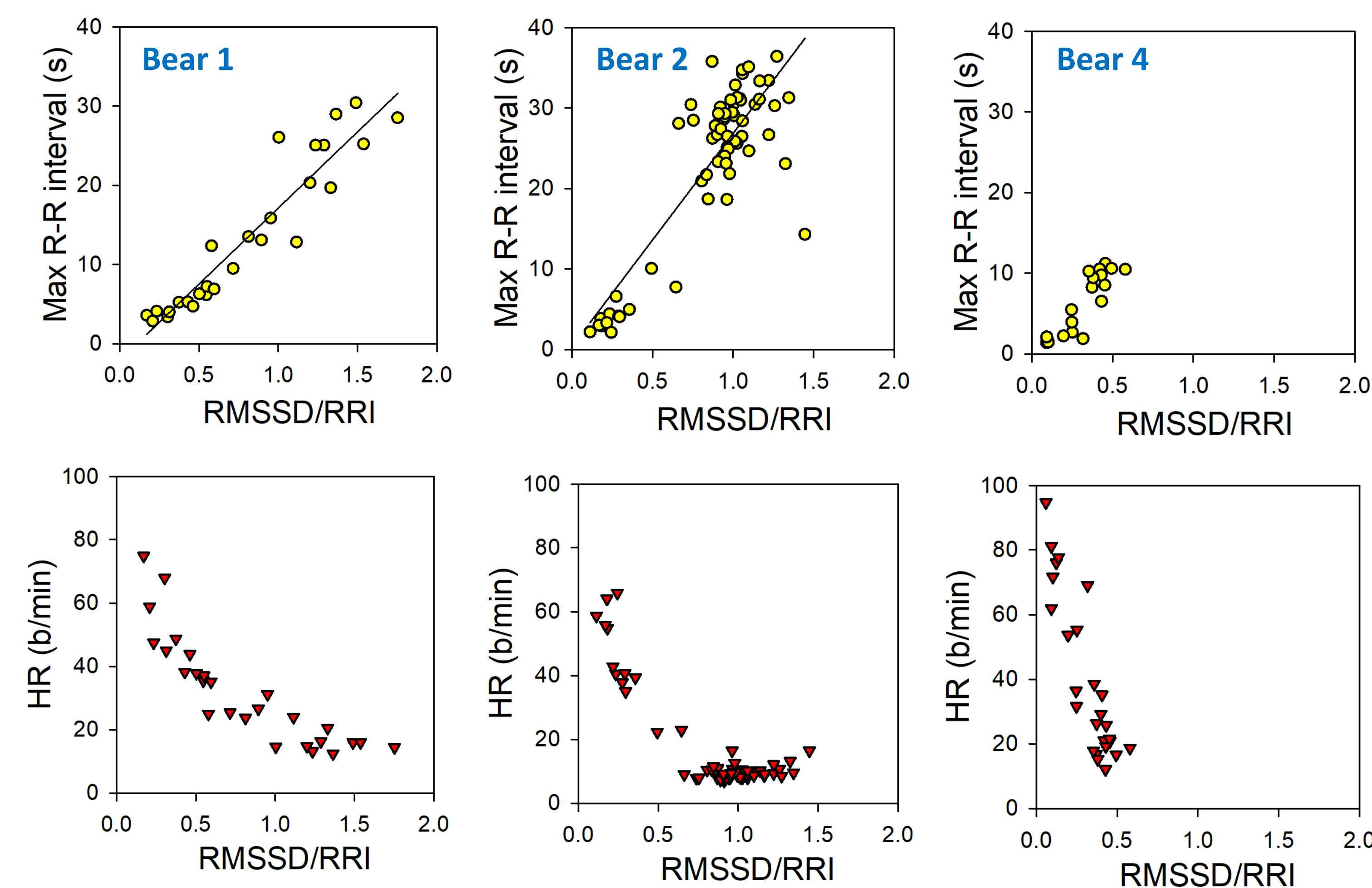


Figure 3. Relationship between maximum R-R interval and parasympathetic activity (RMSSD/RR), and heart rate and parasympathetic activity across three bears. Max R-R interval appears positively correlated with parasympathetic activity. HR and parasympathetic activity appear to have a negative nonlinear relationship.

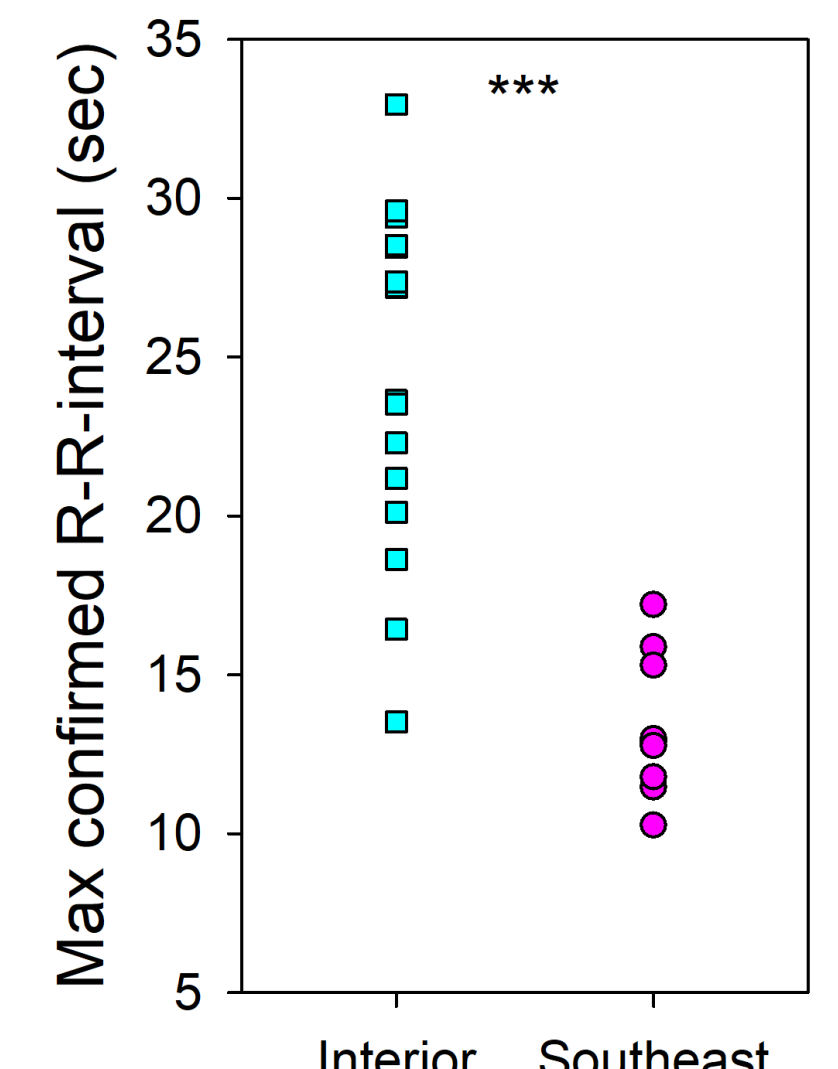
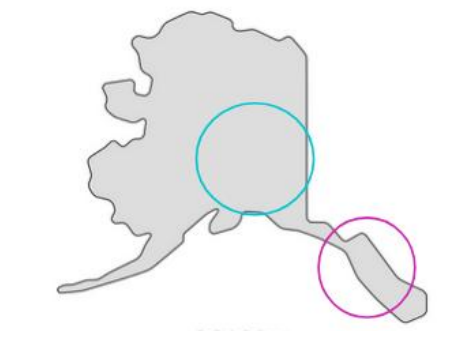


Figure 5. Preliminary survey of capture locations of bears plotted against max R-R intervals for entire dataset. Southeast bears are less extreme.

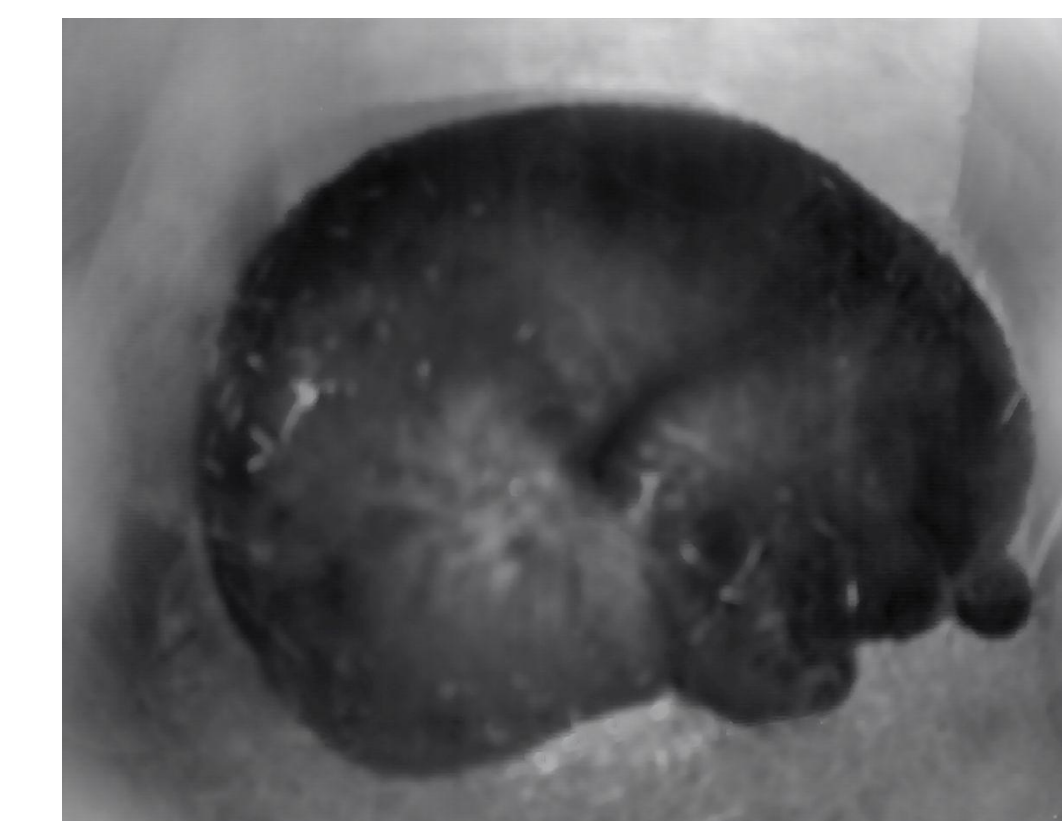


Figure 4. Black bear hibernating in an artificial den. [1]

CONCLUSIONS

- These preliminary results suggest that parasympathetic activity supports suppression of metabolic rate in hibernating black bears.
- Time series indicate delayed recovery of heart rate and reduction of parasympathetic activity after emergence in April, where metabolic activity is still suppressed to a lesser extent.
- Bear 4, captured in Southeast Alaska, exhibited milder increases in parasympathetic activity and shorter max R-R intervals than the two interior bears, suggesting regional differences in metabolic suppression among black bears.
- RMSSD/RR was positively correlated with max RRI and negatively correlated to heart rate, indicating that parasympathetic activity may facilitate depression of heart rate during hibernation.
- Unlike max RRI, heart rate showed a nonlinear relationship to RMSSD/RR, particularly in Bear 2 where HR plateaued above an RMSSD/RR score of ~0.7.
- This may indicate that parasympathetic activity only effects heart rate until an absolute minimum is reached.

Acknowledgments

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