Supplemental Tables for: Relationships between pasture mass at paddock-level and cow data derived from GPS and behavior-monitoring on-animals sensors in rotationally grazed dairy systems

S. J. Hendriks,[1*] M. Qasim,[2] and J. P. Edwards[1]

[1]DairyNZ Ltd., Lincoln 7647, New Zealand

[2]DairyNZ Ltd., Hamilton 3240, New Zealand

[*]Corresponding author: stacey.hendriks@dairynz.co.nz

These authors contributed equally to this work.

Supplemental Table S1. Description of device properties including device name (manufacturer), data captured, recording interval, attachment location, and validation studies, where available, for 5 commercially available on-animal devices fitted to all cows (n = 100 cows).

Device name (manufacturer)	Data captured (units)[1]	Recording interval[2]	Attachment location	Recorded observations relative to theoretical maximum[3], %	Validation studies in grazing and housed cows
eShepherd (Gallagher Group Ltd, formerly Agersens)	Resting (minutes), grazing (minutes), and moving behavior (minutes) and location (longitude, latitude)	10-minutes	Neck-worn collar	88% (n = 504,109/576,000)	
IceQube (Peacock Technology Ltd)	Lying time (minutes), lying bouts (number of transitions), and steps taken (number of steps)	15-minutes	Lateral side of the right hind leg	97% (n = 372,872/384,000)	Grazing cows: Elischer et al. (2013); Housed cows: Reviewed by Hendriks et al. (2020)
AfiCollar (Afimilk Ltd)	Rumination (minutes) and eating behavior (minutes)	60-minutes	Attached to the eShepherd neck-worn collar	96% (n = 92,354/96,000)	Grazing cows: Iqbal et al. (2021); Housed cows: Borchers et al. (2016)
CowManager (CowManager B.V. Gerverscop)	Active and active (high) (minutes), rumination (minutes), and eating behavior (minutes)	60-minutes	In ear on the side free from any management tags	99% (n = 95,612/96,000)	Grazing cows: Pereira et al. (2018); Housed cows: Borchers et al. (2016); Reynolds et al. (2019)
smaXtec (smaXtec animal care GmbH)	Rumination index (minutes per 24 h) and activity index (arbitrary units)	60-minutes	Inserted orally and located in the rumen	97% (n = 93,120/96,000)	

[1] Each manufacturer's behavioral definitions and algorithms are proprietary; thus, the behaviors are named according to the manufacturer's classification (e.g., 'eating' for CowManager and 'grazing' for eShepherd are not equivalent).
[2] For the smaXtec device, data could also be recorded at a 10-minute interval; however, we only used data recorded at a 60-minute interval.
[3] The lower proportion of observations available relative to the theoretical maximum is due to limited data storage capacity for the eShepherd device, where if the device is unable to upload data via the receiver, the data is lost.

Supplemental Table S2. Descriptive statistics (mean, (SD), and 10th and 90th percentiles) for 28 independent variables (location and behavior variables recorded across 5 on-animal devices) and 4 pasture outcome variables. Data were summarized on a daily- or half day-basis (pre-PM Milking: before afternoon milking; post-PM Milking: after afternoon milking) and then across groups according to grazing day (24 h between successive daily allocations of pasture). Std = standardized by area allocated.

		Experimental Period 1			Experimental Period 2		
Independent variables[1]	Device[2]	10th percentile	Mean (SD)	90th percentile	10th percentile	Mean (SD)	90th percentile
Location behaviors							
Mean distance traveled, m/10-min per d	eShepherd	13.26	14.8 (1.45)	16.7	13.4	15.1 (1.73)	16.7
Total distance traveled, m/d	eShepherd	1293	1506 (151)	1707	1388	1575 (149)	1768
Distance traveled (pre-PM Milking), m/d	eShepherd	554	628 (80.3)	737	568	731 (123.4)	891
Distance traveled (post-PM Milking), m/d	eShepherd	675	871 (150.0)	1019	565	835 (157.9)	974
Distance traveled std, m/m^2 area	eShepherd	0.38	0.45 (0.060)	0.53	0.39	0.46 (0.057)	0.54
Distance traveled std (pre-PM Milking), m/m^2 area	eShepherd	0.16	0.19 (0.029)	0.23	0.17	0.21 (0.039)	0.26
Distance traveled std (post-PM Milking), m/m^2 area	eShepherd	0.19	0.26 (0.051)	0.32	0.154	0.25 (0.051)	0.30
Distance to herd mates[3], m	eShepherd	24.2	27.1 (2.09)	29.9	24.3	26.9 (2.03)	29.3
Distance to herd mates[3] (pre-PM Milking), m	eShepherd	26.1	28.6 (1.95)	31.3	22.2	25.8 (2.57)	29.4
Distance to herd mates[3] (post-PM Milking), m	eShepherd	23.0	26.5 (2.56)	29.9	24.2	27.4 (2.48)	30.3
Distance to herd mates std[3], m/m^2 area	eShepherd	0.007	0.008 (0.001)	0.009	0.007	0.008 (0.001)	0.009
Proximity[4], %	eShepherd	9.46	12.3 (2.25)	14.8	9.73	12.3 (2.15)	15.4
Proximity[4] (pre-PM Milking), %	eShepherd	8.43	10.6 (1.87)	12.8	9.81	14.3 (3.63)	19.2
Proximity[4] (post-PM Milking), %	eShepherd	9.55	13.0 (3.06)	16.7	8.80	11.4 (2.65)	15.0
Eating behaviors							
Eating time, min/d	AfiCollar	279	374 (79.1)	478	358	477 (87.4)	571
Eating time, min/d	CowManager	367	430 (46.5)	491	416	455 (31.8)	493
Grazing time, min/d	eShepherd	498	529 (35.2)	570	504	545 (32.6)	591
Lying behavior							
Resting, min/d	eShepherd	591	632 (31.8)	670	545	598 (38.4)	647
Lying time, min/d	IceQube	486	542 (48.1)	609	475	532 (49.5)	598
Lying bouts, no./d	IceQube	14	17 (2.2)	19	12	15 (2.6)	18
Activity							
Active, min/d	CowManager	114	163 (42.0)	210	93.9	137 (39.2)	191
Active (high), min/d	CowManager	101	132 (27.3)	168	152	187 (30.9)	225
Moving, min/d	eShepherd	146	176 (27.7)	210	142	183 (29.9)	222
Steps taken, steps/d	IceQube	4637	5541 (871)	6569	5072	5965 (695)	6770
Activity index, arbitrary units	smaXtec	214	244 (23.0)	275	252	278 (26.9)	312
Rumination							

		Experimental Period 1			Experimental Period 2		
Independent variables[1]	Device[2]	10th percentile	Mean (SD)	90th percentile	10th percentile	Mean (SD)	90th percentile
Rumination time, min/d	AfiCollar	328	400 (61.1)	476	234	295 (48.5)	351
Rumination time, min/d	CowManager	411	456 (47.8)	513	308	381 (48.2)	437
Rumination time, min/d	smaXtec	455	494 (37.2)	543	384	431 (34.7)	478
Outcome variables							
Pasture mass							
Pre-grazing, kg DM/ha	RPM and CC	2548	2822 (266)	3125	2277	2646 (303)	3033
Post-grazing, kg DM/ha	RPM and CC	1508	1761 (210)	2031	1304	1535 (186)	1755
Pre-grazing[5], kg DM/cow	RPM and CC	30.5	38.9 (6.05)	46.7	29.0	36.4 (5.67)	43.9
Post-grazing[5], kg DM/cow	RPM and CC	18.3	23.8 (4.88)	31.3	16.5	21.2 (3.77)	26.3

[1]Each manufacturer's behavioral definitions and algorithms are proprietary; thus, the behaviors are named according to the manufacturer's classification (e.g., 'eating' for Cow Manager and 'grazing' for eShepherd are not equivalent), except for the location behaviors which were user-defined using GPS co-ordinates recorded by the eShepherd devices.
[2]Rising plate meter (RPM) and calibration cuts (CC) = daily.
[3]Mean distance of individual cows to her herd mates for each hour and grazing day or half day (pre-PM Milking and post-PM Milking).
[4]The proportion of herd mates that were within 10 m of an individual cow within 10-minute interval for each grazing day or half day (pre-PM Milking and post-PM Milking).
[5]Cut to ground level.

Supplemental Table S3. Initial models and goodness of fit statistics for models used to build parsimonious models to predict one of four outcome variables (pre- and post-grazing pasture mass (kg DM/cow and kg DM/ha) using location and behavior variables from 5 on-animal devices fitted to 100 dairy cows allocated to different target pasture allowanced to meet either 80%, 100%, or 120% of their estimated ME requirements across two experimental periods (n = 20 d per experimental period). Adj-R^2 = adjusted R-squared. RMSE = Root mean square error. Std = standardized by area allocated. Pre-PM milking = before afternoon milking. Post-PM milking = after afternoon milking.

Outcome variable	Model	Independent variables	Device(s)	R^2	Adj-R^2	RMSE
Pre-grazing mass, kg DM/cow	Model 1	Distance traveled std + Proximity	eShepherd	0.38	0.38	4.61
	Model 2	Grazing time + Moving time + Resting time + Distance traveled std + Proximity	eShepherd	0.43	0.42	4.51
	Model 3	Eating time + Rumination time + Distance traveled std + Distance to herd mates	eShepherd + AfiCollar	0.55	0.54	3.88
	Model 4	Active + Active (high) + Eating time + Rumination time + Distance traveled std + Distance to herd mates	eShepherd + CowManager	0.53	0.51	4.04
	Model 5	Lying time + Lying bouts + Steps + Distance traveled std + Distance to herd mates	eShepherd + IceQube	0.44	0.42	4.40
	Model 6	Rumination time + Activity + Distance traveled std + Distance to herd mates	eShepherd + smaXtec	0.49	0.48	4.19
Post-grazing mass, kg DM/cow	Model 1	Distance traveled std + Distance to herd mates (pre-PM Milking)	eShepherd	0.40	0.40	3.53
	Model 2	Grazing time + Moving time + Resting time + Distance traveled std + Distance to herd mates (pre-PM Milking)	eShepherd	0.49	0.47	3.30
	Model 3	Eating time + Rumination time + Distance traveled std + Distance to herd mates	eShepherd + AfiCollar	0.60	0.59	2.84
	Model 4	Active + Active (high) + Eating time + Rumination time + Distance traveled std + Distance to herd mates	eShepherd + CowManager	0.55	0.54	3.02
	Model 5	Lying time + Lying bouts + Steps + Distance traveled std + Distance to herd mates (pre-PM Milking)	eShepherd + IceQube	0.46	0.44	3.32

Outcome variable	Model	Independent variables	Device(s)	R^2	Adj-R^2	RMSE
	Model 6	Rumination + Activity + Distance traveled std + Distance to herd mates	eShepherd + smaXtec	0.56	0.55	2.99
Pre-grazing mass, kg DM/ha	Model 1	Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd	0.12	0.11	281
	Model 2	Grazing time + Moving time + Resting time + Distance traveled std + Distance to herd mates	eShepherd	0.19	0.17	271
	Model 3	Eating time + Rumination time + Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd + AfiCollar	0.40	0.38	224
	Model 4	Active + Active (high) + Eating time + Rumination time + Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd + CowManager	0.40	0.38	229
	Model 5	Lying time + Lying bouts + Steps + Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd + IceQube	0.26	0.24	254
	Model 6	Rumination + Activity + Distance traveled (pre-PM Milking) + Distance to herd mates	eShepherd + smaXtec	0.32	0.30	244
Post-grazing mass, kg DM/ha	Model 1	Distance traveled std + Distance to herd mates (pre-PM Milking)	eShepherd	0.19	0.18	206
	Model 2	Grazing time + Moving time + Resting time + Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd	0.28	0.26	193
	Model 3	Eating time + Rumination time + Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd + AfiCollar	0.59	0.58	145
	Model 4	Active + Active (high) + Eating time + Rumination time + Distance traveled std (pre-PM Milking) + Distance to herd mates	eShepherd + CowManager	0.56	0.54	151
	Model 5	Lying time + Lying bouts + Steps + Distance traveled std + Distance to herd mates (pre-PM Milking)	eShepherd + IceQube	0.35	0.33	183
	Model 6	Rumination + Activity + Distance traveled (pre-PM Milking) + Distance to herd mates	eShepherd + smaXtec	0.57	0.56	150

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