

An evaluation of landmark-based methods to explore tooth score morphology: a case study on felids and hyenids.

Supplementary File S1

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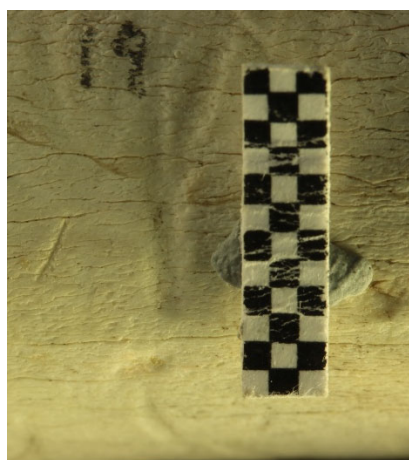
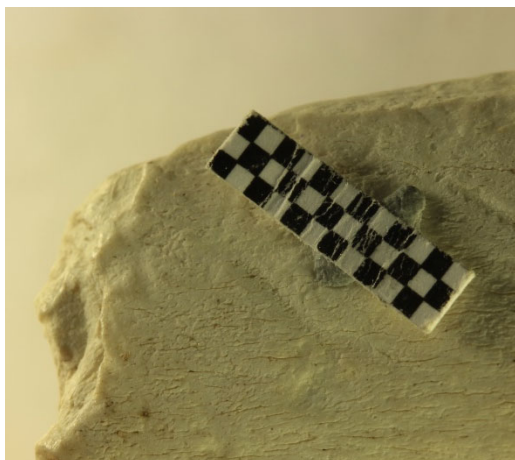
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PHOTOGRAPHS



3D MODELS

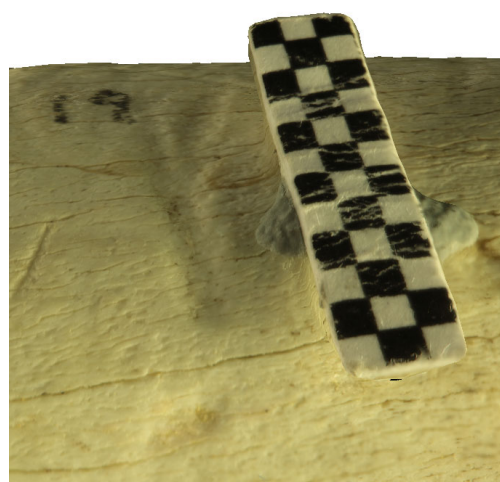
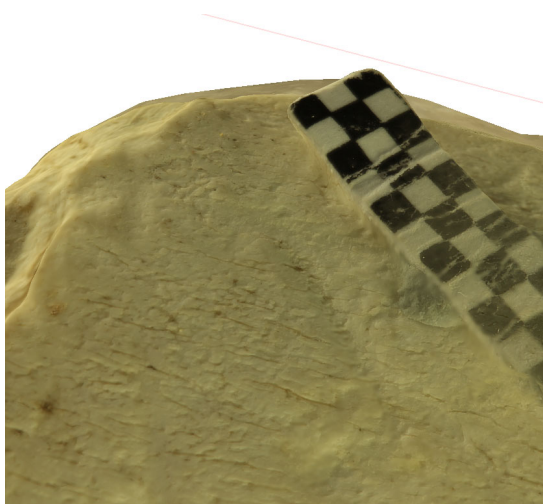
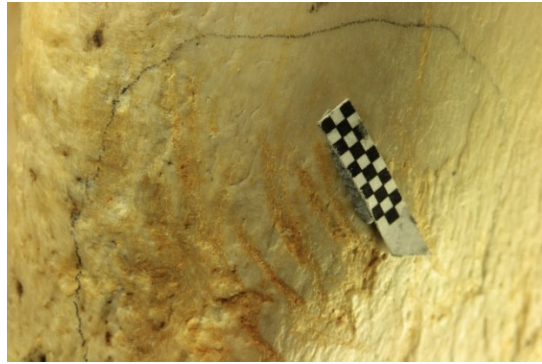
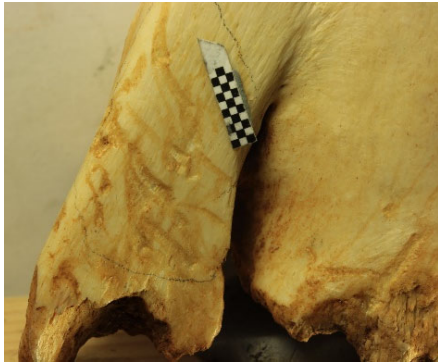


Figure S1. Tooth scores carried out by the lion used for the study. Photographs and 3D models are shown.

PHOTOGRAPHS



3D MODELS

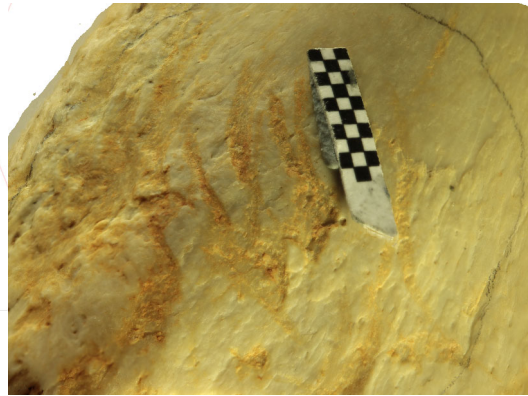
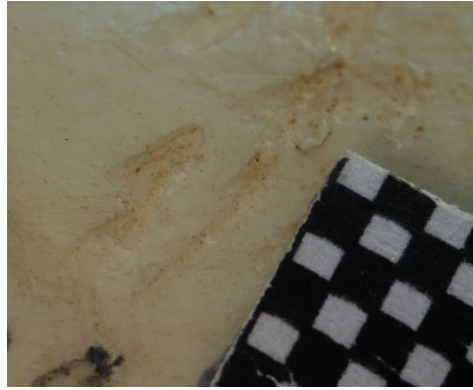


Figure S2. Tooth scores carried out by the spotted hyena used for the study. Photographs and 3D models are shown.

PHOTOGRAPHS



3D MODELS

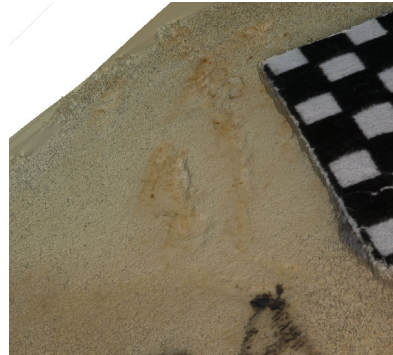


Figure S3. Tooth scores carried out by the brown hyena used for the study. Photographs and 3D models are shown.

PHOTOGRAPHS



3D MODELS



Figure S4. Tooth scores carried out by the leopard used for the study. Photographs and 3D models are shown.

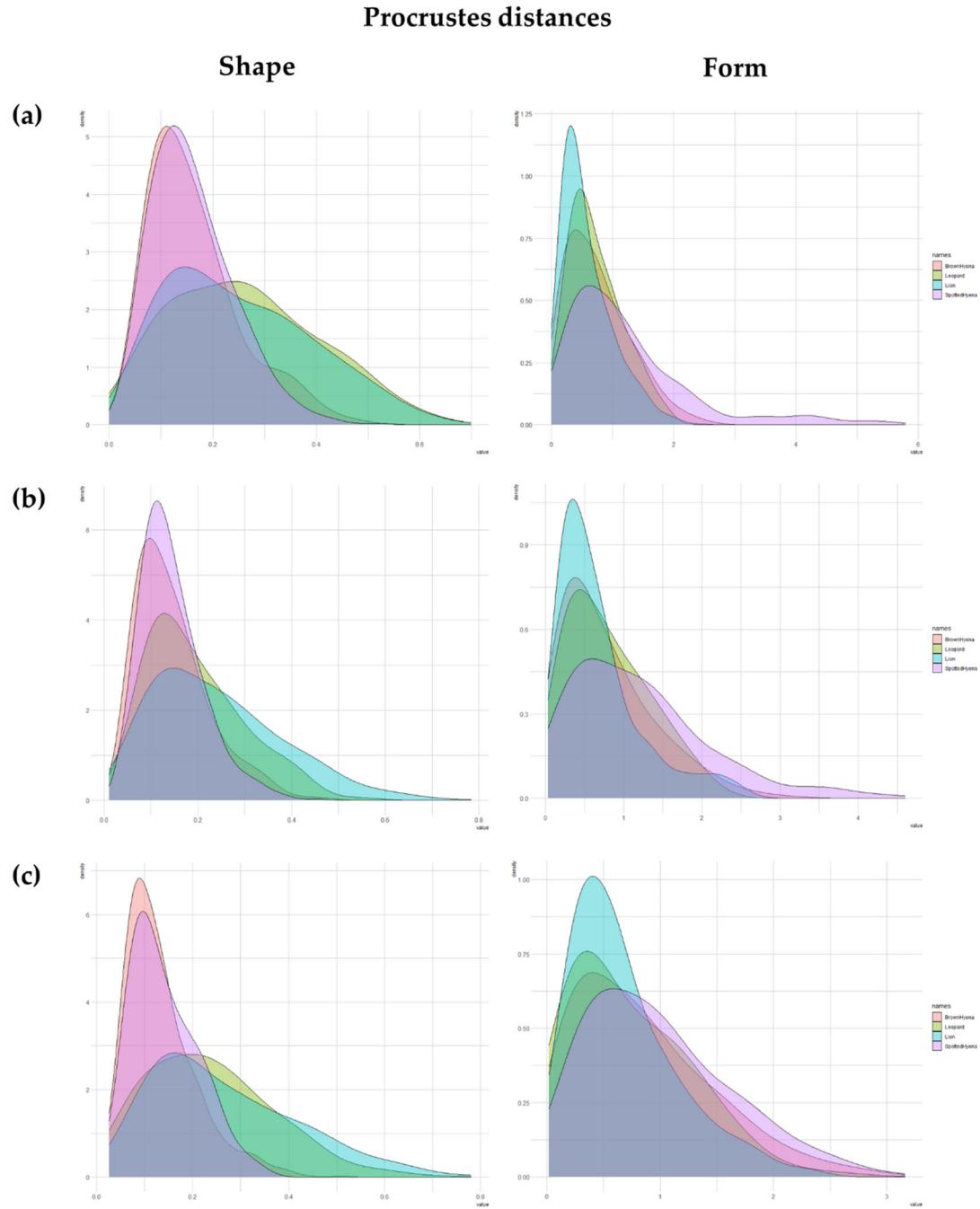
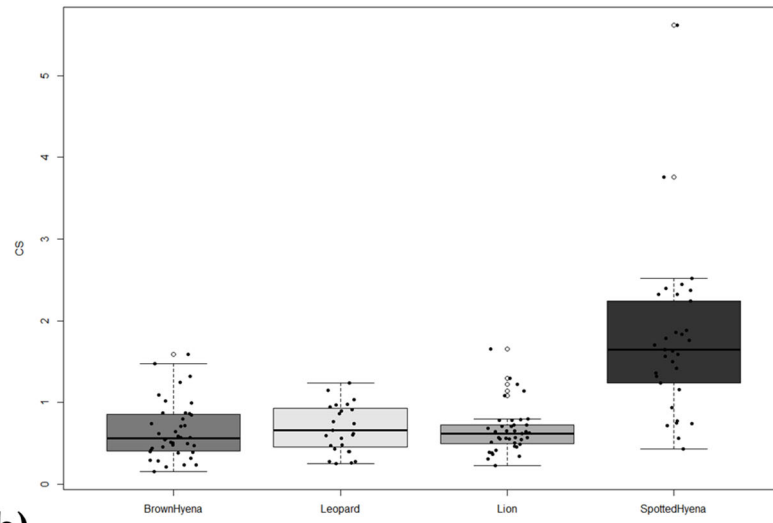
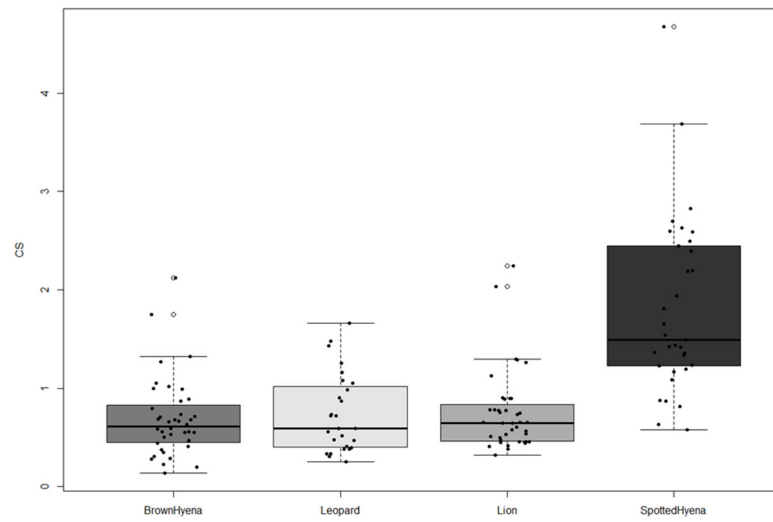


Figure S5. Procrustes distances calculated for the four carnivore groups in shape and form space using the 7-landmark model to characterize the score cross-section at (a) 35% score length; (b) 50% score length; and (c) 65% score length.

(a)



(b)



(c)

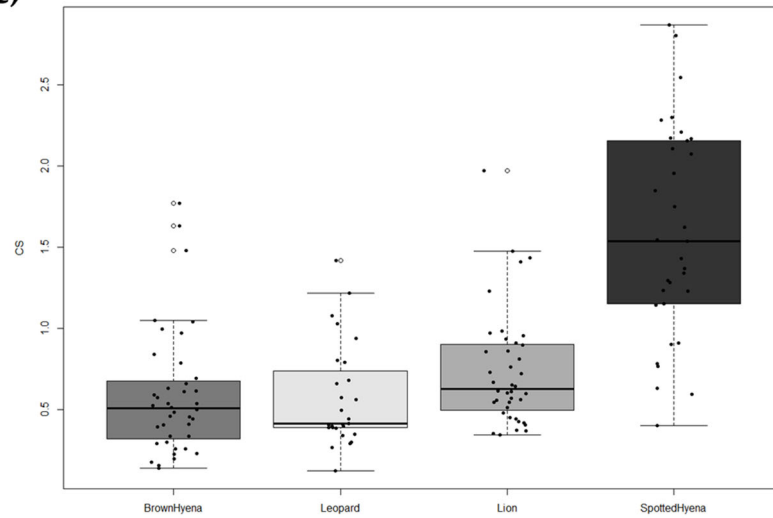


Figure S6. Centroid Size of the carnivore scores included in the present study based on the cross-sections taken at (a) 35% score length; (b) 50% score length; and (c) 65% score length.

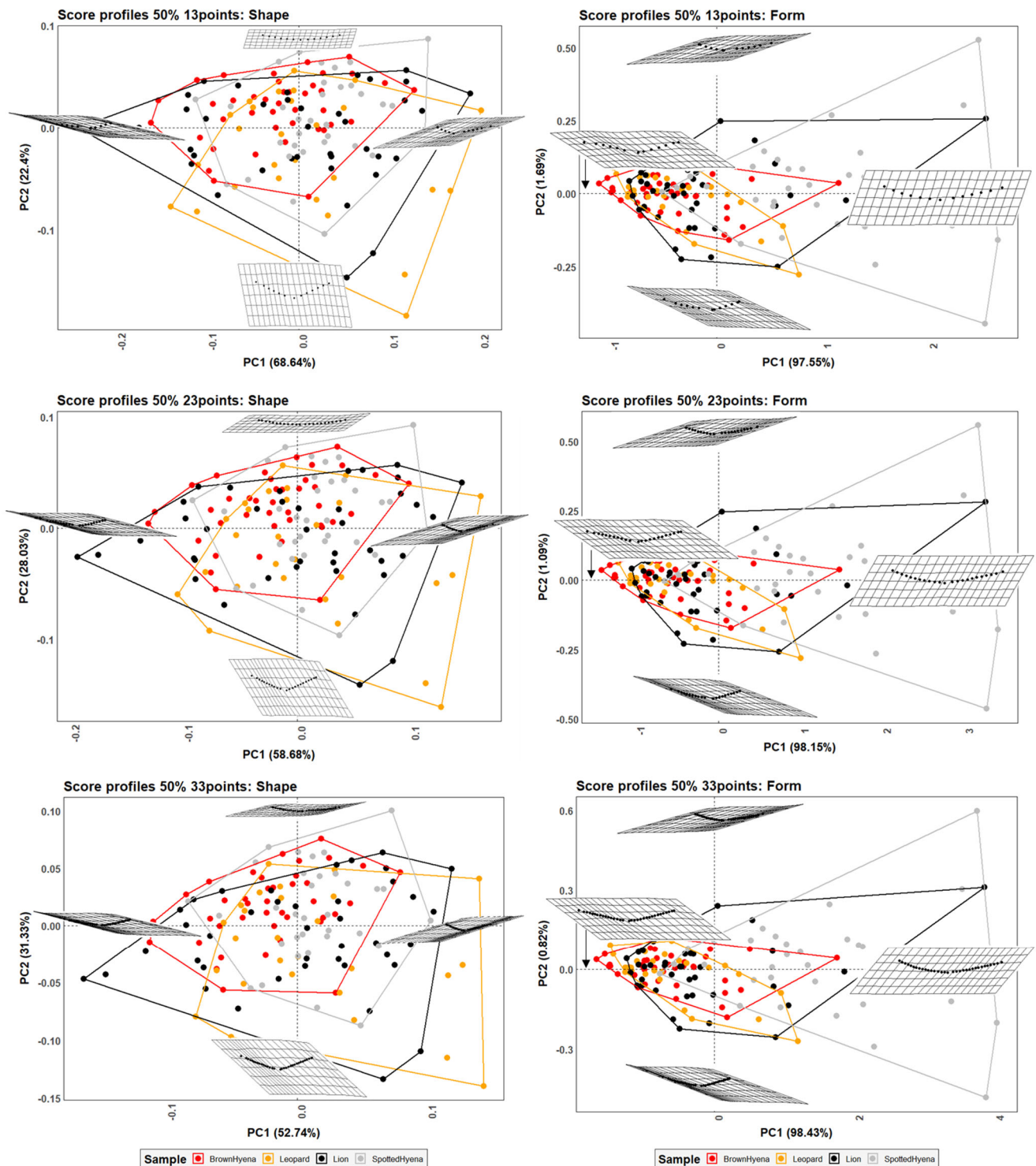


Figure S7. PCA plots in shape and form space on the 2-curves semilandmark models at 50% cross-sectional score length, using 13 points; 23 points; and 33 points. Extreme changes in shape and form along PC1 and PC2 are illustrated with the aid of transformation grids.

Fourier Analysis at 50% score lenght; Shape space

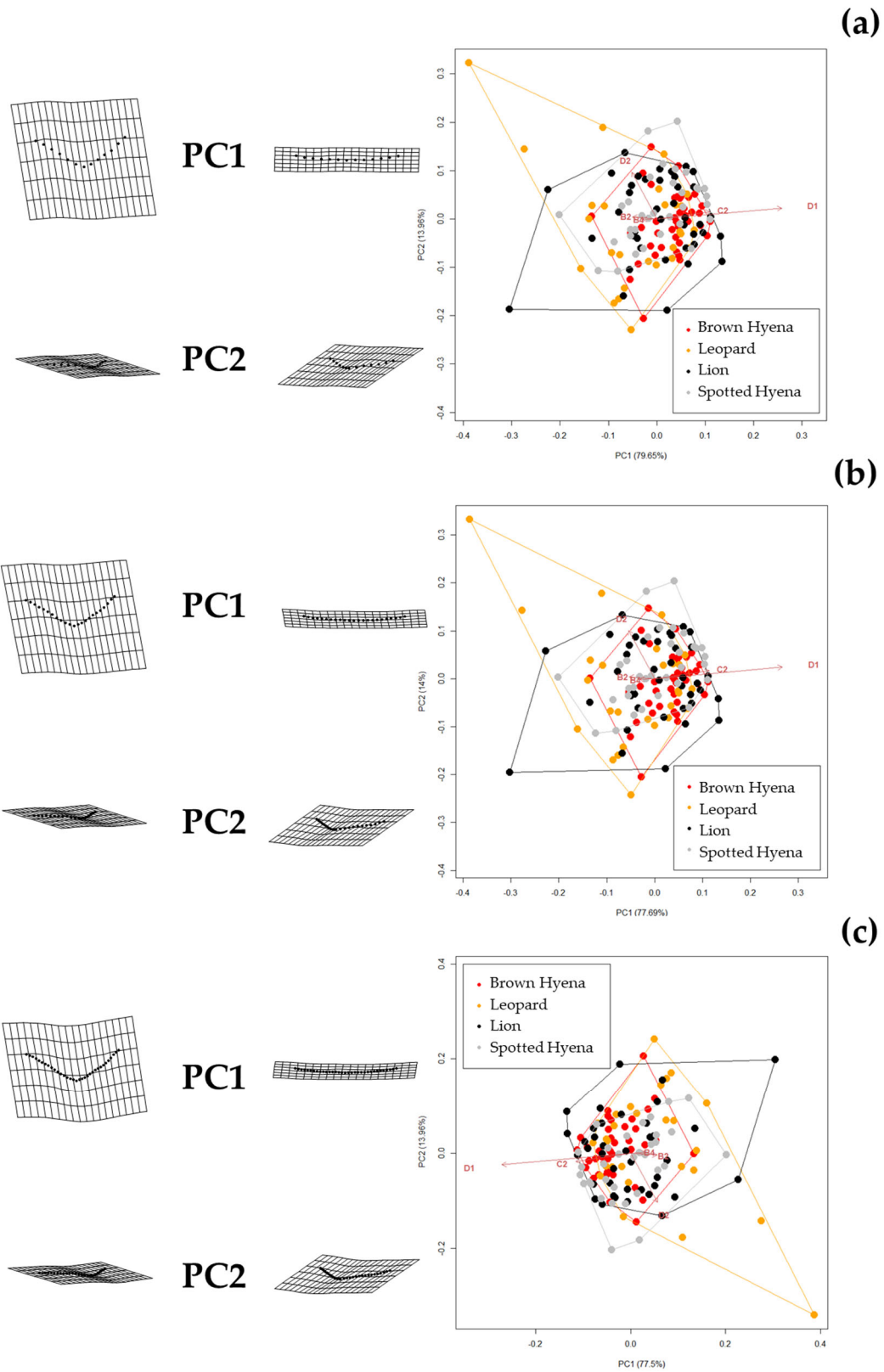
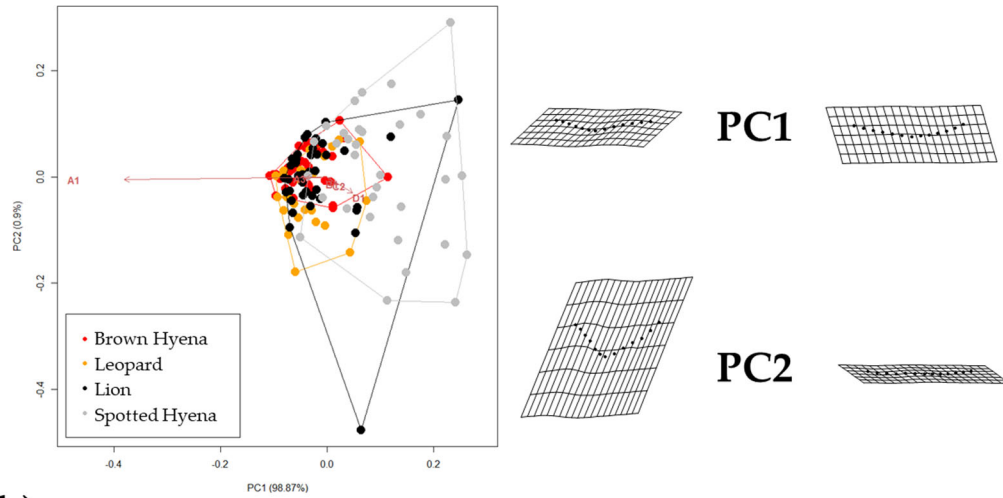


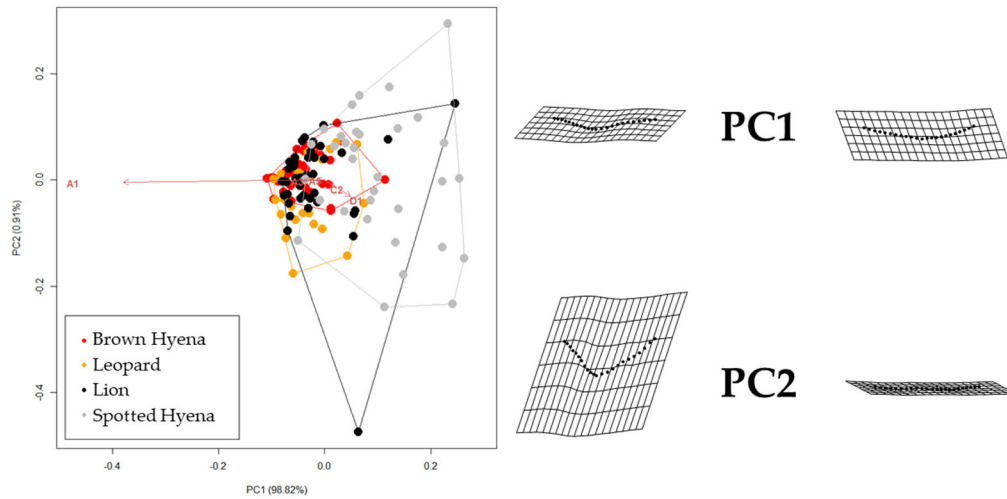
Figure S8. Shape PCA plots on Elliptic Fourier Analysis on the 2-curves semilandmark models at 50% cross-sectional score length, using (a) 13 points; (b) 23 points; and (c) 33 points. Extreme changes in shape along PC1 and PC2 are illustrated with the aid of transformation grids. Optimal harmonics for each model are (a) 4; (b) 6; (c) 6.

Fourier Analysis at 50% score length; Form space

(a)



(b)



(c)

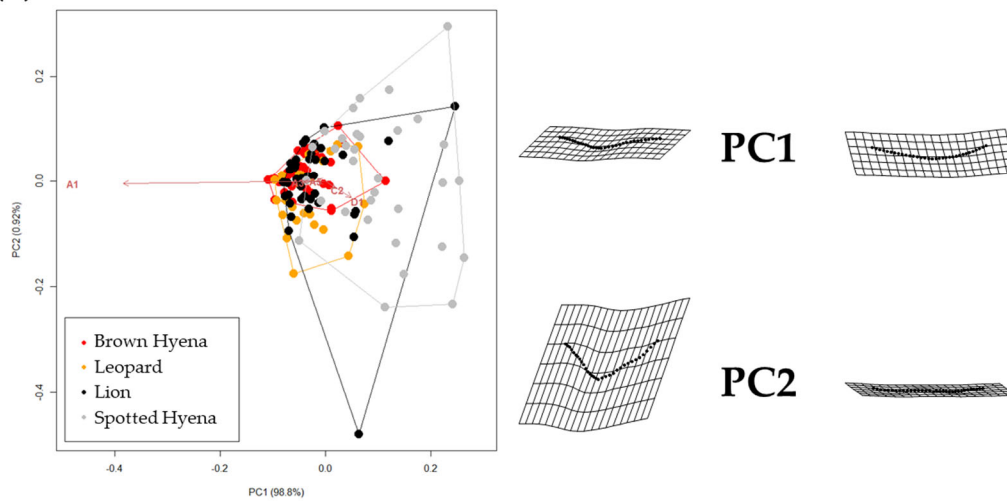


Figure S9. Form PCA plots on Elliptic Fourier Analysis on the 2-curves semilandmark models at 50% cross-sectional score length, using (a) 13 points; (b) 23 points; and (c) 33 points. Extreme changes in form along PC1 and PC2 are illustrated with the aid of transformation grids. Optimal harmonics for each model are (a) 4; (b) 6; (c) 6.

Table S1. MANOVA results obtained on the 13, 23 and 33 semilandmark models on two curves used to describe the cross-sections at 50% of the score length, using a EFA approach

semilandmark models on 2 curves at 50% cross-sectional length - EFA									
13smlm				23smlm			33smlm		
shape									
	B_Hyena	Leopard	Lion	B_Hyena	Leopard	Lion	B_Hyena	Leopard	Lion
Leopard	0.002	-	-	0.003	-	-	0.001	-	-
Lion	0.007	0.025	-	0.002	0.016	-	0.005	0.020	-
S_Hyena	0.010	0.049	0.103	0.009	0.082	0.095	0.009	0.097	0.100
form									
Leopard	0.008	-	-	0.006	-	-	0.005	-	-
Lion	0.061	0.303	-	0.002	0.212	-	0.003	0.202	-
S_Hyena	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Table S2. Statistics by class for the best performing ML and NN models applied on the landmark and semilandmark models generated for the present study.

Models	Brown hyena	Leopard	Lion	Spotted hyena
GBM				
7 lm at 35% - shape				
Sensitivity	0.6364	0.8571	0.8182	0.8889
Specificity	0.8519	0.9677	0.9259	0.9655
Pos Pred Value	0.6364	0.8571	0.8182	0.8889
Neg Pred Value	0.8519	0.9677	0.9259	0.9655
Prevalence	0.2895	0.1842	0.2895	0.2368
Detection rate	0.1842	0.1579	0.2368	0.2105
Detection Prevalence	0.2895	0.1842	0.2895	0.2368
Balanced Accuracy	0.7441	0.9124	0.8721	0.9272
GBM				
7 lm at 35% - form				
Sensitivity	0.7273	0.28571	0.8182	0.6667
Specificity	0.8519	0.93548	0.8148	0.9310
Pos Pred Value	0.6667	0.50000	0.6429	0.7500
Neg Pred Value	0.8846	0.85294	0.9167	0.9000
Prevalence	0.2895	0.18421	0.2895	0.2368
Detection rate	0.2105	0.05263	0.2368	0.1579
Detection Prevalence	0.3158	0.10526	0.3684	0.2105
Balanced Accuracy	0.7896	0.61060	0.8165	0.7989
NN				
7 lm at 50% - shape				
Sensitivity	0.3571	0.5714	0.5833	0.6667
Specificity	0.7600	0.9688	0.7407	0.8485
Pos Pred Value	0.4545	0.8000	0.5000	0.4444
Neg Pred Value	0.6786	0.9118	0.8000	0.9333
Prevalence	0.3590	0.1795	0.3077	0.1538
Detection rate	0.1282	0.1026	0.1795	0.1026
Detection Prevalence	0.2821	0.1282	0.3590	0.2308
Balanced Accuracy	0.5586	0.7701	0.6620	0.7576
GBM				
7 lm at 50% - form				
Sensitivity	0.7273	0.28571	0.5455	0.7778
Specificity	0.7407	0.93548	0.9259	0.8621
Pos Pred Value	0.5333	0.50000	0.7500	0.6364
Neg Pred Value	0.8696	0.85294	0.8333	0.9259
Prevalence	0.2895	0.18421	0.2895	0.2368

Detection rate	0.2105	0.05263	0.1579	0.1842
Detection Prevalence	0.3947	0.10526	0.2105	0.2895
Balanced Accuracy	0.7340	0.61060	0.7357	0.8199
GBM 7 lm at 65% - shape				
Sensitivity	0.3571	0.5714	0.8333	0.6667
Specificity	0.9200	0.9688	0.8519	0.7273
Pos Pred Value	0.7143	0.8000	0.7143	0.3077
Neg Pred Value	0.7188	0.9118	0.9200	0.9231
Prevalence	0.3590	0.1795	0.3077	0.1538
Detection rate	0.1282	0.1026	0.2564	0.1026
Detection Prevalence	0.1795	0.1282	0.3590	0.3333
Balanced Accuracy	0.6386	0.7701	0.8426	0.6970
RF 7 lm at 65% - form				
Sensitivity	0.8571	0.42857	0.5000	1.0000
Specificity	0.8000	0.96875	0.8889	0.9091
Pos Pred Value	0.7059	0.75000	0.6667	0.6667
Neg Pred Value	0.9091	0.88571	0.8000	1.0000
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.3077	0.07692	0.1538	0.1538
Detection Prevalence	0.4359	0.10256	0.2308	0.2308
Balanced Accuracy	0.8286	0.69866	0.6944	0.9545
GBM 7 lm at U section - form				
Sensitivity	0.6923	0.28571	0.5000	0.6667
Specificity	0.7857	0.76471	0.9310	0.9375
Pos Pred Value	0.6000	0.20000	0.7500	0.7500
Neg Pred Value	0.8462	0.83871	0.8182	0.9091
Prevalence	0.3171	0.17073	0.2927	0.2195
Detection rate	0.2195	0.04878	0.1463	0.1463
Detection Prevalence	0.3659	0.24390	0.1951	0.1951
Balanced Accuracy	0.7390	0.52521	0.7155	0.8021
GBM 10 smlm at 50% - shape				
Sensitivity	0.8182	0.28571	0.5455	0.22222
Specificity	0.7407	1.00000	0.7037	0.86207
Pos Pred Value	0.5625	1.00000	0.4286	0.33333
Neg Pred Value	0.9091	0.86111	0.7917	0.78125
Prevalence	0.2895	0.18421	0.2895	0.23684
Detection rate	0.2368	0.05263	0.1579	0.05263
Detection Prevalence	0.4211	0.05263	0.3684	0.15789
Balanced Accuracy	0.7795	0.64286	0.6246	0.54215
RF 10 smlm at 50% - form				
Sensitivity	0.5000	0.14286	0.7500	0.8333
Specificity	0.7600	0.90625	0.8148	0.9091
Pos Pred Value	0.5385	0.25000	0.6429	0.6250
Neg Pred Value	0.7308	0.82857	0.8800	0.9677
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.1795	0.02564	0.2308	0.1282
Detection Prevalence	0.3333	0.10256	0.3590	0.2051
Balanced Accuracy	0.6300	0.52455	0.7824	0.8712
RF 25 smlm at 50% - form				
Sensitivity	0.5714	0.28571	0.8333	0.8333
Specificity	0.8000	0.90625	0.8519	0.9394
Pos Pred Value	0.6154	0.40000	0.7143	0.7143
Neg Pred Value	0.7692	0.85294	0.9200	0.9688
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.2051	0.05128	0.2564	0.1282
Detection Prevalence	0.3333	0.12821	0.3590	0.1795
Balanced Accuracy	0.6857	0.59598	0.8426	0.8864
GBM 50 smlm at 50% - form				
Sensitivity	0.5000	0.7143	0.7500	0.6667

Specificity	0.8800	0.8750	0.8148	0.9394
Pos Pred Value	0.7000	0.5556	0.6429	0.6667
Neg Pred Value	0.7586	0.9333	0.8800	0.9394
Prevalence	0.3590	0.1795	0.3077	0.1538
Detection rate	0.1795	0.1282	0.2308	0.1026
Detection Prevalence	0.2564	0.2308	0.3590	0.1538
Balanced Accuracy	0.6900	0.7946	0.7824	0.8030
GBM				
13 smlm at U section - form				
Sensitivity	0.8000	0.11111	0.5556	1.0000
Specificity	0.6875	1.00000	0.8750	0.8649
Pos Pred Value	0.4444	1.00000	0.7692	0.5000
Neg Pred Value	0.9167	0.80488	0.7241	1.0000
Prevalence	0.2381	0.21429	0.4286	0.1190
Detection rate	0.1905	0.02381	0.2381	0.1190
Detection Prevalence	0.4286	0.02381	0.3095	0.2381
Balanced Accuracy	0.7438	0.55556	0.7153	0.9324
NN				
23 smlm at U section - shape				
Sensitivity	0.8000	0.5556	0.4444	0.20000
Specificity	0.5938	0.9697	0.9583	0.86486
Pos Pred Value	0.3810	0.8333	0.8889	0.16667
Neg Pred Value	0.9048	0.8889	0.6970	0.88889
Prevalence	0.2381	0.2143	0.4286	0.11905
Detection rate	0.1905	0.1190	0.1905	0.02381
Detection Prevalence	0.5000	0.1429	0.2143	0.14286
Balanced Accuracy	0.6969	0.7626	0.7014	0.53243
SVM				
23 smlm at U section- form				
Sensitivity	0.7143	0.40000	0.5385	0.6250
Specificity	0.6774	0.94286	0.9062	0.8919
Pos Pred Value	0.5000	0.66667	0.7000	0.5556
Neg Pred Value	0.8400	0.84615	0.8286	0.9167
Prevalence	0.3111	0.22222	0.2889	0.1778
Detection rate	0.2222	0.08889	0.1556	0.1111
Detection Prevalence	0.4444	0.13333	0.2222	0.2000
Balanced Accuracy	0.6959	0.67143	0.7224	0.7584
SVM				
33 smlm at U section- form				
Sensitivity	0.7143	0.30000	0.4615	0.6250
Specificity	0.7097	0.91429	0.8438	0.8919
Pos Pred Value	0.5263	0.50000	0.5455	0.5556
Neg Pred Value	0.8462	0.82051	0.7941	0.9167
Prevalence	0.3111	0.22222	0.2889	0.1778
Detection rate	0.2222	0.06667	0.1333	0.1111
Detection Prevalence	0.4222	0.13333	0.2444	0.2000
Balanced Accuracy	0.7120	0.60714	0.6526	0.7584
NN				
10 EFA at 50% - form				
Sensitivity	0.4286	0.14286	0.6667	1.0000
Specificity	0.8000	1.00000	0.8148	0.7576
Pos Pred Value	0.5455	1.00000	0.6154	0.4286
Neg Pred Value	0.7143	0.84211	0.8462	1.0000
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.1538	0.02564	0.2051	0.1538
Detection Prevalence	0.2821	0.02564	0.3333	0.3590
Balanced Accuracy	0.6143	0.57143	0.7407	0.8788
RF				
25 EFA at 50% - form				
Sensitivity	0.5000	0.00000	0.6667	1.0000
Specificity	0.7600	0.93750	0.7407	0.9091
Pos Pred Value	0.5385	0.00000	0.5333	0.6667
Neg Pred Value	0.7308	0.81081	0.8333	1.0000
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.1795	0.00000	0.2051	0.1538

Detection Prevalence	0.3333	0.05128	0.3846	0.2308
Balanced Accuracy	0.6300	0.46875	0.7037	0.9545
NN 50 EFA at 50% - form				
Sensitivity	0.5000	0.14286	0.5833	1.0000
Specificity	0.7200	0.93750	0.8148	0.8788
Pos Pred Value	0.5000	0.33333	0.5833	0.6000
Neg Pred Value	0.7200	0.83333	0.8148	1.0000
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.1795	0.02564	0.1795	0.1538
Detection Prevalence	0.3590	0.07692	0.3077	0.2564
Balanced Accuracy	0.6100	0.54018	0.6991	0.9394
GBM 13 EFA at 50% - shape				
Sensitivity	0.5714	0.00000	0.6667	0.6667
Specificity	0.6800	0.96875	0.8148	0.8485
Pos Pred Value	0.5000	0.00000	0.6154	0.4444
Neg Pred Value	0.7391	0.81579	0.8462	0.9333
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.2051	0.00000	0.2051	0.1026
Detection Prevalence	0.4103	0.02564	0.3333	0.2308
Balanced Accuracy	0.6257	0.48438	0.7407	0.7576
RF 13 EFA at 50% - form				
Sensitivity	0.7857	0.00000	0.5833	0.8333
Specificity	0.7200	0.96875	0.8519	0.8788
Pos Pred Value	0.6111	0.00000	0.6364	0.5556
Neg Pred Value	0.8571	0.81579	0.8214	0.9667
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.2821	0.00000	0.1795	0.1282
Detection Prevalence	0.4615	0.02564	0.2821	0.2308
Balanced Accuracy	0.7529	0.48438	0.7176	0.8561
GBM 23 EFA at 50% - shape				
Sensitivity	0.5714	0.00000	0.6667	0.6667
Specificity	0.6800	0.96875	0.8148	0.8485
Pos Pred Value	0.5000	0.00000	0.6154	0.4444
Neg Pred Value	0.7391	0.81579	0.8462	0.9333
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.2051	0.00000	0.2051	0.1026
Detection Prevalence	0.4103	0.02564	0.3333	0.2308
Balanced Accuracy	0.6257	0.48438	0.7407	0.7576
RF 23 EFA at 50%				
Sensitivity	0.7857	0.00000	0.5833	0.8333
Specificity	0.7200	0.96875	0.8519	0.8788
Pos Pred Value	0.6111	0.00000	0.6364	0.5556
Neg Pred Value	0.8571	0.81579	0.8214	0.9667
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.2821	0.00000	0.1795	0.1282
Detection Prevalence	0.4615	0.02564	0.2821	0.2308
Balanced Accuracy	0.7529	0.48438	0.7176	0.8561
GBM 33 EFA at 50% - shape				
Sensitivity	0.8182	0.14286	0.5455	0.4444
Specificity	0.7407	0.93548	0.8519	0.8276
Pos Pred Value	0.5625	0.33333	0.6000	0.4444
Neg Pred Value	0.9091	0.82857	0.8214	0.8276
Prevalence	0.2895	0.18421	0.2895	0.2368
Detection rate	0.2368	0.02632	0.1579	0.1053
Detection Prevalence	0.4211	0.07895	0.2632	0.2368
Balanced Accuracy	0.7795	0.53917	0.6987	0.6360
GBM 33 EFA at 50% - form				
Sensitivity	0.7857	0.00000	0.6667	1.0000
Specificity	0.7600	0.96875	0.9259	0.8485

Pos Pred Value	0.6471	0.00000	0.8000	0.5455
Neg Pred Value	0.8636	0.81579	0.8621	1.0000
Prevalence	0.3590	0.17949	0.3077	0.1538
Detection rate	0.2821	0.00000	0.2051	0.1538
Detection Prevalence	0.4359	0.02564	0.2564	0.2821
Balanced Accuracy	0.7729	0.48438	0.7963	0.9242
GBM				
13 EFA at U section - form				
Sensitivity	0.6923	0.14286	0.5000	0.7778
Specificity	0.7143	0.91176	0.8966	0.8750
Pos Pred Value	0.5294	0.25000	0.6667	0.6364
Neg Pred Value	0.8333	0.83784	0.8125	0.9333
Prevalence	0.3171	0.17073	0.2927	0.2195
Detection rate	0.2195	0.02439	0.1463	0.1707
Detection Prevalence	0.4146	0.09756	0.2195	0.2683
Balanced Accuracy	0.7033	0.52731	0.6983	0.8264
NN				
23 EFA at U section - form				
Sensitivity	0.6000	0.33333	0.5000	0.60000
Specificity	0.5938	0.96970	0.9167	0.86486
Pos Pred Value	0.3158	0.75000	0.8182	0.37500
Neg Pred Value	0.8261	0.84211	0.7097	0.94118
Prevalence	0.2381	0.21429	0.4286	0.11905
Detection rate	0.1429	0.07143	0.2143	0.07143
Detection Prevalence	0.4524	0.09524	0.2619	0.19048
Balanced Accuracy	0.5969	0.65152	0.7083	0.73243
SVM				
33 EFA at U section - form				
Sensitivity	0.6154	0.28571	0.5833	0.44444
Specificity	0.6429	0.88235	0.9310	0.87500
Pos Pred Value	0.4444	0.33333	0.7778	0.50000
Neg Pred Value	0.7826	0.85714	0.8438	0.84848
Prevalence	0.3171	0.17073	0.2927	0.21951
Detection rate	0.1951	0.04878	0.1707	0.09756
Detection Prevalence	0.4390	0.14634	0.2195	0.19512
Balanced Accuracy	0.6291	0.58403	0.7572	0.65972