# supplemental information 1

Equations describing Welch’s two-sample t-test:

 $t=\frac{μ\_{k,j}-μ\_{k,j}}{\sqrt{\frac{σ\_{k,j}^{2}}{n\_{eff,k}}+\frac{σ\_{k,j}^{2}}{n\_{eff,k}}}}$ (1)

 $p\left(t>F(x, df)\right)$ (2)

 $df=\frac{\frac{σ\_{k,j}^{2}}{n\_{eff,k}}+\frac{σ\_{k,j}^{2}}{n\_{eff,k}}}{\frac{σ\_{k,j}^{4}}{n\_{eff,k}^{2}\left(n\_{eff,k}^{2}-1\right)}+\frac{σ\_{k,j}^{4}}{n\_{eff,k}^{2}\left(n\_{eff,k}^{2}-1\right)}}$ (3)

where $t$ is the test statistic, $μ\_{k,j}-μ\_{k,j}$ is the difference in means between sharks, $\sqrt{\frac{σ\_{k,j}^{2}}{n\_{eff,k}}+\frac{σ\_{k,j}^{2}}{n\_{eff,k}}}$ is the pooled variance, and $F\left(x\right)$ is the cumulative distribution function of the standard Student’s t-distribution with degrees of freedom, $df$.

# supplemental table 1

The percentage of total dives by each shark (ID) in each dive shape cluster (A-G).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| ID | A | B | C | D | E | F | G |
| BS-08-01 | 0.20 | 0.60 | 0.20 |  |  |  |  |
| BS-09-01 | 0.16 | 0.56 | 0.16 | 0.13 |  |  |  |
| BS-10-01 | 0.46 |  | 0.21 | 0.13 | 0.18 | 0.03 |  |
| BS-10-02 | 0.25 | 0.04 | 0.46 | 0.12 | 0.10 | 0.03 |  |
| BS-10-03 | 0.22 | 0.22 | 0.35 | 0.04 | 0.09 | 0.09 |  |
| BS-10-04 | 0.35 | 0.33 | 0.12 | 0.09 | 0.05 | 0.07 |  |
| BS-12-02 | 0.14 | 0.34 | 0.17 | 0.20 | 0.09 | 0.06 |  |
| BS-12-01 | 0.26 | 0.31 | 0.07 | 0.19 | 0.17 |  |  |
| BS-12-07 | 0.24 | 0.36 | 0.32 | 0.07 | 0.02 |  |  |
| BS-13-01 | 0.24 | 0.48 | 0.17 | 0.07 | 0.03 |  |  |
| BS-13-02 | 0.27 | 0.24 | 0.42 | 0.03 | 0.04 |  |  |
| BS-13-03 | 0.29 | 0.55 | 0.11 |  | 0.03 | 0.03 |  |
| BS-13-04 | 0.07 | 0.43 |  | 0.10 | 0.40 |  |  |
| BS-14-02 | 0.25 | 0.31 | 0.25 | 0.06 | 0.06 | 0.06 |  |
| BS-14-06 | 0.12 | 0.41 | 0.30 | 0.11 | 0.04 | 0.02 |  |
| BS-14-07 | 0.16 | 0.45 | 0.38 |  |  | 0.01 |  |
| BS-15-01 | 0.12 | 0.08 | 0.24 | 0.24 | 0.28 |  | 0.04 |
| BS-15-02 | 0.24 | 0.21 | 0.33 | 0.15 | 0.06 | 0.01 |  |
| BS-15-09 | 0.14 | 0.34 | 0.28 | 0.10 | 0.14 |  |  |
| BS-16-02 | 0.24 | 0.26 | 0.18 | 0.16 | 0.16 |  |  |
| BS-16-04 | 0.33 | 0.23 | 0.28 | 0.14 | 0.02 |  |  |
| BS-17-01 | 0.06 | 0.64 | 0.22 | 0.02 | 0.05 |  | 0.02 |
| BS-17-02 | 0.07 | 0.75 | 0.18 |  |  |  |  |
| BS-18-01 | 0.37 |  | 0.37 | 0.14 | 0.09 | 0.03 |  |
| BS-18-02 | 0.35 | 0.04 | 0.19 | 0.15 | 0.15 | 0.12 |  |
| BS-18-03 | 0.20 | 0.20 | 0.10 | 0.23 | 0.20 | 0.07 |  |
| BS-18-04 | 0.26 |  | 0.58 | 0.14 |  | 0.02 |  |
| BS-18-05 | 0.15 | 0.33 | 0.26 | 0.18 | 0.05 | 0.03 |  |
| BS-18-06 | 0.63 | 0.13 | 0.13 |  |  | 0.13 |  |
| BS-18-10 | 0.21 | 0.45 | 0.34 |  |  |  |  |
| BS-18-09 | 0.17 | 0.25 | 0.17 | 0.08 | 0.08 | 0.25 |  |
| BS-18-11 | 0.60 |  | 0.15 | 0.10 | 0.15 |  |  |
| BS-18-12 | 0.38 | 0.08 | 0.31 | 0.08 | 0.15 |  |  |
| BS-19-01 | 0.25 | 0.31 | 0.41 | 0.03 |  |  |  |
| BS-19-02 | 0.13 | 0.03 | 0.82 | 0.02 |  |  |  |
| BS-19-03 | 0.25 | 0.35 | 0.05 | 0.20 | 0.15 |  |  |
| BS-19-04 | 0.05 |  | 0.95 |  |  |  |  |
| BS-19-05 | 0.19 | 0.33 | 0.47 | 0.02 |  |  |  |
| BS-19-06 | 0.11 |  | 0.89 |  |  |  |  |
| BS-19-07 | 0.05 |  | 0.95 |  |  |  |  |
| BS-20-01 | 0.22 |  | 0.31 | 0.16 | 0.31 |  |  |
| BS-20-02 | 0.23 | 0.13 | 0.60 | 0.02 | 0.02 |  |  |

# supplemental table 2

The effective sample size (N), the percent of time in the surface component for the diel (dawn, dusk) and tidal (high slack, ebb, low slack, and flood) periods, the DVM assignment (with s. denoting a strong vertical migrator), and the $χ^{2}$ for the test of equal proportion (significance is indicated by the asterisks and bold emphasis).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Percent of time in the surface component |  | $$χ^{2}$$ |
| ID | N | Dawn | Dusk | High slack | Ebb | Low slack | Flood | DVM | Diel | Tidal |
| BS-08-01 | 15 | 0.3 | 0.29 | 0 | 0.48 | 0.55 | 0.1 | RDVM | 0 | 3.05 |
| BS-09-01 | 18 | 0.18 | 0.8 | 0.42 | 0.56 | 0.57 | 0.39 | DVM | **4.64\*** | 0.49 |
| BS-10-01 | 55 | 0.41 | 0.35 | 0.34 | 0.4 | 0.32 | 0.39 | RDVM | 0.05 | 0.16 |
| BS-10-02 | 79 | 0.21 | 0.38 | 0.25 | 0.34 | 0.22 | 0.25 | DVM | 2.08 | 0.79 |
| BS-10-03 | 59 | 0.1 | 0.01 | 0.15 | 0.07 | 0.05 | 0.04 | RDVM | 0.82 | 0.85 |
| BS-10-04 | 38 | 0.21 | 0.11 | 0.11 | 0.22 | 0.06 | 0.13 | RDVM | 0.13 | 0.79 |
| BS-12-01 | 24 | 0.35 | 0.21 | 0.35 | 0.44 | 0.29 | 0.12 | RDVM | 0.07 | 2.46 |
| BS-12-02 | 45 | 0.14 | 0.36 | 0.34 | 0.23 | 0.16 | 0.24 | DVM | 1.92 | 0.36 |
| BS-12-07 | 52 | 0.38 | 0.16 | 0.35 | 0.28 | 0.31 | 0.26 | RDVM | 2.09 | 0.2 |
| BS-13-01 | 80 | 0.24 | 0.21 | 0.34 | 0.21 | 0.11 | 0.24 | RDVM | 0.01 | 1.08 |
| BS-13-02 | 130 | 0.14 | 0.06 | 0.1 | 0.08 | 0.05 | 0.15 | RDVM | 1.18 | 1.81 |
| BS-13-03 | 31 | 0.06 | 0.11 | 0.03 | 0.08 | 0.07 | 0.1 | DVM | 0 | 0.11 |
| BS-13-04 | 22 | 0.46 | 0.21 | 0.27 | 0.42 | 0.26 | 0.28 | RDVM | 0.66 | 0.52 |
| BS-14-02 | 34 | 0.25 | 0.14 | 0 | 0.2 | 0.25 | 0.24 | RDVM | 0.1 | 0.82 |
| BS-14-06 | 55 | 0.21 | 0.15 | 0.1 | 0.19 | 0.06 | 0.2 | RDVM | 0.04 | 0.73 |
| BS-14-07 | 74 | 0.28 | 0.26 | 0.26 | 0.28 | 0.3 | 0.26 | RDVM | 0 | 0.06 |
| BS-15-01 | 20 | 0.18 | 0.22 | 0 | 0.27 | 0.37 | 0.13 | DVM | 0 | 1.28 |
| BS-15-02 | 94 | 0.17 | 0.17 | 0.19 | 0.2 | 0.16 | 0.15 | RDVM | 0 | 0.37 |
| BS-15-09 | 15 | 0.26 | 0.21 | 0.2 | 0.18 | 0.21 | 0.3 | RDVM | 0 | 0.24 |
| BS-16-02 | 62 | 0.43 | 0.09 | 0.3 | 0.28 | 0.17 | 0.32 | RDVM | **7.01\*\*** | 0.46 |
| BS-16-04 | 51 | 0.3 | 0.36 | 0.23 | 0.29 | 0.34 | 0.37 | DVM | 0.02 | 0.46 |
| BS-17-01 | 37 | 0.29 | 0.23 | 0.18 | 0.2 | 0.32 | 0.33 | RDVM | 0 | 0.82 |
| BS-17-02 | 199 | 0.31 | 0.18 | 0.19 | 0.31 | 0.28 | 0.21 | RDVM | 3.69 | 2.67 |
| BS-18-01 | 25 | 0.44 | 0.38 | 0.24 | 0.4 | 0.46 | 0.46 | RDVM | 0 | 0.35 |
| BS-18-02 | 48 | 0.21 | 0.06 | 0.1 | 0.09 | 0.25 | 0.19 | RDVM | 1.02 | 1.34 |
| BS-18-03 | 21 | 0.31 | 0.11 | 0.17 | 0.19 | 0.12 | 0.28 | RDVM | 0.3 | 0.32 |
| BS-18-04 | 50 | 0.38 | 0.57 | 0.48 | 0.48 | 0.45 | 0.44 | DVM | 1.2 | 0.07 |
| BS-18-05 | 27 | 0.33 | 0.34 | 0.32 | 0.25 | 0.19 | 0.46 | DVM | 0 | 1.43 |
| BS-18-06 | 14 | 0.14 | 0 | 0 | 0.13 | 0.19 | 0.04 | RDVM | 0 | 0.57 |
| BS-18-09 | 32 | 0.04 | 0 | 0.09 | 0.03 | 0.02 | 0.01 | RDVM | 0 | 0.6 |
| BS-18-10 | 25 | 0.24 | 0.17 | 0.17 | 0.31 | 0.45 | 0.06 | RDVM | 0 | 2.61 |
| BS-18-11 | 86 | 0.05 | 0.04 | 0.02 | 0.02 | 0.03 | 0.07 | RDVM | 0 | 1.35 |
| BS-18-12 | 12 | 0.2 | 0.28 | 0.73 | 0.17 | 0.45 | 0.13 | DVM | 0 | 2.16 |
| BS-19-01 | 64 | 0.28 | 0.41 | 0.19 | 0.36 | 0.33 | 0.32 | DVM | 0.6 | 0.59 |
| BS-19-02 | 176 | 0.38 | 0.35 | 0.41 | 0.43 | 0.23 | 0.33 | RDVM | 0.04 | 2.97 |
| BS-19-03 | 14 | 0.24 | 0 | 0.12 | 0.2 | 0.16 | 0.07 | RDVM | 0.21 | 0.45 |
| BS-19-04 | 181 | 0.28 | 0.43 | 0.36 | 0.32 | 0.52 | 0.34 | DVM | **4.26\*** | 2.05 |
| BS-19-05 | 32 | 0.22 | 0.37 | 0.26 | 0.44 | 0.38 | 0.13 | DVM | 0.29 | 3.26 |
| BS-19-06 | 161 | 0.56 | 0.53 | 0.68 | 0.57 | 0.41 | 0.51 | RDVM | 0.06 | 2.37 |
| BS-19-07 | 161 | 0.42 | 0.45 | 0.41 | 0.41 | 0.55 | 0.44 | DVM | 0.08 | 0.8 |
| BS-20-01 | 35 | 0.29 | 0.33 | 0.27 | 0.33 | 0.36 | 0.28 | DVM | 0 | 0.18 |
| BS-20-02 | 143 | 0.35 | 0.46 | 0.27 | 0.35 | 0.42 | 0.47 | DVM | 1.31 | 2.41 |
| \*\*\**p*<0.001, \*\**p*<0.01, \**p*<0.05 |

# Supplemental Table 3

The Akaike’s Information Criterion (AIC) values for the models of the vertical movement metrics: maximum deployment depth (max D), percent time subsurface $\left(λ\_{2}\right)$, mean subsurface movement depth $\left(μ\_{2}\right)$, subsurface movement rate (Rate), the first principal component scores of the proportion subsurface movements in each movement shape cluster (PC1), and the second principal component scores of the proportion subsurface movements in each movement shape cluster (PC2). Nine models were tested with three different covariates: Julian Day, thermocline depth (TD), or both along with three different dispersion structures: constant variance $\left(σ\right)$, covariance with Julian Day $\left(σ\_{JD}\right)$, or covariance with thermocline depth $\left(σ\_{TD}\right)$. The lowest AIC value and the most parsimonious model is accented in bold.

|  |  |  |  |
| --- | --- | --- | --- |
|  | ~ Julian | ~ TD | ~ Julian + TD |
|  | $$σ$$ | $$σ\_{JD}$$ | $$σ\_{TD}$$ | $$σ$$ | $$σ\_{JD}$$ | $$σ\_{TD}$$ | $$σ$$ | $$σ\_{JD}$$ | $$σ\_{TD}$$ |
| max D | 47.32 | 48.47 | 48.29 | **41.88** | 43.60 | 43.43 | 43.86 | 45.53 | 45.41 |
| $$λ\_{2}$$ | 47.50 | 41.83 | 34.68 | 46.73 | 40.91 | **34.07** | 48.59 | 42.80 | 35.88 |
| $$μ\_{2}$$ | 45.54 | 46.76 | 47.50 | **45.12** | 46.65 | 46.55 | 46.22 | 47.91 | 47.96 |
| Rate | 48.64 | 50.23 | 50.57 | **47.74** | 49.74 | 49.74 | 49.46 | 51.26 | 51.46 |
| PC1 | **48.04** | 49.89 | 50.04 | 49.72 | 50.73 | 51.69 | 49.99 | 51.76 | 51.99 |
| PC2 | **47.83** | 49.75 | 49.77 | 48.29 | 49.75 | 50.11 | 49.71 | 51.63 | 51.59 |

Supplemental Figure 1



# supplemental figure



(Top) The $χ^{2}$ statistic for Fisher’s exact probability test between each shark’s $λ\_{2}$ in the upper off-diagonal, the significance in the lower off-diagonal ($α<0.05$ denoted by an asterisk), and the proportion of observations in each component along the diagonal ($λ\_{1}$ in the upper left and $λ\_{2}$ in the lower right). (Bottom) The mean of the finite mixture model components along the diagonal ($μ\_{1}$ in the upper left, $μ\_{2}$ in the lower right), difference between $μ\_{1}$ $\left(Δμ\_{1}\right)$ for each shark in the upper off-diagonal, difference between $μ\_{2}$ $\left(Δμ\_{2}\right)$ for each shark in the lower off-diagonal.

# supplemental Figure



The relative density of time per subsurface movement for each individual shark.

# supplemental Figure



The $Gap\_{w}$ statistic for 1 to 15 possible clusters of the dynamic time-warped Euclidean distances between shark subsurface movements. The red circle indicates the optimal number of clusters, $k$, determined using the first SE max criterion.

# Supplemental Figure



# Supplemental figure



The membership of each shark to a movement strategy and the clustering of those strategies relative to one another based on a hierarchical clustering of behavior metrics (maximum deployment depth; $λ\_{2}$, percent bottom time; $μ\_{2}$, mean depth of the second mixture component; subsurface movement rate, and the proportion of subsurface movements in each shape cluster).

# supplemental figure 6



Residuals of the Dirichlet regression describing the proportion of time in each movement shape cluster as a function of the diel (left) and tidal (right) time periods. Membership to the cluster was artificially jittered to ease visualization.

# Supplemental Figure 7



Water column temperature below 150 m (<150), between 150 and 100 m (150-100), between 100 and 50 m (100-50), and between 50 and 0 m (>50) as a function of thermocline depth (A) and Julian day (B).