*Supplementary Tables*

*Gleiss, Potvin & Goldbogen (2017)* Physical trade-offs shape the evolution of buoyancy control in sharks. *Proceedings of the Royal Society B*

**Table S1 Details of all species used in our phylogenetic analysis.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Species** | | **Abbreviation** | **n\*** | **Standard Length (cm)** | **Mass (kg)** | **Overall Tissue Density (kg/m3)** | **Liver Mass (kg)** | **Liver Density**  **(kg/m3)** |
| ***Carcharhinus acronatus*** | CA | | 2 | 77.7 ± 7.85 | 5.5 ± 1.5 | 1078 ± 1 | 0.24 ± 0.03 | 996 ± 6 |
| ***Carcharhinus brevipinna*** | CB | | 1 | 153.13 | 44.2 | 1087 | 1.86 | 1040 |
| ***Carcharhinus falciformis*** | CF | | 2 | 73.85 ± 12.72 | 5.13 ± 1.93 | 1076 ± 2 | 0.2 ± 0.06 | 1010 ± 14 |
| ***Carcharhinus leucas*** | CL | | 6 | 178.24 ± 17.51 | 119.63 ± 36.92 | 1062 ± 6 | 13.2 ± 8.0 | 965 ±29 |
| ***Carcharhinus limbatus*** | CLi | | 1 | 133.44 | 26.8 | 1081 | 1.43 | 973 |
| ***Sphyrna mokarran*** | SMo | | 1 | 217.67 | 141 | 1074 | 13.4 | 963 |
| ***Carcharhinus obscurus*** | CO | | 2 | 231.26 ±13.45 | 213.6 ± 34.9 | 1048 ± 0.007 | 38.3 ± 15.7 | 945 ± 6 |
| ***Carcharhinus plumbeus*** | CP | | 7 | 173.84 ± 4.97 | 62.16 ± 5.45 | 1066 ± 5 | 7.83 ± 2.98 | 956 ± 11 |
| ***Rhizoprionodon terranovea*** | RT | | 1 | 45.72 | 0.98 | 1079 | 0.04 | 1020 |
| ***Centrophorus squomosus*** | CS | | 2 | 101.27 | 8.09 ± 0.79 | 1024 ± 1 | 1.73 ± 0.17 | 890 ± 9 |
| ***Centroscymnus coelolepis*** | CC | | 2 | 68.52 ± 9.33 | 4.23 ± 1.46 | 1023 ± 2 | 1.17 ± 0.54 | 906 ± 3 |
| ***Cephaloscyllium isabellum*** | CI | | 1 | 47.71 | 0.85 | 1059 | 0.04 | 1000 |
| ***Cephaloscyllium ventriosum*** | CV | | 1 | 45.98 | 1.52 | 1071 | 0.11 | 1036 |
| ***Cetorhinus maximus*** | CM | | 1 | 591.4 | 1677.98 | 1032 | 254.24 | 939 |
| ***Daliatis licha*** | DL | | 1 | 90.65 | 18.02 | 1026 | 3.56 | 905 |
| ***Deania calcea*** | DC | | 1 | 73.89 | 2.64 | 1025 | 0.54 | 890 |
| ***Echinorhinus brucus*** | EB | | 1 | 120.6 | 36.32 | 1027 | 5.43 | 1027 |
| ***Etmopterus princeps*** | EP | | 1 | 49.6 | 1.22 | 1026 | 0.24 | 891 |
| ***Galeocerdo cuvier*** | GC | | 13 | 192.21 ± 65.79 | 73.37 ± 126.97 | 1035 ± 11 | 7.59 ± 22.12 | 956 ± 36 |
| ***Galeorhinus galeus*** | GG | | 4 | 47.39 ± 11.02 | 0.83 ± 0.54 | 1062 ± 5 | 0.06 ± 0.05 | 952 ± 38 |
| ***Lamna nasus*** | LN | | 3 | 128.9 ± 21.6 | 33.67 ± 14.37 | 1059 ± 10 | 2.13 ± 0.86 | 1006 ± 12 |
| ***Mustelus antarcticus*** | MA | |  | 43.79 | 0.58 | 1062 | 0.03 | 1025 |
| ***Mustelus asterias*** | MAs | | 4 | 61.38 ± 17.71 | 1.32 ± 0.95 | 1069 ± 4 | 0.08 ± 0.82 | 999 ± 20 |
| ***Mustelus norrisi*** | MN | | 2 | 51.02 ± 0.00 | 0.89 ± 0.014 | 1076 ± 0 | 0.05 ± 0.00 | 952 ± 23 |
| ***Negaprion brevirostris*** | NB | | 5 | 211.9 ± 7.01 | 110.56 ± 15.67 | 1066 ± 6 | 10.29 ± 4.84 | 952 ± 22 |
| ***Prionace glauca*** | PG | | 6 | 131.28 ± 29.07 | 21.26 ± 13.98 | 1051 ± 9 | 1.89 ± 1.55 | 988 ± 21 |
| ***Scyliorhinus canicula*** | SC | | 15 | 44.86 ± 6.77 | 0.51 ± 0.25 | 1075 ± 55 | 0.03 ± 0.03 | 996 ± 17 |
| ***Scyliorhinus stellaris*** | SS | | 1 | 81.13 | 4.36 | 1080 | 0.46 | 984 |
| ***Sphyrna tiburo*** | ST | | 2 | 55.79 ± 6.57 | 1.69 ± 0.43 | 1081 ± 5 | 0.04 ± 0.01 | 1035 ± 21 |
| ***Squalus acanthias*** | SA | | 6 | 66.77 ±12 | 2.2 ± 1.5 | 1055 ± 34 | 0.19 ± 0.15 | 975 ± 17 |
| ***Squatina squatina*** | SSq | | 5 | 70.05 ± 26.71 | 4.89 ± 4.85 | 1092 ± 9 | 0.15 ± 0.29 | 1041 ± 26 |
| ***Triakis semifasciata*** | TS | | 1 | 104 | 8.31 | 1070 | 0.48 | 1014 |

**Table S1 *contd.***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Volume (ml)** | **Liver Volume (ml)** | **Lean Volume (ml)** | **% Liver Volume** | **Lean Tissue Density (kg/m3)** | **Source** |
| ***Carcharhinus acronatus*** | 5096 ± 1430 | 240 ± 27 | 4855 ± 1402 | 4.72 ± 0.81 | 1082 ± 2 | [[1](#_ENREF_1)] |
| ***Carcharhinus brevipinna*** | 40674 | 1788 | 38885 | 4.4 | 1089 | [[1](#_ENREF_1)] |
| ***Carcharhinus falciformis*** | 4762 ± 1784 | 201 ± 62 | 4560 ±1722 | 4.3 ± 0.3 | 1079 ± 2 | [[1](#_ENREF_1)] |
| ***Carcharhinus leucas*** | 112770 ± 35334 | 13681 ± 8499 | 99088 ± 27771 | 11.27 ± 4.70 | 1076 ± 4 | [[1](#_ENREF_1)] |
| ***Carcharhinus limbatus*** | 24803 | 1469 | 23333 | 5.93 | 1087 | [[1](#_ENREF_1)] |
| ***Sphyrna mokarran*** | 131322 | 13914 | 117406 | 10.6 | 1087 | [[1](#_ENREF_1)] |
| ***Carcharhinus obscurus*** | 203941 ± 34789 | 40550 ± 16893 | 163390 ± 17895 | 19.49 ± 4.96 | 1073 ± 0 | [[1](#_ENREF_1)] |
| ***Carcharhinus plumbeus*** | 58337 ± 5242 | 8191 ± 3217 | 50145 ± 3333 | 13.86 ± 4.44 | 1084 ± 7 | [[1](#_ENREF_1)] |
| ***Rhizoprionodon terranovea*** | 905 | 39 | 865 | 4.35 | 1081 | [[1](#_ENREF_1)] |
| ***Centrophorus squomosus*** | 7903 ± 783 | 1946 ± 209 | 5957 ± 783 | 24.62 ± 0.20 | 1067 ± 2 | [[1](#_ENREF_1)] |
| ***Centroscymnus coelolepis*** | 4133 ± 1436 | 1294 ± 600 | 2839 ± 837 | 30.7 ± 3.81 | 1076 ± 8 | [[1](#_ENREF_1)] |
| ***Cephaloscyllium isabellum*** | 799 | 43 | 756 | 5.38 | 1062 | [[2](#_ENREF_2)] |
| ***Cephaloscyllium ventriosum*** | 1420 | 101 | 1319 | 7.13 | 1074 | [[3](#_ENREF_3)] |
| ***Cetorhinus maximus*** | 1625488 | 270789 | 1354698 | 16.66 | 1051 | [[3](#_ENREF_3)] |
| ***Daliatis licha*** | 17559 | 3927 | 13630 | 22.37 | 1061 | [[4](#_ENREF_4)] |
| ***Deania calcea*** | 2573 | 608 | 1964 | 23.64 | 1067 | [[4](#_ENREF_4)] |
| ***Echinorhinus brucus*** | 35382 | 5289 | 30092 | 14.95 | 1027 | [[3](#_ENREF_3)] |
| ***Etmopterus princeps*** | 1185 | 265 | 918 | 22.45 | 1065 | [[4](#_ENREF_4)] |
| ***Galeocerdo cuvier*** | 71481 ± 123744 | 7944 ± 24845 | 63536 ± 98992 | 11.11 ± 5.18 | 1061 ± 6 | [1] |
| ***Galeorhinus galeus*** | 786 ± 509 | 65 ± 49 | 719 ± 461 | 8.36 ± 1.83 | 1072 ± 7 | [[2](#_ENREF_2)] |
| ***Lamna nasus*** | 31800 ± 13774 | 2117 ± 871 | 29682 ± 12919 | 6.66 ± 0.43 | 1062 ± 10 | [[3](#_ENREF_3)] |
| ***Mustelus antarcticus*** | 543 | 24 | 517 | 4.59 | 1063 | [[2](#_ENREF_2)] |
| ***Mustelus asterias*** | 1232 ± 889 | 79 ± 84 | 1152 ± 804 | 6.48 ± 2.03 | 1074 ± 3 | [[3](#_ENREF_3)] |
| ***Mustelus norrisi*** | 823 ± 12 | 47 ± 0 | 775 ± 13 | 5.8 ± 0.17 | 1084 ± 1 | [[1](#_ENREF_1)] |
| ***Negaprion brevirostris*** | 103786 ± 15148 | 10806 ± 4928 | 92900 ± 11615 | 10.41 ± 3.62 | 1078 ± 5 | [[1](#_ENREF_1)] |
| ***Prionace glauca*** | 20234 ± 13392 | 1912 ± 1575 | 18321 ± 11864 | 9.45 ± 2.64 | 1057 ± 5 | [[3](#_ENREF_3)] |
| ***Scyliorhinus canicula*** | 475 ± 234 | 31 ± 33 | 443 ± 204 | 6.67 ± 2.76 | 1073 ± 5 | [[3](#_ENREF_3)] |
| ***Scyliorhinus stellaris*** | 4034 | 462 | 3570 | 11.48 | 1093 | [[3](#_ENREF_3)] |
| ***Sphyrna tiburo*** | 1562 ± 398 | 39 ± 14.63 | 1522 ± 383 | 2.53 ± 0.23 | 1083 ± 5 | [[1](#_ENREF_1)] |
| ***Squalus acanthias*** | 2067 ± 1444 | 215 ± 156 | 1851 ±1305 | 10.45 ± 2.44 | 1064 ± 4 | [[1](#_ENREF_1)] |
| ***Squatina squatina*** | 4481 ± 4480 | 140 ± 288 | 4340 ± 4200 | 3.13 ± 1.18 | 1093 ± 9 | [[3](#_ENREF_3)] |
| ***Triakis semifasciata*** | 7760 | 475 | 7285 | 6.12 | 1074 | Unpubl. data |

**Table S2 Minimum and maximum depth records used to calculate Median Depth of Occurrence (MDO)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Species** | **Min. Depth (m)** | **Max. Depth (m)** | **MDO (m)** | **N\*** | **Method\*** | **Source** |
| ***Carcharhinus acronatus*** | ***9*** | 64 | 36.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Carcharhinus brevipinna*** | ***0*** | 100 | 50 |  | Data-base | [[5](#_ENREF_5)] |
| ***Carcharhinus falciformis*** | ***0*** | 150 | 75 | 10, 13 | PSAT | [[6](#_ENREF_6),[7](#_ENREF_7)] |
| ***Carcharhinus leucas*** | ***0*** | 204.4 | 100 | 16, 18 | PSAT | [[8](#_ENREF_8),[9](#_ENREF_9)] |
| ***Carcharhinus limbatus*** | ***0*** | 30 | 15 |  | Data-base | [[5](#_ENREF_5)] |
| ***Sphyrna mokarran*** | ***1*** | 100 | 50.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Carcharhinus obscurus*** | ***0*** | 355 | 177.5 | 3 | PSAT | [[10](#_ENREF_10)] |
| ***Carcharhinus plumbeus*** | ***0*** | 287 | 143.5 | 8, 17 | PSAT | [[11](#_ENREF_11),[12](#_ENREF_12)] |
| ***Rhizoprionodon terranovea*** | ***0*** | 10 | 5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Centrophorus squomosus*** | ***600*** | 1600 | 1100 | 8 | PSAT | [[13](#_ENREF_13)] |
| ***Centroscymnus coelolepis*** | ***400*** | 2000 | 1200 |  | Data-base | [[5](#_ENREF_5)] |
| ***Cephaloscyllium isabellum*** | ***5*** | 690 | 347.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Cephaloscyllium ventriosum*** | ***5*** | 37 | 21 |  | Data-base | [[5](#_ENREF_5)] |
| ***Cetorhinus maximus*** | ***0*** | 1000 | 500 | 4, 2, 18 | PSAT | [[14-16](#_ENREF_14)] |
| ***Daliatis licha*** | ***300*** | 600 | 450 |  | Data-base | [[5](#_ENREF_5)] |
| ***Deania calcea*** | ***400*** | 1400 | 900 |  | Data-base | [[5](#_ENREF_5)] |
| ***Echinorhinus brucus*** | ***900*** | 350 | 625 |  | Data-base | [[5](#_ENREF_5)] |
| ***Etmopterus princeps*** | ***300*** | 2000 | 1150 |  | Data-base | [[5](#_ENREF_5)] |
| ***Galeocerdo cuvier*** | ***0*** | 1136 | 568 | 5, 9, 8 | PSAT | [[17-19](#_ENREF_17)] |
| ***Galeorhinus galeus*** | ***0*** | 600 | 300 | 9 | Archival Tags | [[20](#_ENREF_20)] |
| ***Lamna nasus*** | ***0*** | 700 | 350 | 4, 3 | PSAT | [[21](#_ENREF_21),[22](#_ENREF_22)] |
| ***Mustelus antarcticus*** | ***0*** | 80 | 40 |  | Data-base | [[5](#_ENREF_5)] |
| ***Mustelus asterias*** | ***0*** | 350 | 175 |  | Data-base | [[5](#_ENREF_5)] |
| ***Mustelus norrisi*** | ***3*** | 40 | 21.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Negaprion brevirostris*** | ***0*** | 50 | 25 |  | Data-base | [[5](#_ENREF_5)] |
| ***Prionace glauca*** | ***0*** | 1160 | 580 | 13, 3 | PSAT | [[23](#_ENREF_23),[24](#_ENREF_24)] |
| ***Scyliorhinus canicula*** | ***80*** | 100 | 90 |  | Data-base | [[5](#_ENREF_5)] |
| ***Scyliorhinus stellaris*** | ***20*** | 63 | 41.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Sphyrna tiburo*** | ***10*** | 25 | 17.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Squalus acanthias*** | ***0*** | 600 | 300 | 3 | PSAT | [[25](#_ENREF_25)] |
| ***Squatina squatina*** | ***5*** | 150 | 77.5 |  | Data-base | [[5](#_ENREF_5)] |
| ***Triakis semifasciata*** | ***6*** | 156 | 81 |  | Data-base | [[5](#_ENREF_5)] |
| \*N refers to the number of individuals tracked in the respective study, with each individual contributing between 1 and >180 days of depth data  \*\*Data-base records refer to species where no electronic tagging was available. These generally originate from large reference works [[e.g. see 26](#_ENREF_26)], which do not provide sample sizes. | | | | | | |
|  | | | | | | |

**Table S3 Scaling of liver and lean tissue based on three different models of character evolution along three phylogenetic trees with different branch length transformations and one model ignoring phylogenetic dependence.** Naylor’s branch lengths refer to empirically determined molecular branch lengths, whereas Grafen’s and Punctuated models used arbitrary branch-lengths and the topology of Naylor. Λ denotes the amount of phylogenetic signal, with λ = 0 suggesting phylogenetic independence and λ=1 if the traits have evolved as expected under Brownian Motion. Models were compared on their basis of their small sample corrected AICc.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | | **Naylor’s** | | | | | | | **Grafen’s** | | | | | | | | **Punctuated** | | | | | | | | |
|  | |  | | **AICc** | **Exponent** | | **Intercept** | | **λ \*** | | **AICc** | | **Exponent** | | **Intercept** | | **λ \*** | | **AICc** | | **Exponent** | | **Intercept** | | | **λ \*** |
|  | | log(SL) ~ log(Vliver) | | 18.96 | 3.77 ± 0.20 | | -4.46 ± 0.42 | | 0.8 | | 20.91 | | 3.73 **±** 0.21 | | -4.47 **±** 0.44 | | 0.5 | | 20.28 | | 3.77 **±** 0.20 | | 4.51 **±** 0.42 | | | 0.6 |
|  | | log(SL) ~ log(Vlean) | | -18.81 | 3.07 ± 0.11 | | -2.16 ± 0.22 | | 0.9 | | -14.14 | | 3.12 **±** 0.11 | | -2.39 **±** 0.22 | | 0.2 | | -17.03 | | 3.08 **±** 0.11 | | 2.21 **±** 0.23 | | | 0.7 |
|  |  | |  | | |  | |  | |  | |  | |  | |  | |  | |  | |  | |  |

**Table S4 Summary of all analysis over the three different branch lengths for the evolution of tissue volume, buoyancy and Median Depth of Occurrence (MDO).** Naylor’s branch lengths refer to empirically determined molecular branch lengths, Grafen’s and Punctuated refer to the models ran with arbitrary branch-lengths, while retaining Naylor’s topology. Models were compared on their basis of their small sample corrected AICc.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Naylor’s** | |  | **Grafen’s** | |  | **Punctuated** | |  | |
|  |  | **AICc** | **Parameter Estimate** | **λ** | **AICc** | **Parameter Estimate** | **λ** | **AICc** | **Parameter Estimate** | **λ** | |
|  | Density ~ VLiver | | | 6.1 | -6.93 ± 1.36\*\*\* | 0.77 | 4.9 | -8.87 ± 2.27\*\*\* | 0.46 | 4.9 | -8.78 ± 2.33\*\*\* | 0.59 | |
| Density ~1 | | | 14.3 |  | 1.03 | 18.5 |  | 0.41 | 17.8 |  | 0.58 | |
|  | Density ~ VLean | | | -23.2 | 0.25 ± 1.58 | 0.85 | -18.3 | 0.99 ± 1.51 | 0.22 | -20.8 | 0.00 ± 1.52 | 0.68 | |
| Density ~ 1 | | | -25.8 |  | 0.85 | -17.8 |  | 0.23 | -20.8 |  | 0.68 | |
|  | VLiver ~ VLean | | | 5.8 | 1.07 ± 0.28\*\* | 0.93 | 13.3 | 0.91 ± 0.27\* | 0.69 | 9.5 | 1.11 ± 0.28\*\*\* | 0.82 | |
| VLiver ~ 1 | | | 14.3 |  | 0.76 | 18.5 |  | 0.46 | 17.8 |  | 0.58 | |
|  | log (MDO) ~ Density | | | 77.1 | -58.32 ± 5.72\*\*\* | -0.11 | 79.1 | -60.96 ± 5.84\*\*\* | -0.06 | 79.0 | -60.94 ± 5.88 \*\*\* | -0.08 | |
|  | Density ~1 | | | 112.8 |  | 0.59 | 111.36 |  | 0.62 | 112 |  | 0.6 | |
| \*<0.05 \*\*<0.005 \*\*\*<0.0005 | | | | | | | | | | |

**Table S5. Drag in accelerated motions (eqns. 8 – 11). Surge time *ns = 1.0.***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SL (m) | FR | W (N) | CS (m/s, eqn. 6) | k | fpara | find | far | a (eqn. 7) [m/s2 (g’s)] | <Dtot> (N) |
| 1.0 | 6.3 | 0.4 | 0.75 | 0.045 | 0.00421 | 0.00004 | 0.00169 | 0.84 (0.086) | 1.70 |
| 1.0 | 7.0 | 3.4 | 0.75 | 0.035 | 0.00368 | 0.00108 | 0.00106 | 0.84 (0.086) | 1.68 |
| 2.0 | 6.3 | 3.21 | 1.11 | 0.045 | 0.00340 | 0.00000 | 0.00169 | 0.92 (0.094) | 12.78 |
| 2.0 | 7.0 | 27.4 | 1.11 | 0.035 | 0.00298 | 0.00093 | 0.00106 | 0.92 (0.094) | 12.48 |
| 4.0 | 6.3 | 25.7 | 1.59 | 0.045 | 0.00273 | 0.00000 | 0.00169 | 0.95 (0.097) | 92.30 |
| 4.0 | 7.0 | 218.0 | 1.59 | 0.035 | 0.00241 | 0.00087 | 0.00106 | 0.95 (0.097) | 89.98 |
| 7.0 | 6.3 | 137.8 | 2.10 | 0.045 | 0.00231 | 0.00000 | 0.00169 | 0.95 (0.097) | 446.63 |
| 7.0 | 7.0 | 1168.3 | 2.10 | 0.035 | 0.00204 | 0.00087 | 0.00106 | 0.95 (0.097) | 440.11 |

ρw = 1025kg/m3, ν = 0.00000115m2/s, INT = - 0.25 (Ryan et al., 2015), δ = 0 and φ = 0.95

**Table S6. Drag in accelerated motions (eqns. 8 – 11). Surge time *ns = 0.2.***

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *SL (m)* | *FR* | *W (N)* | *CS (m/s, eqn. 6)* | *k* | *fpara* | *find* | *far* | *a (eqn. 7) [m/s2 (g’s)]* | *<Dtot> (N)* |
| *1.0* | *6.3* | *0.4* | *0.75* | *0.045* | *0.00421* | *0.00004* | *0.00845* | *4.20 (0.430)* | *3.66* |
| *1.0* | *7.0* | *3.4* | *0.75* | *0.035* | *0.00368* | *0.00108* | *0.00530* | *4.20 (0.430)* | *2.90* |
| *2.0* | *6.3* | *3.21* | *1.11* | *0.045* | *0.00340* | *0.00000* | *0.00845* | *4.60 (0.470)* | *29.74* |
| *2.0* | *7.0* | *27.4* | *1.11* | *0.035* | *0.00298* | *0.00093* | *0.00530* | *4.60 (0.470)* | *23.12* |
| *4.0* | *6.3* | *25.7* | *1.59* | *0.045* | *0.00273* | *0.00003* | *0.00845* | *4.74 (0.483)* | *232.4* |
| *4.0* | *7.0* | *218.0* | *1.59* | *0.035* | *0.00240* | *0.00086* | *0.00532* | *4.74 (0.483)* | *177.48* |
| *7.0* | *6.3* | *137.8* | *2.10* | *0.045* | *0.00231* | *0.00003* | *0.00845* | *4.72 (0.482)* | *1194.9* |
| *7.0* | *7.0* | *1168.3* | *2.10* | *0.035* | *.00204* | *0.00087* | *0.00532* | *4.72 (0.482)* | *911.10* |

*ρw = 1025kg/m3, ν = 0.00000115m2/s, INT = - 0.25 (Ryan et al., 2015), δ = 0 and φ = 0.95*

**Table S7 Drag in steady state motions for a range of body sizes (eqns. 8 – 11).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SL (m)** | **FR** | **W (N)** | **CS** (m/s, eqn. 6) | **k** | **fpara** | **find** | **far** | **a** (eqn. 7) [m/s2 (g’s)] | **<Dtot>** (N) |
| 1.0 | *6.3* | *0.4* | *0.75* | *0.* | *0.00198* | *0.00008* | *0.00000* | *0.00 (0.000)* | *0.59* |
| 1.0 | *7.0* | *3.4* | *0.75* | *0.* | *0.00173* | *0.00216* | *0.00000* | *0.00 (0.000)* | *1.12* |
| 2.0 | *6.3* | *3.21* | *1.11* | *0.* | *0.00159* | *0.00000* | *0.00000* | *0.00 (0.000)* | *3.99* |
| 2.0 | *7.0* | *27.4* | *1.11* | *0.* | *0.00140* | *0.00186* | *0.00000* | *0.00 (0.000)* | *8.18* |
| 4.0 | *6.3* | *25.7* | *1.59* | *0.* | *0.00128* | *0.00006* | *0.00000* | *0.00 (0.000)* | *27.88* |
| 4.0 | *7.0* | *218.0* | *1.59* | *0.* | *0.00113* | *0.00172* | *0.00000* | *0.00 (0.000)* | *59.13* |
| 7.0 | *6.3* | *137.8* | *2.10* | *0.* | *0.00109* | *0.00006* | *0.00000* | *0.00 (0.000)* | *127.13* |
| 7.0 | *7.0* | *1168.3* | *2.10* | *0.* | *0.00096* | *0.00173* | *0.00000* | *0.00 (0.000)* | *297.90* |

*ρw = 1025kg/m3, ν = 0.00000115m2/s, INT = - 0.25 [*[*27*](#_ENREF_27)*], δ = 0 and φ = 0.95*

**References**

1. Baldridge Jr HD (1970) Sinking factors and average densities of Florida sharks as functions of liver buoyancy. Copeia: 744-754.

2. Smith MP (1975) The buoyancy of six New Zealand species of elasmobranch: University of Otago. 1-54 p.

3. Bone Q, Roberts BL (1969) The density of elasmobranchs. J Mar Biol Assoc UK 49: 913-937.

4. Corner E, Denton E, Forster G (1969) On the buoyancy of some deep-sea sharks. Proceedings of the Royal Society B: Biological Sciences 171: 415-429.

5. Froese R, Pauly D (2017) FishBase.

6. Musyl MK, Brill RW, Curran DS, Fragoso NM, McNaughton LM, et al. (2011) Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the central Pacific Ocean. Fishery Bulletin 109: 341-368.

7. Filmalter J, Cowley P, Forget F, Dagorn L (2015) Fine-scale 3-dimensional movement behaviour of silky sharks Carcharhinus falciformis associated with fish aggregating devices (FADs). Marine Ecology Progress Series 539: 207-223.

8. Brunnschweiler JM, Barnett A (2013) Opportunistic visitors: long-term behavioural response of bull sharks to food provisioning in Fiji. PLoS One 8: e58522.

9. Carlson J, Ribera M, Conrath C, Heupel M, Burgess G (2010) Habitat use and movement patterns of bull sharks Carcharhinus leucas determined using pop‐up satellite archival tags. Journal of fish biology 77: 661-675.

10. Rogers PJ, Huveneers C, Goldsworthy SD, Mitchell JG, Seuront L (2013) Broad‐scale movements and pelagic habitat of the dusky shark Carcharhinus obscurus off Southern Australia determined using pop‐up satellite archival tags. Fisheries Oceanography 22: 102-112.

11. Barnes CJ, Butcher PA, Macbeth WG, Mandelman JW, Smith SDA, et al. (2016) Movements and mortality of two commercially exploited carcharhinid sharks following longline capture and release off eastern Australia. Endangered Species Research 30: 193-208.

12. Conrath CL, Musick JA (2008) Investigations into depth and temperature habitat utilization and overwintering grounds of juvenile sandbar sharks, Carcharhinus plumbeus: the importance of near shore North Carolina waters. Environmental Biology of Fishes 82: 123-131.

13. Rodríguez-Cabello C, González-Pola C, Sánchez F (2016) Migration and diving behavior of Centrophorus squamosus in the NE Atlantic. Combining electronic tagging and Argo hydrography to infer deep ocean trajectories. Deep Sea Research Part I: Oceanographic Research Papers 115: 48-62.

14. Skomal GB, Zeeman SI, Chisholm JH, Summers EL, Walsh HJ, et al. (2009) Transequatorial migrations by basking sharks in the Western Atlantic Ocean. Current Biology 19: 1019-1022.

15. Sims DW, Southall EJ, Tarling GA, Metcalfe JD (2005) Habitat-specific normal and reverse diel vertical migration in the plankton-feeding basking shark. Journal of Animal Ecology 74: 755-761.

16. Gore MA, Rowat D, Hall J, Gell FR, Ormond RF (2008) Transatlantic migration and deep mid-ocean diving by basking shark. Biology Letters 4: 395-398.

17. Meyer CG, Papastamatiou YP, Holland KN (2010) A multiple instrument approach to quantifying the movement patterns and habitat use of tiger (Galeocerdo cuvier) and Galapagos sharks (Carcharhinus galapagensis) at French Frigate Shoals, Hawaii. Marine biology 157: 1857-1868.

18. Werry JM, Planes S, Berumen ML, Lee KA, Braun CD, et al. (2014) Reef-fidelity and migration of tiger sharks, Galeocerdo cuvier, across the Coral Sea. PLoS One 9: e83249.

19. Vaudo JJ, Wetherbee BM, Harvey G, Nemeth RS, Aming C, et al. (2014) Intraspecific variation in vertical habitat use by tiger sharks (Galeocerdo cuvier) in the western North Atlantic. Ecology and evolution 4: 1768-1786.

20. West GJ, Stevens JD (2001) Archival tagging of school shark, *Galeorhinus galeus*, in Australia: initial results. Environmental Biology of Fishes 60: 283-298.

21. Pade NG, Queiroz N, Humphries NE, Witt MJ, Jones CS, et al. (2009) First results from satellite-linked archival tagging of porbeagle shark, Lamna nasus: area fidelity, wider-scale movements and plasticity in diel depth changes. Journal of Experimental Marine Biology and Ecology 370: 64-74.

22. Saunders RA, Royer F, Clarke MW (2011) Winter migration and diving behaviour of porbeagle shark, *Lamna nasus*, in the Northeast Atlantic. ICES Journal of Marine Science: Journal du Conseil 68: 166-174.

23. Queiroz N, Humphries NE, Noble LR, Santos AM, Sims DW (2012) Spatial dynamics and expanded vertical niche of blue sharks in oceanographic fronts reveal habitat targets for conservation. PLoS One 7: e32374.

24. Stevens JD, Bradford RW, West GJ (2010) Satellite tagging of blue sharks (Prionace glauca) and other pelagic sharks off eastern Australia: depth behaviour, temperature experience and movements. Marine biology 157: 575-591.

25. Sulikowski JA, Galuardi B, Bubley W, Furey NB, Driggers III WB, et al. (2010) Use of satellite tags to reveal the movements of spiny dogfish Squalus acanthias in the western North Atlantic Ocean. Marine Ecology Progress Series 418: 249-254.

26. Compagno LJ (2001) Sharks of the world: an annotated and illustrated catalogue of shark species known to date: Food & Agriculture Org.

27. Ryan LA, Meeuwig JJ, Hemmi JM, Collin SP, Hart NS (2015) It is not just size that matters: shark cruising speeds are species-specific. Marine Biology 162: 1307-1318.