Supplementary Material

# Supplementary Figures and Tables

## Supplementary Tables

**Supplementary Table 1.** Breakdown of sightings per reproductive class per year. Whales can be represented multiple times in the annual numbers within each reproductive class depending on the number of body condition determinations for that individual.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Reproductive class** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| **Calf** | 0 | 1 | 3 | 0 | 1 | 6 | 19 | 4 | 7 | 3 | 4 | 2 | 0 | 0 |
| **LF** | 0 | 7 | 3 | 0 | 2 | 8 | 35 | 3 | 7 | 5 | 4 | 2 | 0 | 0 |
| **Other** | 106 | 342 | 339 | 160 | 170 | 451 | 236 | 80 | 358 | 373 | 149 | 263 | 272 | 175 |
| **Total** | **106** | **350** | **405** | **160** | **173** | **465** | **290** | **87** | **372** | **381** | **157** | **267** | **272** | **175** |

*LF, lactating female.*

**Supplementary Table 2.** Description of the three possible scores for body photo quality and proportion visible.

|  |  |  |
| --- | --- | --- |
| **Score** | **Photo quality description** | **Proportion visible description** |
| **1** | Excellent quality- the whale was clearly able to be seen | Good view forward of the dorsal fin |
| **2** | Good quality- a slightly fuzzy image, but details on the whale were still able to be seen | More limited view forward of the dorsal fin (50% reduction in visible area compared to scores of 1) |
| **3** | Fair quality- details on the whale were difficult to see | Very limited view forward of the dorsal fin (75% reduction in visible area compared to scores of 1) |

**Supplementary Table 3.** Indices and their sources used in model creation.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Abbreviation** | **Spatial Area Covered** | **Months Covered** | **Source** |
| Biologically Effective Upwelling Transport Index | BEUTI | 31-39N | Jan-Dec | mjacox.com/upwelling-indices/ |
| Catch Per Unit Effort (krill) | CPUE | 32-42N | Jan | oceanview.pfeg.noaa.gov/whale\_indices/ |
| Habitat Compression Index | HCI | 35-40N | Jun-Oct | oceanview.pfeg.noaa.gov/whale\_indices/ |
| Length of Upwelling Season | LUSI | 30-39N | Length of upwelling season | Derived from oceanview.pfeg.noaa.gov/products/upwelling/bakun |
| Oceanic Niño Index | ONI | 5N-5S | Jan-Dec | oceanview.pfeg.noaa.gov/whale\_indices/ |
| Pacific Decadal Oscillation | PDO | 20-70N | Jan-Dec | [ncdc.noaa.gov/teleconnections/pdo/](https://www.ncdc.noaa.gov/teleconnections/pdo/) |
| Total Upwelling Magnitude Index | TUMI | 30-39N | Length of upwelling season | Derived from oceanview.pfeg.noaa.gov/products/upwelling/bakun |

**Supplementary Table 4.** All models tested with no temporal lag. Models are listed from lowest AIC to highest. The model used in the final analysis is shown in bold.

|  |  |  |  |
| --- | --- | --- | --- |
| **Model (no lag)** | **K** | **AIC** | **RMSE** |
| **Score~ RepClass \* LUSI + BestProp + PDO.Value + (1|Year) + (1|ID)** | **14** | **8442.150** | **1.313** |
| Score~ RepClass + BestProp + PDO.Value + (1|Year) + (1|ID) | 11 | 8452.742 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + BEUTI + (1|Year) + (1|ID) | 12 | 8447.625 | 1.314 |
| Score~ RepClass + BestProp + HCI + (1|Year) + (1|ID) | 11 | 8452.952 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + LUSI + (1|Year) + (1|ID) | 12 | 8450.362 | 1.314 |
| Score~ RepClass + BestProp + ONI + (1|Year) + (1|ID) | 11 | 8457.652 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + BEUTI + LUSI + (1|Year) + (1|ID) | 13 | 8447.620 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + CPUE + (1|Year) + (1|ID) | 12 | 8453.727 | 1.314 |
| Score~ RepClass + BestProp + PDO + (1|Year) + (1|ID) | 11 | 8458.583 | 1.314 |
| Score~ RepClass + BestProp + HeatWave + (1|Year) + (1|ID) | 11 | 8458.583 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + BEUTI + CPUE + (1|Year) + (1|ID) | 11 | 8449.569 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + BEUTI + CPUE + LUSI + (1|Year) + (1|ID) | 14 | 8447.913 | 1.314 |
| Score~ RepClass + BestProp + ONI + BEUTI + (1|Year) + (1|ID) | 12 | 8458.651 | 1.314 |
| Score~ RepClass + BestProp + ONI + LUSI + (1|Year) + (1|ID) | 12 | 8459.127 | 1.314 |
| Score~ RepClass + BestProp + ONI + CPUE + (1|Year) + (1|ID) | 12 | 8459.378 | 1.314 |
| Score~ RepClass \* BEUTI + BestProp + PDO.Value + LUSI + (1|Year) + (1|ID) | 15 | 8451.598 | 1.314 |
| Score~ RepClass \* PDO.Value + BestProp + BEUTI + CPUE + LUSI + (1|Year) + (1|ID) | 16 | 8450.792 | 1.314 |
| Score~ RepClass + BestProp + PDO.Value + TUMI + (1|Year) + (1|ID) | 12 | 8749.448 | 1.359 |
| Score~ RepClass + BestProp + PDO.Value + BEUTI + TUMI + (1|Year) + (1|ID) | 13 | 8751.407 | 1.359 |
| Score~ RepClass + BestProp + PDO.Value + TUMI + LUSI + (1|Year) + (1|ID) | 13 | 8751.427 | 1.359 |
| Score~ RepClass + BestProp + PDO.Value + TUMI + CPUE + (1|Year) + (1|ID) | 13 | 8751.447 | 1.359 |
| Score~ RepClass + BestProp + PDO.Value + TUMI + CPUE + LUSI + (1|Year) + (1|ID) | 14 | 8753.385 | 1.359 |
| Score~ RepClass + BestProp + ONI + TUMI + (1|Year) + (1|ID) | 12 | 8763.749 | 1.359 |

*Score, body condition score; RepClass, reproductive class (calf, lactating female, or other); BestProp, proportion of whale seen in best image; BEUTI, Biologically Effective Upwelling Transport Index; CPUE, Catch Per Unit Effort (krill); HCI, Habitat Compression Index; HeatWave, presence or absence of a heatwave; LUSI, Length of Upwelling Season; ONI, Oceanic Niño Index; PDO, Pacific Decadal Oscillation (positive or negative); PDO.Value, Pacific Decadal Oscillation value; TUMI, Total Upwelling Magnitude Index.*

**Supplementary Table 5.** All models tested with a one-year temporal lag for environmental indices. Models are listed from lowest AIC to highest. The models used in the final analysis are shown in bold.

|  |  |  |  |
| --- | --- | --- | --- |
| **Model (1-year lag)** | **K** | **AIC** | **RMSE** |
| **Score~ RepClass + BestProp + Lag1PDO +** (1|Year) + (1|ID) | **11** | **8453.292** | **1.314** |
| **Score~ RepClass + BestProp + Lag1HeatWave +** (1|Year) + (1|ID) | **11** | **8453.292** | **1.314** |
| Score~ RepClass + BestProp + Lag1PDO.Value + (1|Year) + (1|ID) | 11 | 8454.399 | 1.314 |
| Score~ RepClass + BestProp + Lag1HCI + (1|Year) + (1|ID) | 11 | 8456.582 | 1.314 |
| Score~ RepClass + BestProp + Lag1ONI + (1|Year) + (1|ID) | 11 | 8456.925 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO + Lag1BEUTI + (1|Year) + (1|ID) | 12 | 8454.412 | 1.314 |
| Score~ RepClass + BestProp + Lag1HeatWave + Lag1BEUTI + (1|Year) + (1|ID) | 12 | 8454.412 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO.Value + Lag1CPUE + (1|Year) + (1|ID) | 12 | 8454.599 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO + Lag1LUSI + (1|Year) + (1|ID) | 12 | 8455.047 | 1.314 |
| Score~ RepClass + BestProp + Lag1HeatWave + Lag1LUSI + (1|Year) + (1|ID) | 12 | 8455.047 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO + Lag1CPUE + (1|Year) + (1|ID) | 12 | 8455.291 | 1.314 |
| Score~ RepClass + BestProp + Lag1HeatWave + Lag1CPUE + (1|Year) + (1|ID) | 12 | 8455.291 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO.Value + Lag1BEUTI + (1|Year) + (1|ID) | 12 | 8456.112 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO.Value + Lag1LUSI + (1|Year) + (1|ID) | 12 | 8456.398 | 1.314 |
| Score~ RepClass \* Lag1PDO + BestProp + (1|Year) + (1|ID) | 13 | 8456.509 | 1.314 |
| Score~ RepClass \* Lag1HeatWave + BestProp + (1|Year) + (1|ID) | 13 | 8456.509 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO.Value + Lag1CPUE + Lag1LUSI + (1|Year) + (1|ID) | 13 | 8456.192 | 1.314 |
| Score~ RepClass \* Lag1PDO.Value + BestProp + (1|Year) + (1|ID) | 13 | 8457.816 | 1.314 |
| Score~ RepClass \* Lag1CPUE + BestProp + Lag1PDO.Value + (1|Year) + (1|ID) | 14 | 8456.832 | 1.314 |
| Score~ RepClass + BestProp + Lag1PDO.Value + Lag1TUMI + (1|Year) + (1|ID) | 12 | 8780.138 | 1.360 |
| Score~ RepClass + BestProp + Lag1PDO + Lag1TUMI + (1|Year) + (1|ID) | 12 | 8779.372 | 1.360 |
| Score~ RepClass + BestProp + Lag1HeatWave + Lag1TUMI + (1|Year) + (1|ID) | 12 | 8779.372 | 1.360 |

*Score, body condition score; RepClass, reproductive class (calf, lactating female, or other); BestProp, proportion of whale seen in best image; BEUTI, Biologically Effective Upwelling Transport Index; CPUE, Catch Per Unit Effort (krill); HCI, Habitat Compression Index; HeatWave, presence or absence of a heatwave; LUSI, Length of Upwelling Season; ONI, Oceanic Niño Index; PDO, Pacific Decadal Oscillation (positive or negative); PDO.Value, Pacific Decadal Oscillation value; TUMI, Total Upwelling Magnitude Index.*

**Supplementary Table 6.** All models tested with a two-year temporal lag for environmental indices. Models are listed from lowest AIC to highest. The model used in the final analysis is shown in bold.

|  |  |  |  |
| --- | --- | --- | --- |
| **Model (2-year lag)** | **K** | **AIC** | **RMSE** |
| **Score~ RepClass + BestProp + Lag2HeatWave +** | **11** | **8454.832** | **1.314** |
| Score~ RepClass + BestProp + Lag2PDO + | 11 | 8457.644 | 1.314 |
| Score~ RepClass \* Lag2HeatWave + BestProp + | 13 | 8453.119 | 1.314 |
| Score~ RepClass + BestProp + Lag2PDO.Value + | 11 | 8459.332 | 1.314 |
| Score~ RepClass + BestProp + Lag2HCI + | 11 | 8459.464 | 1.314 |
| Score~ RepClass + BestProp + Lag2ONI + | 11 | 8459.553 | 1.314 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2BEUTI + | 12 | 8456.734 | 1.314 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2LUSI + | 12 | 8456.666 | 1.314 |
| Score~ RepClass + BestProp + Lag2PDO + Lag2LUSI + | 12 | 8458.622 | 1.314 |
| Score~ RepClass + BestProp + Lag2PDO + Lag2BEUTI + | 12 | 8459.644 | 1.314 |
| Score~ RepClass + BestProp + Lag2PDO.Value + Lag2BEUTI + | 12 | 8461.321 | 1.314 |
| Score~ RepClass + BestProp + Lag2PDO.Value + Lag2LUSI+ | 12 | 8461.259 | 1.314 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2BEUTI + Lag2CPUE + | 11 | 8458.738 | 1.314 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2LUSI + Lag2CPUE + | 13 | 8458.629 | 1.314 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2BEUTI + Lag2LUSI + | 13 | 8458.645 | 1.314 |
| Score~ RepClass \* Lag2LUSI + BestProp + Lag2HeatWave +  | 14 | 8458.812 | 1.314 |
| Score~ RepClass \* Lag2BEUTI + BestProp + Lag2HeatWave + | 14 | 8460.177 | 1.314 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2TUMI + | 13 | 8794.851 | 1.363 |
| Score~ RepClass + BestProp + Lag2HeatWave + Lag2TUMI + Lag2LUSI + | 13 | 8795.469 | 1.363 |
| Score~ RepClass + BestProp + Lag2PDO + Lag2TUMI + | 12 | 8799.206 | 1.363 |
| Score~ RepClass + BestProp + Lag2PDO.Value + Lag2TUMI + | 12 | 8800.338 | 1.363 |

*Score, body condition score; RepClass, reproductive class (calf, lactating female, or other); BestProp, proportion of whale seen in best image; BEUTI, Biologically Effective Upwelling Transport Index; CPUE, Catch Per Unit Effort (krill); HCI, Habitat Compression Index; HeatWave, presence or absence of a heatwave; LUSI, Length of Upwelling Season; ONI, Oceanic Niño Index; PDO, Pacific Decadal Oscillation (positive or negative); PDO.Value, Pacific Decadal Oscillation value; TUMI, Total Upwelling Magnitude Index.*

**Supplementary Table 7.** The estimated parameters for each variable in the most parsimonious model of blue whale body condition. Rows shown in bold indicate significant effects; asterisks indicate the level of significance. RepClassLF, lactating females; RepClassother, general whale population; LUSI, length of the upwelling season; BestProp.L, the proportion of image seen (linear); BestProp.Q, the proportion of image seen (quadratic); BestProp.C, the proportion of image seen (cubic); PDO.Value, the PDO value; RepClassLF:LUSI, the interaction between lactating females and LUSI; RepClassother:LUSI, the interaction between the general population and LUSI.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Coefficients** | **Estimate** | **Standard Error** | **Z Value**  | **P value** |
| **RepClassLF** | **-42.77** | **18.26** | **-2.34** | **0.019 \***  |
| RepClassother | 2.37 | 7.76 | 0.31 | 0.760 |
| LUSI | 0.02 | 0.02 | 1.06 | 0.290 |
| **BestProp.L** | **-1.13** | **0.13** | **-8.66** | **< 2e-16 \*\*\*** |
| **BestProp.Q** | **0.58** | **0.10** | **5.56** | **2.64e-08 \*\*\*** |
| BestProp.C | -0.12 | 0.07 | -1.72 | 0.086 |
| **PDO.Value** | **0.48** | **0.12** | **4.05** | **5.10e-05 \*\*\*** |
| **RepClassLF:LUSI** | **0.15** | **0.06** | **2.58** | **0.010 \*\*** |
| RepClassother:LUSI | -0.002 | 0.02 | -0.08 | 0.933 |
| Year (intercept) | 0.14 | 0.37 |  |  |