Supplemental material for

# Multi-species telemetry quantifies current and future efficacy of a remote marine protected area

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This supplemental material contains the following:

**Figure S8**: Habitat suitability for yellowfin tuna, calculated for three model types and three pseudo-absence types.

**Figure S9**: Habitat suitability for sooty tern, calculated for three model types and three pseudo-absence types.

**Figure S10**: Habitat suitability for great frigatebird, calculated for three model types and three pseudo-absence types.

**Figure S11**: Habitat suitability for red-footed booby, calculated for three model types and three pseudo-absence types.

**Figure S12**: Habitat suitability for melon-headed whale, calculated for three model types and three pseudo-absence types.

**Figure S13**: Habitat suitability for bottlenose dolphin, calculated for three model types and three pseudo-absence types.

## Text S1

**Species distribution modeling approaches**: Models that used background sampling and boosted regression trees consistently returned the best model fits and had the highest predictive skill for all species except sooty terns (**Table S2, S3**). The best fitting models resulted in distinct regions of high (>0.67) and low (<0.3) habitat suitability, whereas poorer fitting models corresponded to moderate habitat suitability (0.5) that was relatively homogenous throughout the model extents (**Figures S6–S13**). Homogenous moderate habitat suitability was consistently prominent among the CRW pseudo-absences, especially when combined with GLMMs. Two temporal resolutions were used to construct CRW pseudo-absences: daily median locations and CRW at the original resolution of the tag; the latter approach enabled larger sample sizes. However, the original resolution-CRW resulted in more homogenous moderate habitat suitability than the daily resolution-CRW, and model results were similar between BRT, GAMM, and GLMM within this pseudo-absence type (e.g., **Figure S10**). Environmental dissimilarity, represented by Bhattacharyya coefficients, was slightly higher for CRW pseudo-absences than background pseudo-absences (**Table S2**). These differences were relatively small, and visually, the contrast between high and low habitat suitability was most distinct for background pseudo-absences (**Figures S6–S13**).

# Table S1

**Table S1**: Summary of Global Position Estimator 3 (GPE3) model scores and associated speeds for Wildlife Computers MiniPAT-348 tags. Dash indicates speed threshold was not tested for that species.

| | **Mean (± SD) model score** | | | |
|---|---|---|---|---|
| **Species** | Blue marlin | Grey reef shark | Reef manta ray | Yellowfin tuna |
| **Speed threshold (m $s^{-1}$)** | (n=1) | (n=6) | (n=4) | (n=9) |
| 0.5 | – | 77.6 ± 3.8 | – | – |
| 0.75 | – | 78.7 ± 3.1 | – | – |
| 1.0 | – | 78.3 ± 3.0 | – | 51.3 ± 12.2 |
| 1.25 | – | 77.0 ± 4.3 | – | – |
| 1.5 | 77.0 | 77.0 ± 4.2 | 50.1 ± 16.6 | 55.1 ± 11.2 |
| 1.75 | – | 77.1 ± 4.0 | – | – |
| 2.0 | 77.9 | 77.0 ± 3.8 | 50.6 ± 16.5 | 55.8 ± 11.4 |
| 2.25 | – | 77.0 ± 3.7 | – | – |
| 2.5 | 78.0 | 76.9 ± 3.7 | 51.7 ± 16.0 | 55.9 ± 12.5 |
| 2.75 | – | 76.9 ± 3.6 | – | – |
| 3.0 | 78.0 | 76.8 ± 3.6 | 52.4 ± 15.5 | 56.9 ± 11.7 |

## Table S2

**Table S2**: Model predictive skill statistics summary. The top three model metrics per species are bolded. Abbreviations: PA: pseudo-absence; BA: Bhattacharyya coefficient; AUC: area under the receiver operator curve; TSS: true test statistic; BRT: boosted regression tree; GAMM: generalized additive mixed model; GLMM: generalized linear mixed model.

| Species | PA-type | Temporal res. | Mean BA | Model type | $R^2$ | AUC | TSS |
|---|---|---|---|---|---|---|---|
| Reef manta ray | Background | Daily | 0.90 | BRT | **0.79** | **0.91** | **0.77** |
| | | | | GAMM | 0.41 | 0.88 | 0.68 |
| | | | | GLMM | 0.34 | 0.86 | 0.63 |
| | CRW | Original | 0.93 | BRT | **0.72** | **0.90** | **0.69** |
| | | | | GAMM | 0.30 | 0.79 | 0.53 |
| | | | | GLMM | 0.13 | 0.69 | 0.40 |
| | CRW | Daily | 0.92 | BRT | **0.79** | **0.95** | **0.83** |
| | | | | GAMM | 0.41 | 0.86 | 0.63 |
| | | | | GLMM | 0.22 | 0.78 | 0.53 |
| Grey reef shark | Background | Daily | 0.86 | BRT | **0.65** | **0.91** | **0.76** |
| | | | | GAMM | **0.63** | **0.95** | **0.78** |
| | | | | GLMM | **0.47** | **0.91** | **0.72** |
| | CRW | Original | 0.96 | BRT | 0.33 | 0.80 | 0.47 |
| | | | | GAMM | 0.19 | 0.77 | 0.42 |
| | | | | GLMM | 0.09 | 0.69 | 0.31 |
| | CRW | Daily | 0.96 | BRT | 0.39 | 0.82 | 0.52 |
| | | | | GAMM | 0.17 | 0.74 | 0.39 |
| | | | | GLMM | 0.08 | 0.68 | 0.30 |
| Yellowfin tuna | Background | Daily | 0.91 | BRT | **0.66** | **0.89** | **0.70** |
| | | | | GAMM | 0.34 | **0.84** | **0.59** |
| | | | | GLMM | 0.21 | 0.78 | 0.52 |
| | CRW | Original | 0.94 | BRT | **0.53** | 0.83 | 0.55 |
| | | | | GAMM | 0.28 | 0.80 | 0.50 |
| | | | | GLMM | 0.10 | 0.69 | 0.36 |
| | CRW | Daily | 0.93 | BRT | **0.58** | **0.87** | **0.62** |
| | | | | GAMM | 0.24 | 0.77 | 0.51 |
| | | | | GLMM | 0.14 | 0.72 | 0.41 |
| Sooty tern | Background | Daily | 0.87 | BRT | **0.71** | 0.44 | 0.29 |
| | | | | GAMM | 0.13 | 0.42 | 0.32 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | GLMM | 0.09 | 0.48 | 0.36 |
| | CRW | Original | 0.88 | BRT | **0.65** | 0.41 | 0.25 |
| | | | | GAMM | 0.10 | 0.54 | 0.42 |
| | | | | GLMM | 0.10 | 0.58 | 0.42 |
| | CRW | Daily | 0.84 | BRT | **0.71** | **0.67** | **0.55** |
| | | | | GAMM | 0.29 | **0.59** | **0.47** |
| | | | | GLMM | 0.25 | **0.65** | **0.48** |
| Red-footed booby | Background | Daily | 0.80 | BRT | **0.81** | **0.90** | **0.76** |
| | | | | GAMM | 0.54 | **0.88** | **0.74** |
| | | | | GLMM | 0.34 | **0.85** | **0.63** |
| | CRW | Original | 0.94 | BRT | **0.58** | 0.78 | 0.52 |
| | | | | GAMM | 0.20 | 0.78 | 0.54 |
| | | | | GLMM | 0.20 | 0.78 | 0.54 |
| | CRW | Daily | 0.91 | BRT | **0.71** | 0.79 | 0.55 |
| | | | | GAMM | 0.32 | 0.81 | 0.55 |
| | | | | GLMM | 0.19 | 0.74 | 0.47 |
| Great frigatebird | Background | Daily | 0.89 | BRT | **0.67** | **0.90** | **0.70** |
| | | | | GAMM | 0.46 | 0.88 | 0.67 |
| | | | | GLMM | 0.36 | 0.86 | 0.62 |
| | CRW | Original | 0.98 | BRT | 0.27 | 0.60 | 0.23 |
| | | | | GAMM | 0.05 | 0.62 | 0.28 |
| | | | | GLMM | 0.04 | 0.62 | 0.28 |
| | CRW | Daily | 0.84 | BRT | **0.71** | **0.92** | **0.70** |
| | | | | GAMM | **0.54** | **0.91** | **0.70** |
| | | | | GLMM | 0.36 | 0.86 | 0.60 |
| Melon-headed whale | Background | Daily | 0.78 | BRT | **0.95** | **0.95** | **0.86** |
| | | | | GAMM | 0.73 | **0.94** | **0.83** |
| | | | | GLMM | 0.68 | **0.94** | **0.86** |
| | CRW | Original | 0.90 | BRT | **0.77** | 0.86 | 0.72 |
| | | | | GAMM | 0.32 | 0.79 | 0.57 |
| | | | | GLMM | 0.31 | 0.79 | 0.57 |
| | CRW | Daily | 0.86 | BRT | **0.86** | 0.93 | 0.82 |
| | | | | GAMM | 0.61 | 0.90 | 0.76 |
| | | | | GLMM | 0.48 | 0.90 | 0.78 |
| Bottlenose dolphin | Background | Daily | 0.73 | BRT | **0.99** | **0.99** | **0.94** |
| | | | | GAMM | **0.99** | **0.97** | **0.91** |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | GLMM | **0.99** | **0.98** | **0.93** |
| | CRW | Original | 0.92 | BRT | 0.48 | 0.52 | 0.30 |
| | | | | GAMM | 0.19 | 0.66 | 0.46 |
| | | | | GLMM | 0.06 | 0.47 | 0.28 |
| | CRW | Daily | 0.93 | BRT | 0.59 | 0.53 | 0.26 |
| | | | | GAMM | 0.19 | 0.80 | 0.64 |
| | | | | GLMM | 0.12 | 0.58 | 0.36 |

## Table S3

**Table S3**: Area under the curve (AUC) values from the receiver operator curves for the boosted regression tree (BRT) model and the mean AUC from each of the cross validation (CV) approaches.

| Species | AUC | | |
|---|---|---|---|
| | BRT model | 10-fold CV | Spatial block CV |
| Reef manta ray | 0.91 | 0.91 | 0.75 |
| Grey reef shark | 0.89 | 0.91 | 0.82 |
| Yellowfin tuna | 0.87 | 0.89 | 0.80 |
| Sooty tern | 0.65 | 0.44 | 0.85 |
| Red-footed booby | 0.93 | 0.90 | 0.89 |
| Great frigatebird | 0.86 | 0.90 | 0.83 |
| Melon-headed whale | 0.95 | 0.95 | 0.89 |
| Bottlenose dolphin | 0.99 | 0.99 | 0.89 |

## Table S4

**Table S4**: Climate models used in habitat suitability models with climate predictions from the Climate Model Intercomparison Project Phase 6 (CMIP6). Model names are structured as follows: (mip_era)s.%(activity_drs)s.%(institution_id)s.%(source_id)s.%(experiment_id)s.%(member_id)s.%(table_id)s.%(variable_id)s.%(grid_label)s. Within each model/experiment, all available members (which typically had different starting parameters) were used.

| **Variable** | **Variable ID** | **Climate scenario** | **Model (experiment) name** | **DOI** |
|---|---|---|---|---|
| Chlorophyll-*a* | chlpico | SSP-1-2.6 | CMIP.NCAR.CESM2-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11297 |
| | | | CMIP.NCAR.CESM2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.7627 |
| | | | CMIP.NCAR.CESM2-WACCM-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11298 |
| | | | CMIP.NCAR.CESM2-WACCM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10071 |
| | | | ScenarioMIP.NCAR.CESM2-WACCM.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10100 |
| Chlorophyll-*a* | chlpico | SSP-3-7.0 | CMIP.NCAR.CESM2-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11297 |
| | | | CMIP.NCAR.CESM2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.7627 |
| | | | CMIP.NCAR.CESM2-WACCM-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11298 |
| | | | CMIP.NCAR.CESM2-WACCM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10071 |
| | | | ScenarioMIP.NCAR.CESM2-WACCM.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10102 |
| Dissolved oxygen | o2sat | SSP-1-2.6 | CMIP.NCC.NorESM2-LM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8036 |
| | | | CMIP.NCC.NorESM2-MM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8040 |
| | | | CMIP.NOAA-GFDL.GFDL-ESM4.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8597 |
| | | | ScenarioMIP.NOAA-GFDL.GFDL-ESM4.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8684 |
| Dissolved oxygen | o2sat | SSP-3-7.0 | CMIP.NCC.NorESM2-LM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8036 |
| | | | CMIP.NCC.NorESM2-MM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8040 |
| | | | CMIP.NOAA-GFDL.GFDL-ESM4.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8597 |
| | | | ScenarioMIP.NCC.NorESM2-LM.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8268 |
| | | | ScenarioMIP.NCC.NorESM2-MM.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8270 |
| | | | ScenarioMIP.NOAA-GFDL.GFDL-ESM4.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8691 |
| SST | tos | SSP-3-7.0 | CMIP.E3SM-Project.E3SM-1-0.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.4497 |
| | | | CMIP.E3SM-Project.E3SM-1-1.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11485 |
| | | | CMIP.E3SM-Project.E3SM-1-1-ECA.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11486 |
| | | | CMIP.EC-Earth-Consortium.EC-Earth3-Veg.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.4706 |
| | | | CMIP.MRI.MRI-ESM2-0.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.6842 |
| | | | CMIP.NCAR.CESM2-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11297 |

| | | | | |
|---|---|---|---|---|
| | | | CMIP.NCAR.CESM2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.7627 |
| | | | CMIP.NCAR.CESM2-WACCM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10071 |
| | | | CMIP.NCAR.CESM2-WACCM-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11298 |
| | | | CMIP.NIMS-KMA.KACE-1-0-G.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8378 |
| | | | CMIP.NOAA-GFDL.GFDL-CM4.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8594 |
| | | | CMIP.NOAA-GFDL.GFDL-ESM4.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8597 |
| | | | ScenarioMIP.MRI.MRI-ESM2-0.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.6915 |
| | | | ScenarioMIP.NCAR.CESM2-WACCM.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10102 |
| | | | ScenarioMIP.NIMS-KMA.KACE-1-0-G.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8437 |
| | | | ScenarioMIP.NOAA-GFDL.GFDL-ESM4.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8691 |
| SST | tos | SSP-1-2.6 | CMIP.E3SM-Project.E3SM-1-0.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.4497 |
| | | | CMIP.E3SM-Project.E3SM-1-1.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11485 |
| | | | CMIP.E3SM-Project.E3SM-1-1-ECA.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11486 |
| | | | CMIP.EC-Earth-Consortium.EC-Earth3-Veg.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.4706 |
| | | | CMIP.MRI.MRI-ESM2-0.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.6842 |
| | | | CMIP.NCAR.CESM2-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11297 |
| | | | CMIP.NCAR.CESM2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.7627 |
| | | | CMIP.NCAR.CESM2-WACCM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10071 |
| | | | CMIP.NCAR.CESM2-WACCM-FV2.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11298 |
| | | | CMIP.NIMS-KMA.KACE-1-0-G.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8378 |
| | | | CMIP.NOAA-GFDL.GFDL-CM4.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8594 |
| | | | CMIP.NOAA-GFDL.GFDL-ESM4.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8597 |
| | | | ScenarioMIP.MRI.MRI-ESM2-0.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.6909 |
| | | | ScenarioMIP.NCAR.CESM2-WACCM.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.10100 |
| | | | ScenarioMIP.NIMS-KMA.KACE-1-0-G.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8432 |
| | | | ScenarioMIP.NOAA-GFDL.GFDL-ESM4.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8684 |
| Surface currents: u, v | uo, vo | SSP-1-2.6 | CMIP.E3SM-Project.E3SM-1-1-ECA.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11486 |
| | | | CMIP.E3SM-Project.E3SM-1-1.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11485 |
| | | | CMIP.NCC.NorESM2-LM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8036 |
| | | | ScenarioMIP.NCC.NorESM2-LM.ssp126.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8248 |
| Surface currents: u, v | uo, vo | SSP-3-7.0 | CMIP.E3SM-Project.E3SM-1-1.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11486 |
| | | | CMIP.E3SM-Project.E3SM-1-1-ECA.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.11485 |
| | | | CMIP.NASA-GISS.GISS-E2-1-H.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.7128 |

| | | | | |
|---|---|---|---|---|
| | | | CMIP.NCC.NorESM2-LM.historical.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8036 |
| | | | ScenarioMIP.NCC.NorESM2-LM.ssp370.Omon.gr | https://doi.org/10.22033/ESGF/CMIP6.8268 |

## Table S5

**Table S5**: Relative influence (%) of environmental variables in species distribution models. Bolded values indicate relative influence >10%.

| Primary habitat group | Species | Bathymetric depth | Dissolved $O_2$ | SST | Chl-*a* | Surface current velocity | Surface current heading |
|---|---|---|---|---|---|---|---|
| Reef–pelagic | Reef manta ray | **46.2** | **22.3** | 6.8 | 7.8 | 5.9 | **11.0** |
| | Grey reef shark | **76.9** | 4.2 | 2.8 | 9.0 | 2.7 | 4.3 |
| Pelagic | Yellowfin tuna | **52.1** | **12.2** | **11.0** | **11.6** | 5.1 | 8.0 |
| | Sooty tern | **18.9** | **21.1** | **10.7** | **18.2** | **17.6** | **13.6** |
| | Great frigatebird | **54.5** | 7.8 | **12.8** | **10.5** | 4.4 | 9.9 |
| Nearshore–pelagic | Bottlenose dolphin | **93.4** | 2.1 | 0.7 | 0.7 | 1.1 | 2.1 |
| | Melon-headed whale | **69.2** | 6.3 | 2.5 | 7.7 | 5.7 | 8.6 |
| | Red-footed booby | **57.3** | 5.3 | 6.3 | 6.9 | **11.6** | **12.5** |

Abbreviations: Chl-*a*, chlorophyll-*a*; SST, sea surface temperature.

# Table S6

**Table S6**: Predicted median habitat suitability (HS) and percent change in HS under two climate scenarios at Palmyra. Percent change in HS between historic (1984–2014) and projected time periods (2040–2050; 2090–2100) are listed in parentheses with +/- indicating the direction of the change. The percentage of grid cells with highly suitable habitat (HS >0.67) within the marine protected area (MPA) and U.S. exclusive economic zone (EEZ) are also provided. The mean change per habitat group is also shown.

| | | | **Habitat suitability 1984–2014** | | | | **2040–2050** | | | | **2090–2100** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **MPA** | | **EEZ** | | **MPA** | | **EEZ** | | **MPA** | | **EEZ** | |
| | **Scenario** | | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** |
| **Primary habitat** | **Species** | | | | | | | | | | | | | |
| Reef-pelagic | Reef manta ray | Median HS | 0.53 | 0.82 | 0.53 | 0.62 | 0.26 | 0.69 | 0.69 | 0.67 | 0.71 | 0.92 | 0.63 | 0.70 |
| | | % Change in HS | – | – | – | – | (-51%) | (-16%) | (+30%) | (+8%) | (+34%) | (+12%) | (+19%) | (+13%) |
| | | % Highly suitable habitat | 0% | 79% | 31% | 45% | 0 | 54% | 50% | 5% | 68% | 91% | 49% | 60% |
| | Grey reef shark | Median HS | 0.11 | 0.12 | 0.05 | 0.06 | 0.02 | 0.06 | 0.05 | 0.03 | 0.04 | 0.05 | 0.06 | 0.17 |
| | | % Change in HS | – | – | – | – | (-82%) | (-50%) | (0%) | (-50%) | (-64%) | (-58%) | (+20%) | (+183%) |
| | | % Highly suitable habitat | 0% | 0% | 16% | 15% | 0 | 0 | 0 | 13% | 0 | 0 | 10% | 0.2% |
| | **Mean % change in HS** | | | | | | **-66%** | **-33%** | **+15%** | **-21%** | **-15%** | **-23%** | **+20%** | **+98%** |
| Pelagic | Yellowfin tuna | Median HS | 0.87 | 0.96 | 0.86 | 0.86 | 0.85 | 0.93 | 0.80 | 0.82 | 0.92 | 0.96 | 0.84 | 0.86 |
| | | % Change in HS | – | – | – | – | (-2%) | (-3%) | (-7%) | (-5%) | (+6%) | (0%) | (-2%) | (0%) |
| | | % Highly suitable habitat | 100% | 100% | 96% | 93% | 100% | 98% | 78% | 83% | 100% | 100% | 74% | 90% |
| | Sooty tern | Median HS | 0.83 | 0.48 | 0.75 | 0.34 | 0.73 | 0.30 | 0.88 | 0.30 | 0.81 | 0.30 | 0.80 | 0.32 |
| | | % Change in HS | – | – | – | – | (-12%) | (-38%) | (+17%) | (-12%) | (-2%) | (-38%) | (+7%) | (-6%) |
| | | % Highly suitable habitat | 100% | 2% | 65% | 8% | 100% | 0 | 94% | 2% | 100% | 0 | 81% | 1% |
| | Great frigatebird | Median HS | 0.81 | 0.87 | 0.73 | 0.70 | 0.77 | 0.18 | 0.20 | 0.14 | 0.85 | 0.82 | 0.64 | 0.60 |
| | | % Change in HS | – | – | – | – | (-5%) | (-79%) | (-73%) | (-80%) | (+5%) | (-6%) | (-12%) | (-14%) |
| | | % Highly suitable habitat | 83% | 92% | %55 | 55% | 89% | 37% | 21% | 23% | 98% | 81% | 47% | 44% |
| | **Mean % change in HS** | | | | | | **-6%** | **-40%** | **-21%** | **-32%** | **+3%** | **-15%** | **-2%** | **-7%** |
| Nearshore-pelagic | Red-footed booby | Median HS | 0.80 | 0.51 | 0.43 | 0.45 | 0.39 | 0.20 | 0.44 | 0.35 | 0.73 | 0.44 | 0.43 | 0.43 |
| | | % Change in HS | – | – | – | – | (-51%) | (-61%) | (+2%) | (-22%) | (-9%) | (-14%) | (0%) | (-4%) |
| | | % Highly suitable habitat | 75% | 18% | 27% | 26% | 18% | 11% | 20% | 15% | 94% | 10% | 33% | 21% |

## Table S7

**Table S7**: Mean (± SD) predicted change in habitat suitability within the marine protected area (MPA) and U.S. exclusive economic zone (EEZ) surrounding Palmyra-Kingman between the historic model and each decade of interest for each climate scenario. Mean changes >0.2 are bolded. Habitat suitability was estimated with background samples and boosted regression trees.

| | | **Change in habitat suitability** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Historical: 2040–2050** | | | | **Historical: 2090–2100** | | | |
| | | **MPA** | | **EEZ** | | **MPA** | | **EEZ** | |
| **Primary habitat** | **Scenario** / **Species** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** | **1-2.6** | **3-7.0** |
| Reef-pelagic | Reef manta ray | -0.03 ± 0.28 | -0.07 ± 0.20 | 0.16 ± 0.32 | 0.05 ± 0.16 | **0.21 ± 0.15** | 0.09 ± 0.10 | 0.10 ± 0.28 | 0.08 ± 0.13 |
| | Grey reef shark | -0.10 ± 0.10 | -0.04 ± 0.04 | -0.15 ± 0.32 | -0.04 ± 0.14 | -0.08 ± 0.12 | -0.03 ± 0.08 | -0.04 ± 0.45 | -0.02 ± 0.31 |
| | Mean change | -0.04 | -0.06 | +0.01 | +0.01 | +0.07 | +0.03 | +0.03 | +0.03 |
| Pelagic | Yellowfin tuna | -0.02 ± 0.07 | -0.04 ± 0.05 | -0.08 ± 0.13 | -0.04 ± 0.07 | 0.04 ± 0.02 | -0.02 ± 0.02 | -0.08 ± 0.17 | -0.01 ± 0.08 |
| | Sooty tern | -0.04 ± 0.04 | -0.06 ± 0.22 | 0.15 ± 0.16 | -0.07 ± 0.25 | -0.01 ± 0.07 | -0.02 ± 0.16 | 0.06 ± 0.21 | -0.05 ± 0.21 |
| | Great frigatebird | -0.03 ± 0.13 | **-0.38 ± 0.32** | **-0.24 ± 0.28** | **-0.26 ± 0.30** | 0.03 ± 0.11 | -0.01 ± 0.13 | -0.04 ± 0.36 | $6.6 \times 10^{-5}$ ± 0.28 |
| | Mean change | -0.03 | -0.16 | -0.06 | -0.12 | 0.02 | -0.02 | -0.02 | -0.02 |
| Nearshore-pelagic | Red-footed booby | **-0.29 ± 0.29** | -0.19 ± 0.14 | -0.02 ± 0.25 | -0.06 ± 0.16 | 0.03 ± 0.14 | -0.09 ± 0.27 | 0.01 ± 0.21 | 0.03 ± 0.32 |

## Figure S1

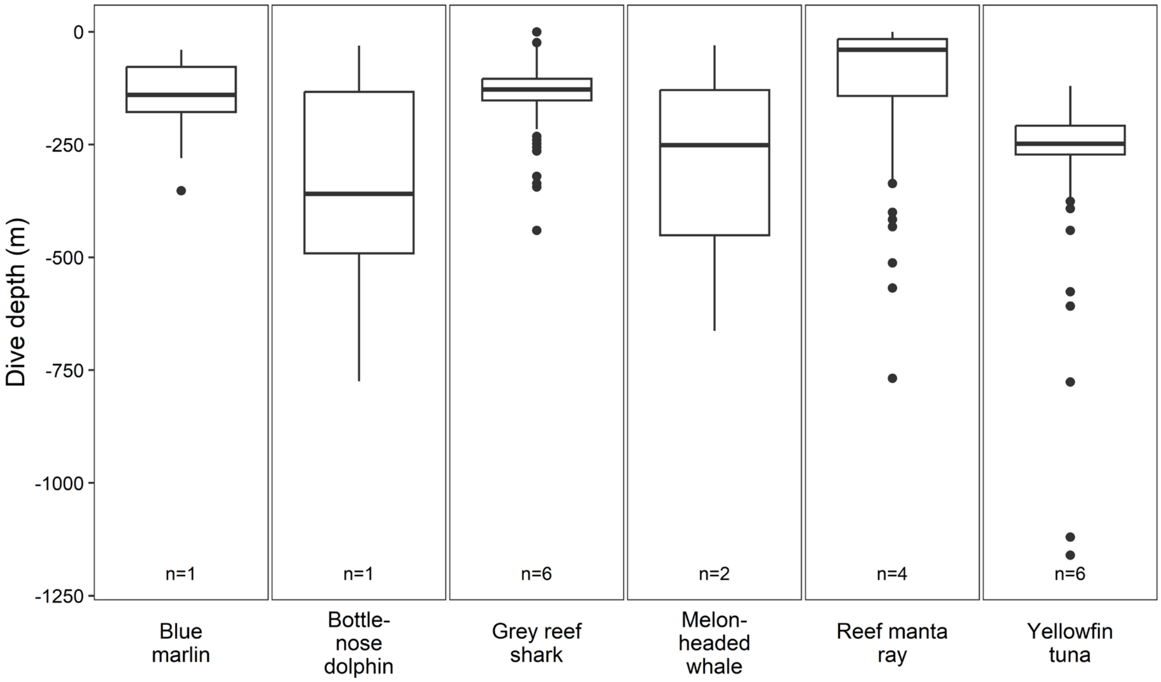


**Figure S1**: Water column use by cetaceans and fishes. Boxplots represent maximum dive depth (m) recorded per day per individual, grouped by species. Individual points represent observations that occurred outside the interquartile range and horizontal line within boxes are the mean maximum daily depth. Sample sizes are provided within each panel.

## Figure S2

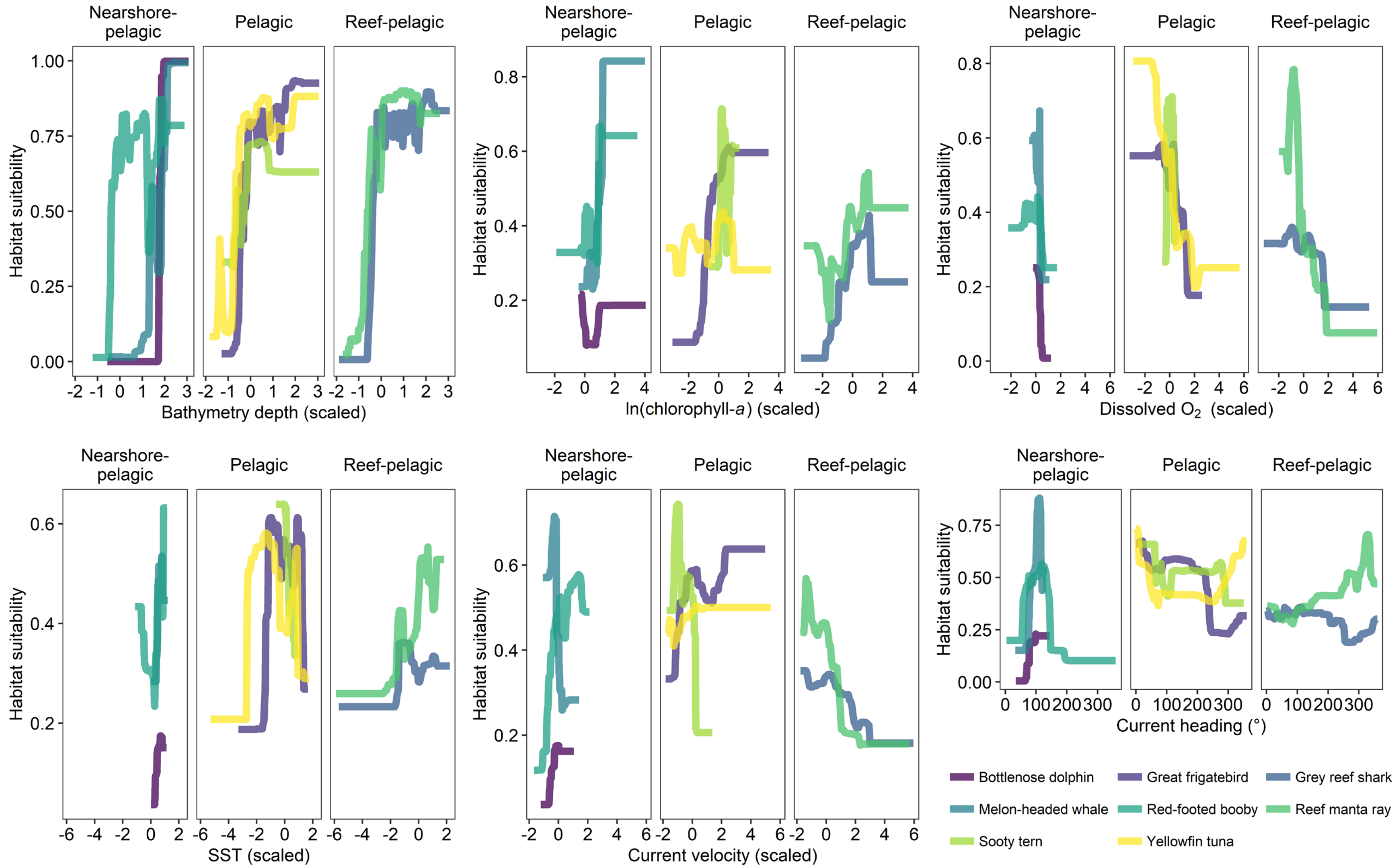


**Figure S2**: Partial effects plots of each environmental variable on habitat suitability from boosted regression trees conducted with background pseudo-absences. All variables except current heading were centered and scaled before analyses and are unitless.

# Figure S3

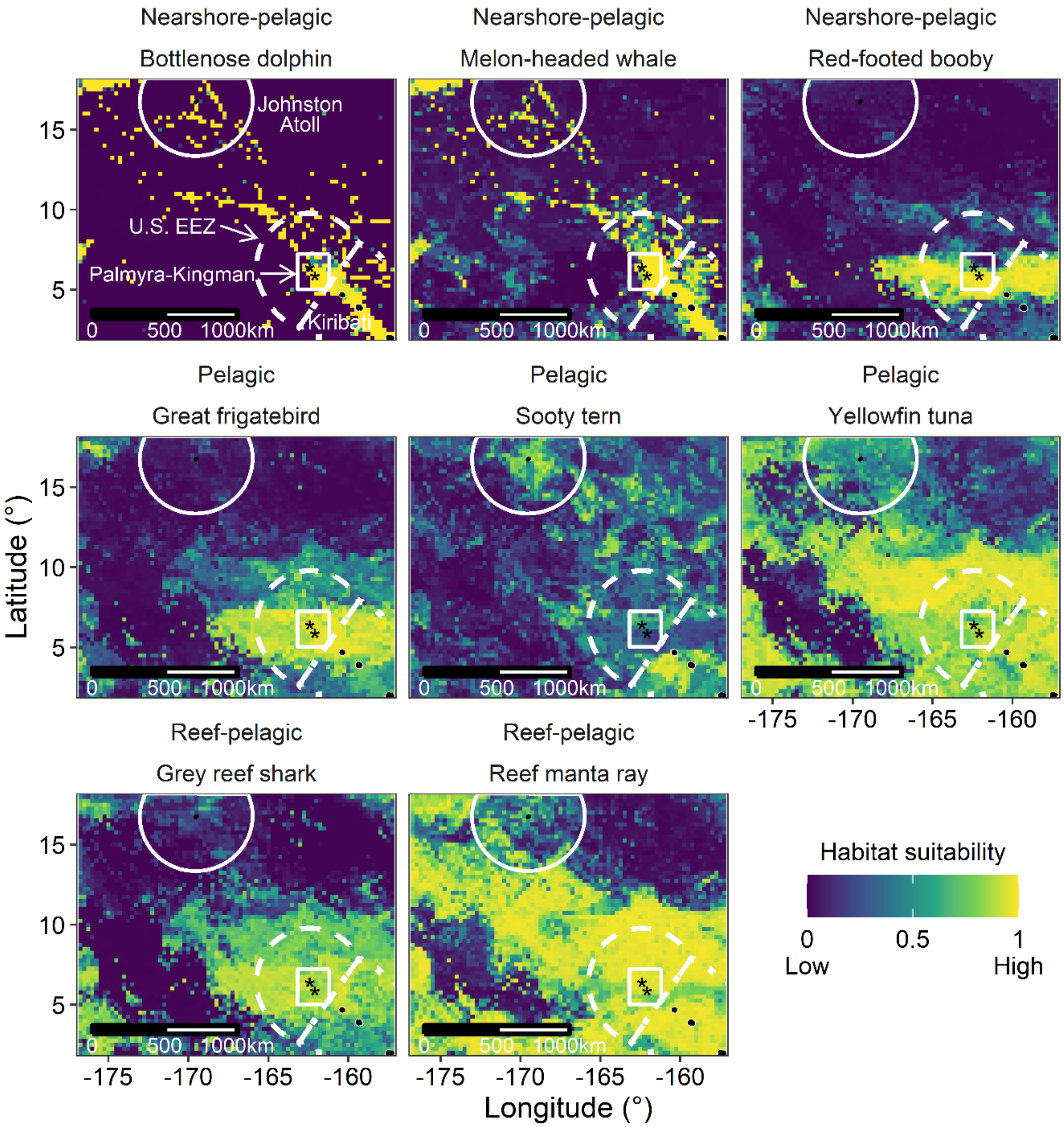


**Figure S3**: Habitat suitability calculated per species per 0.25 x 0.25° grid cell, predicted for boreal spring/summer (June 1, 2022). The relative influence of variables per species are listed in Table 3. Habitat suitability is indicated by gradient scale of dark–light colors that indicate low to high habitat suitability, respectively. Habitat suitability was predicted by species distribution models that were estimated separately for each species via boosted regression trees that used background sampling. Solid white lines indicate boundaries of the Pacific Islands Heritage Marine National Monument, dashed lines indicate the U.S. Exclusive Economic Zone (EEZ), and dotted lines indicate the Kiribati EEZ. Geographic features are labeled in the top-left panel. Species are grouped into habitats (top rows of text). Map lines delineate study areas and do not necessarily depict accepted national boundaries.

## Figure S4

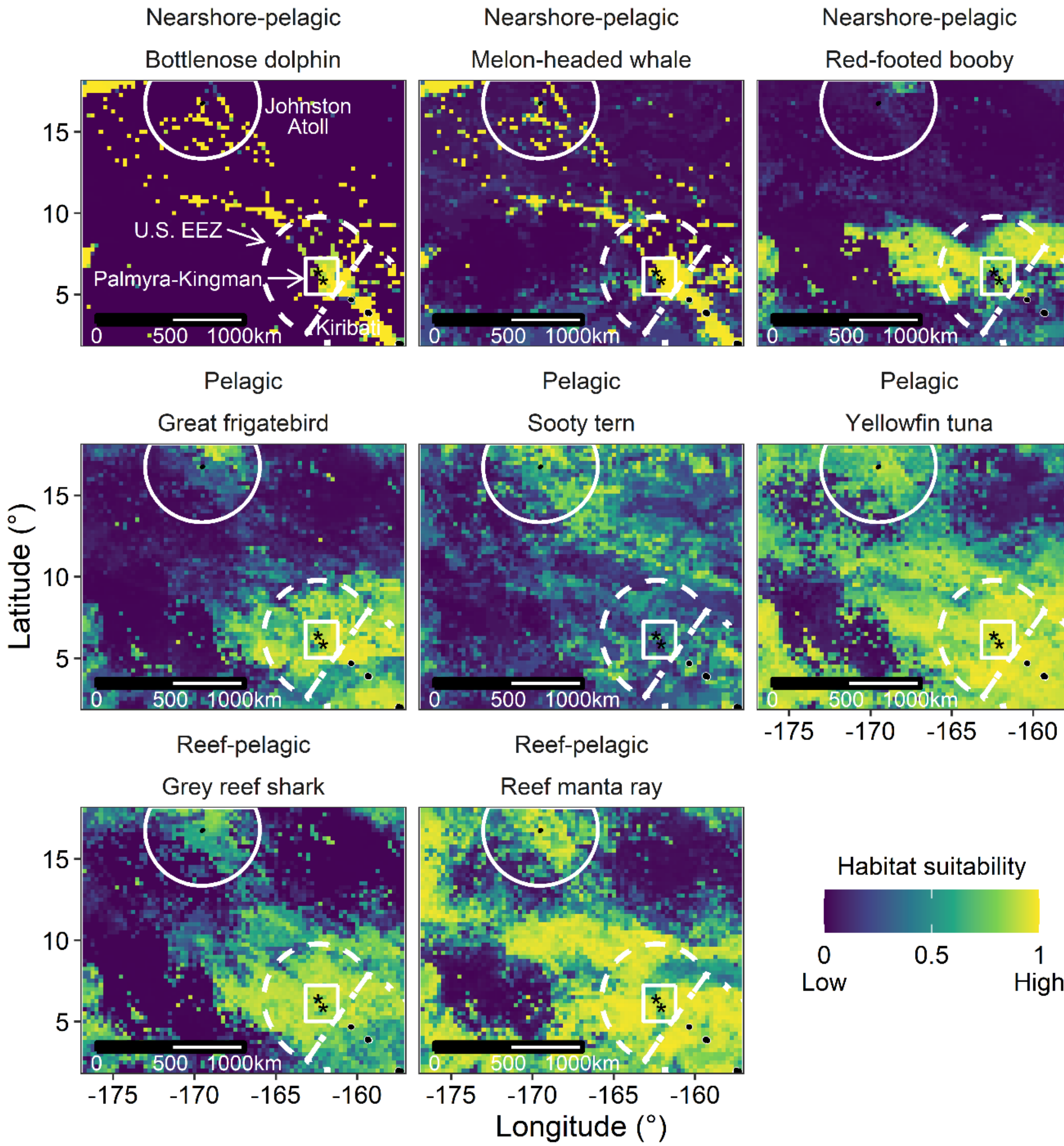


**Figure S4**: Habitat suitability per species predicted for boreal winter (December 1, 2022). The relative influence of variables per species are listed in Table 3. Habitat suitability is indicated by gradient scale of dark–light colors that indicate low to high habitat suitability, respectively. Habitat suitability was predicted by species distribution models that were estimated separately for each species via boosted regression trees that used background sampling. Solid black lines indicate Pacific Islands Heritage Marine National Monument boundaries and dashed lines indicate the U.S. Exclusive Economic Zone. Boundaries are labeled in the top-left box to provide geographical context. Species are grouped into primary habitat types (top). Map lines delineate study areas and do not necessarily depict accepted national boundaries.

## Figure S5

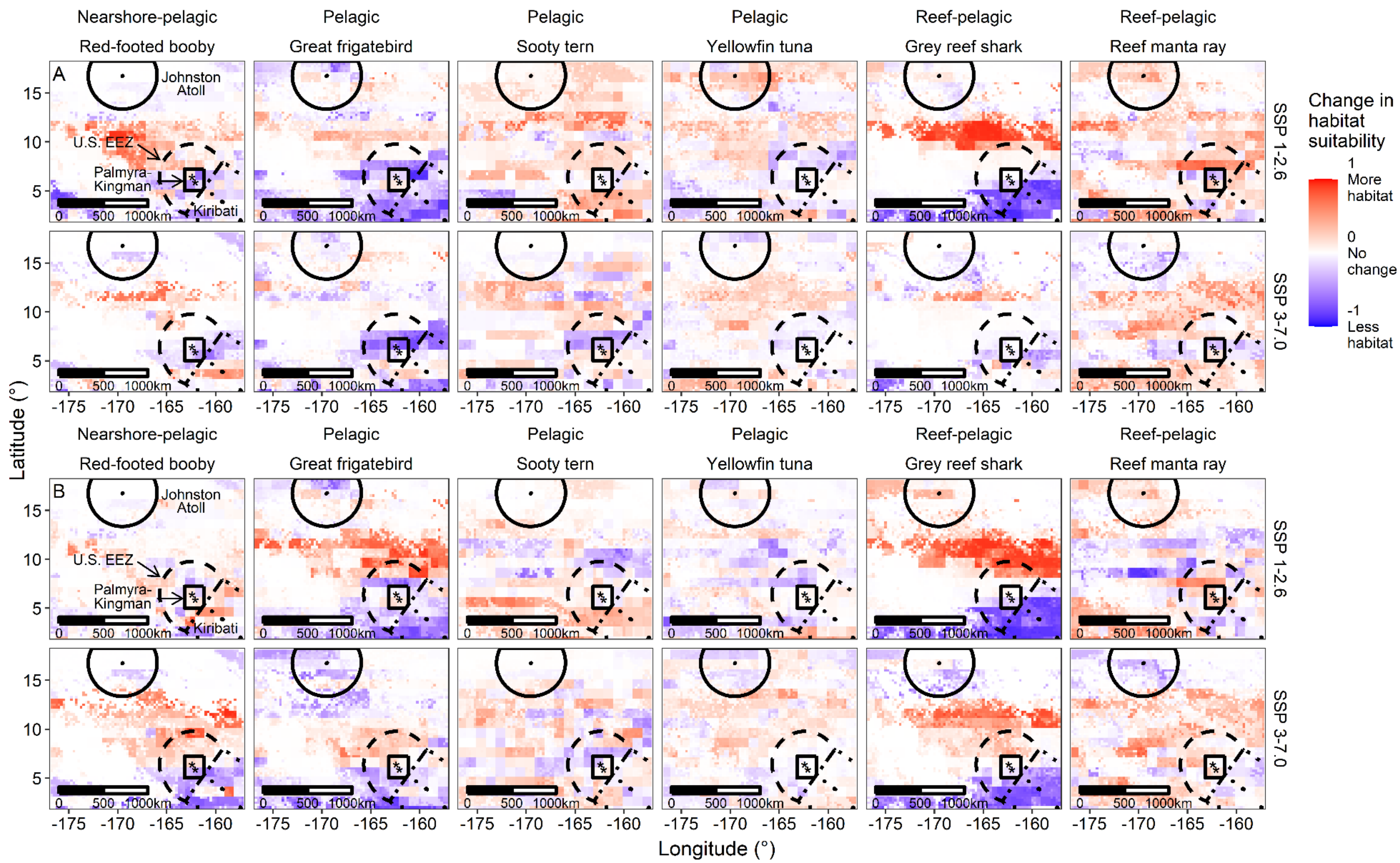


**Figure S5**: Predicted change in habitat suitability under two climate scenarios, SSP 1-2.6 and SSP 3-7.0, and two time periods, 2040–2050 (**A**) and 2090–2100 (**B**) based on the boreal summer model (June 1, 2022). The scale of change ranges from -1 (decreased habitat; blue colors) to 1 (increased habitat; red colors). For regional orientation and geographical context, features are labeled for red-footed boobies (upper left panels) within each decadal plot group. Median habitat suitability values and the percent change in habitat suitability are quantified in Tables S6 and S7. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

# Figure S6

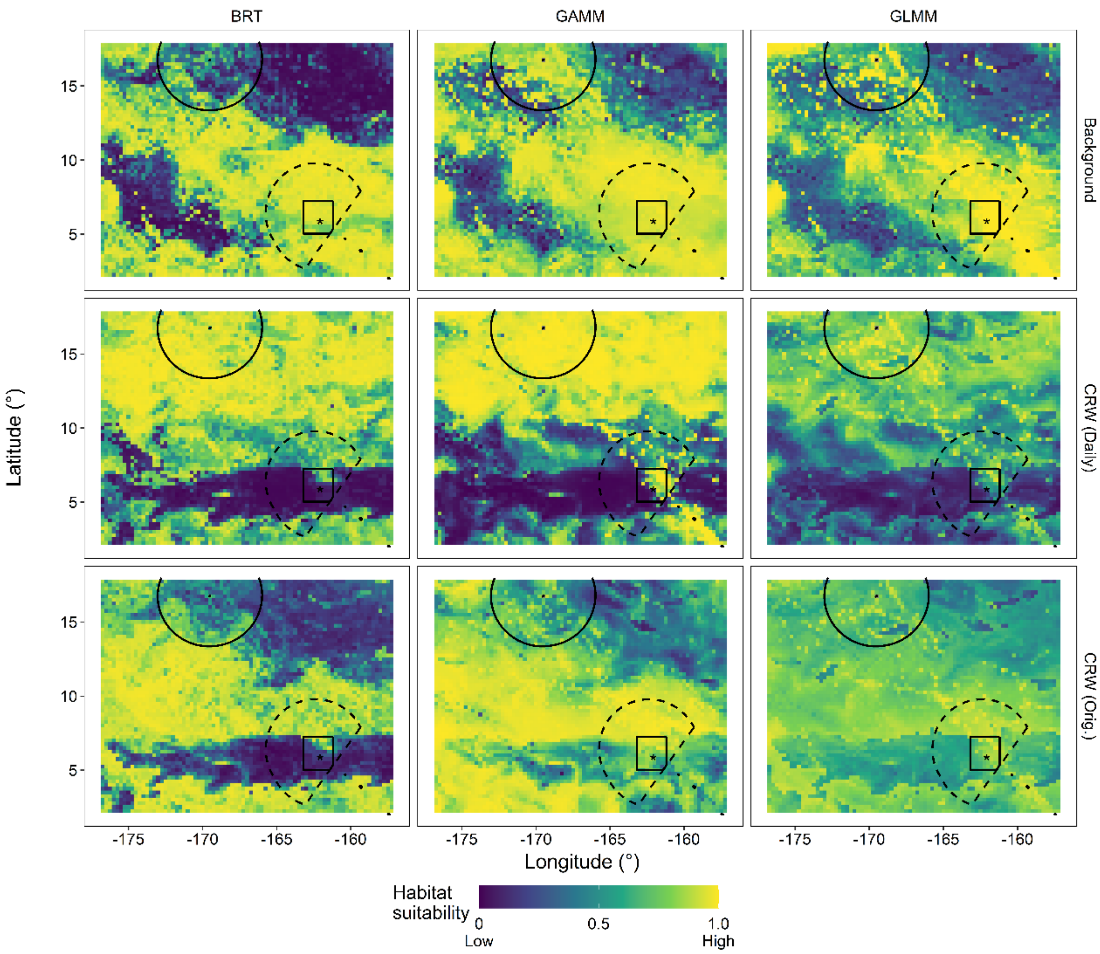


**Figure S6**: **Species distribution model results for reef manta ray**. Model types correspond to columns and pseudo-absence types correspond to rows. Abbreviations: BRT: boosted regression tree; GAMM: generalized additive mixed model; GLMM: generalized linear mixed model; CRW: correlated random walk. CRW are presented for two temporal resolutions: daily (CRW was conducted on median daily locations per individual) and original (CRW was conducted at the original tag sample resolution per individual, and then the median daily location was calculated). Black polygons represent Pacific Islands Heritage Marine National Monument boundaries, dashed black line represents the U.S. exclusive economic zone surrounding the Palmyra-Kingman unit, and asterisk indicates the location of Palmyra Atoll. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

## Figure S7

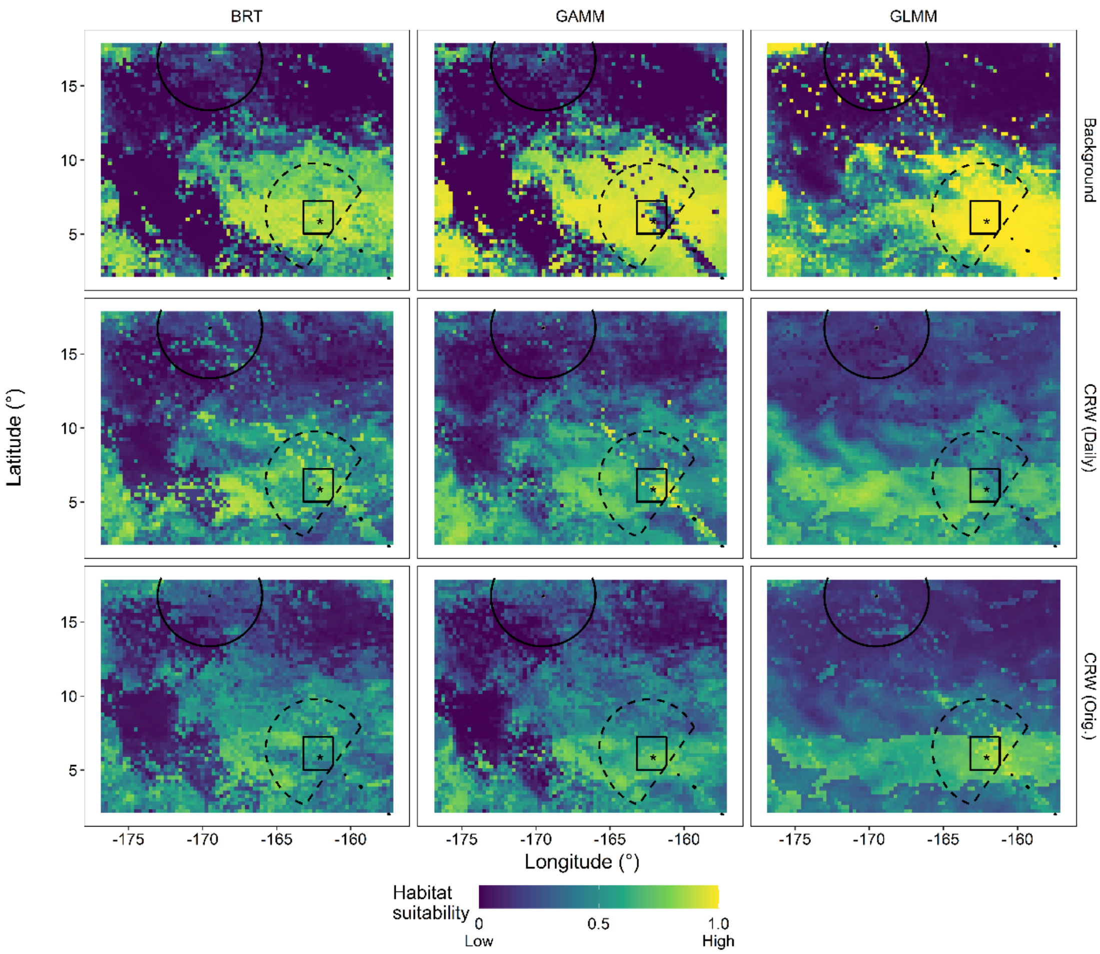


**Figure S7**: **Species distribution model results for grey reef shark**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

# Figure S8

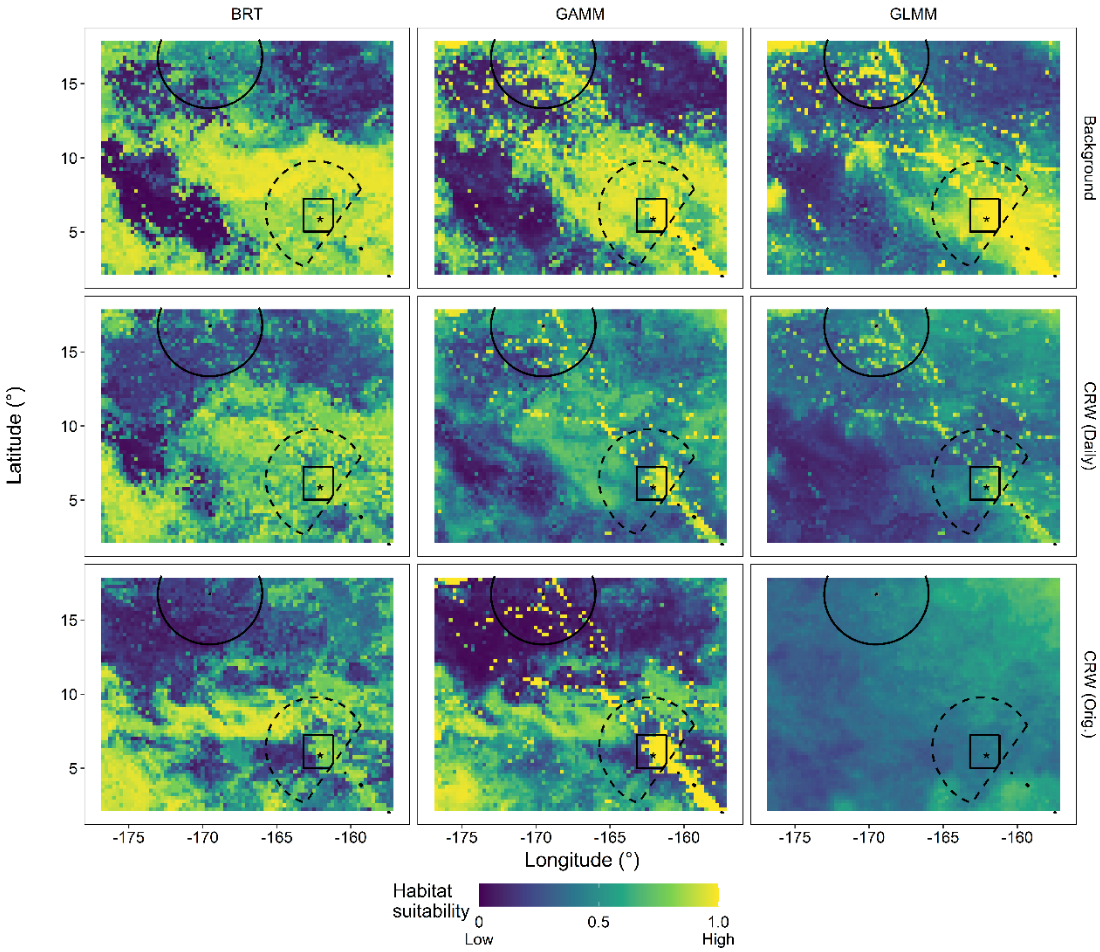


**Figure S8**: **Species distribution model results for yellowfin tuna**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

# Figure S9

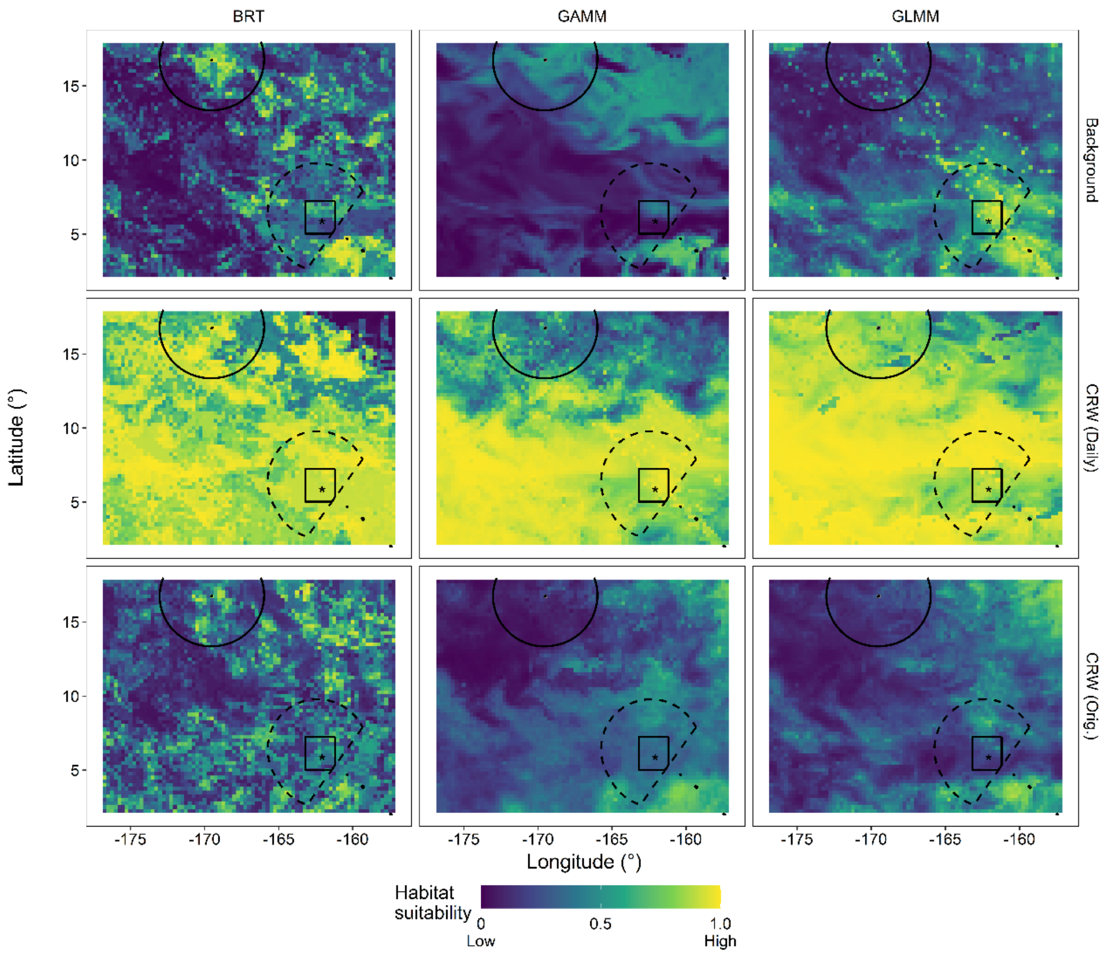


**Figure S9**: **Species distribution model results for sooty tern**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

# Figure S10

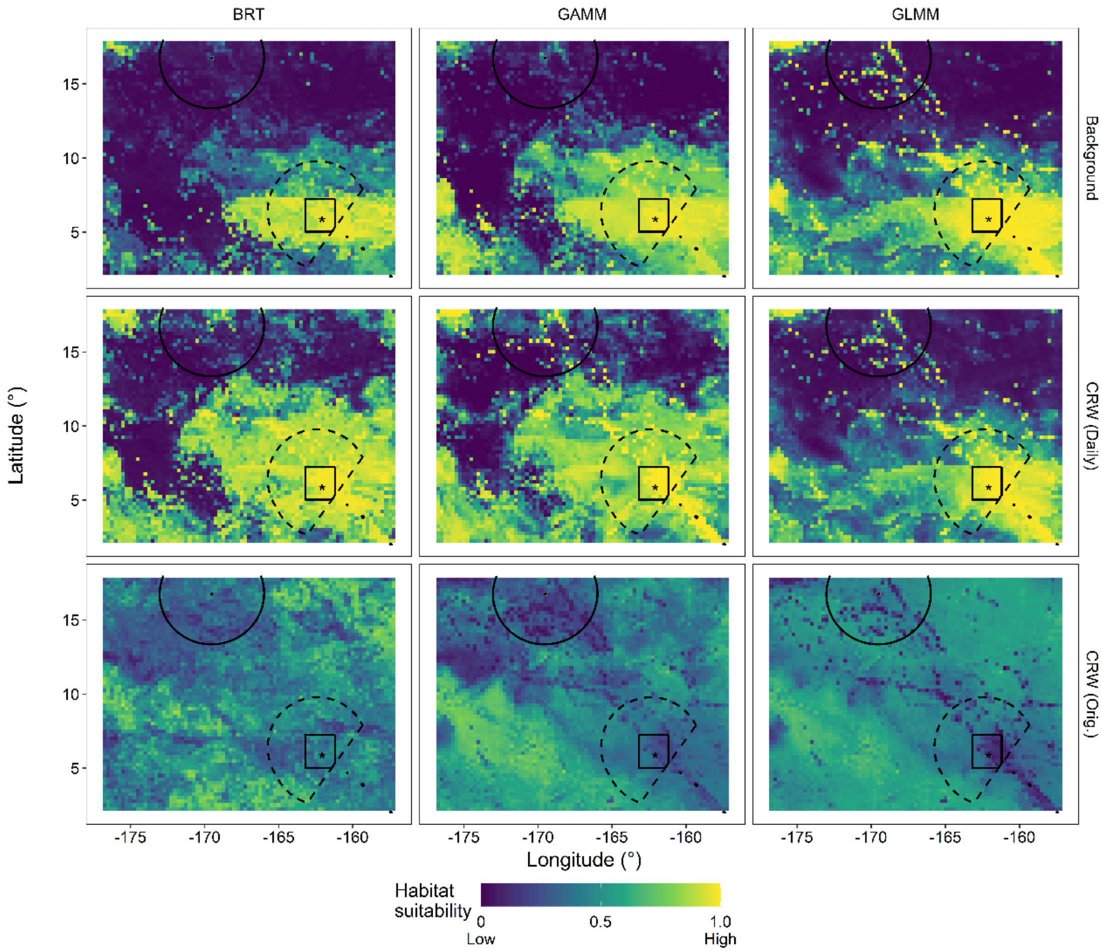


**Figure S10**: **Species distribution model results for great frigatebird**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

## Figure S11

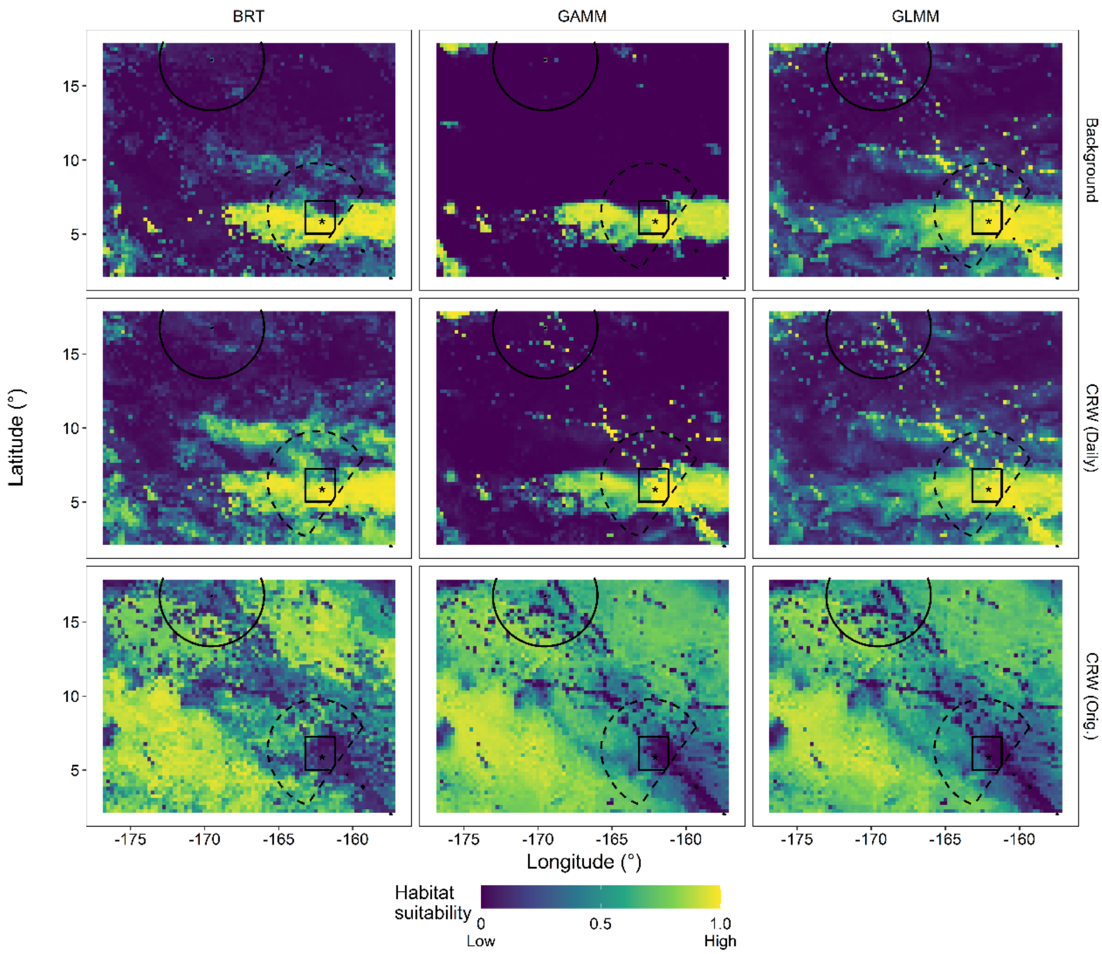


**Figure S11**: **Species distribution model results for red-footed booby**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

# Figure S12

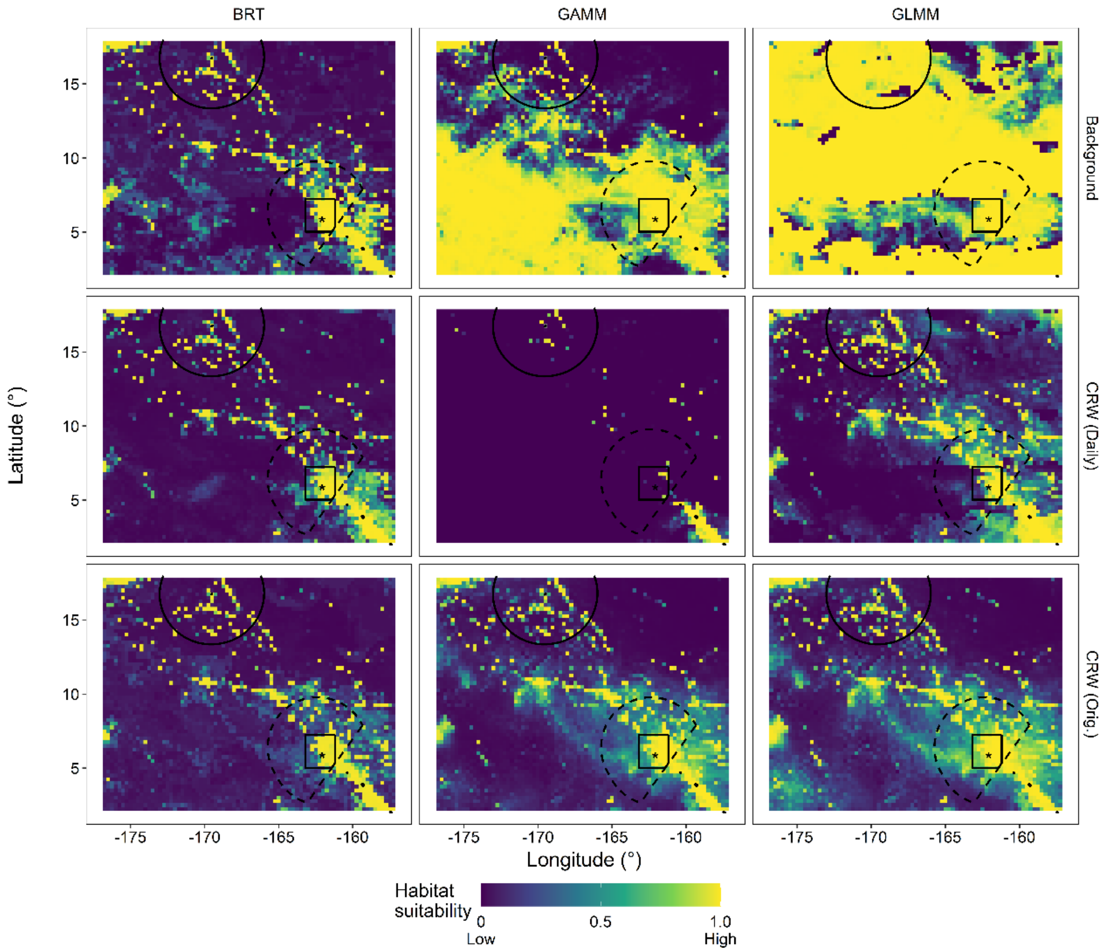


**Figure S12**: **Species distribution model results for melon-headed whale**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

# Figure S13

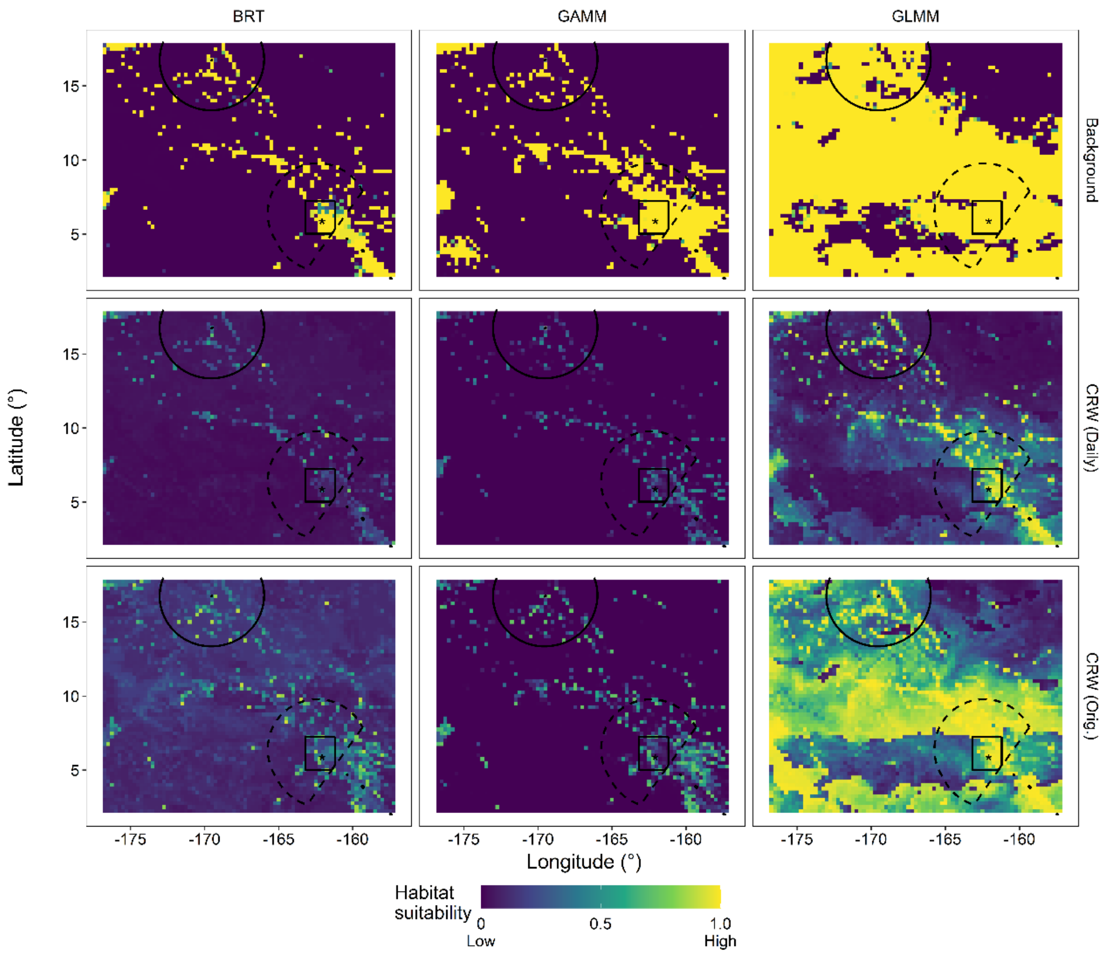


**Figure S13**: **Species distribution model results for bottlenose dolphin**. Figure legend and abbreviations are the same as in Figure S6. Map lines delineate study areas and do not necessarily depict accepted national boundaries.