Appendix S2: Code for Application 3.2

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Load required R packages

```
require(tidyverse)
require(ggspatial)
require(patchwork)
require(sf)
require(foieGras)
```

Fit `crw` SSM with 5-min `time.step` to time-regularise little penguin tracks

```
## Load GPS location data from .csv file
lipe <- read.csv("../data/lipe_gps_ex32.csv")

## Load prey capture data from .csv file
lipe.pc <- read.csv("../data/lipe_pc_ex32.csv")

## fit `crw` SSM, using: 1) speed filter (vmax) of 5 m/s to exclude any extreme
##   observations; 2) excluding any locations occurring < 5 s apart in time (min.dt);
##   3) a 5-min time.step
fit <- fit_ssm(lipe, vmax=5, min.dt=5, model="crw", time.step=5/60)
```

Fit move persistence model with `fit_mpm` to SSM-predicted locations

```
## use `jmpm` model to fit jointly across the 4 penguin tracks
fmp <- fit_mpm(fit, what = "predicted", model = "jmpm")
```

Function to merge track & predation events

```
merge.tracks.preds <- function(tracks, preds){
  # drop tracks not in events
  tracks$id <- as.character(tracks$id)
  tracks <- tracks[tracks$id %in% unique(preds$id),]
  tracks$preyCount <- 0

  predsl <- split(preds, with(preds, interaction(id)), drop = TRUE)
  # Unique events
  uniqueEventsl2 <- lapply(predsl,
                           function(x) x[round(diff(as.POSIXct(x$date))) > 2,])

  # Loop events
  tracks <- split(tracks, tracks$id)
```

```
  for (i in 1:length(tracks)){
    # go through events and find the nearest track timestamp for each
    events <- uniqueEvents12[[tracks[[i]]$id[1]]]
    events$idx <- sapply(events$date, function(dt)
      which.min(abs(as.numeric(difftime(dt, tracks[[i]]$date, unit='sec')))))
    # populate tracks
    for (idx in unique(events$idx)){
      tracks[[i]]$preyCount[idx] <- sum(events$idx == idx)
    }
  }
  # merge tracks back together
  tracks <- do.call(rbind, tracks)
  row.names(tracks) <- NULL
  return(tracks)
}
```

Aggregate prey capture events & append to locations

```
## grab SSM-predicted locations
peng.ssm_sf <- grab(fit, "p", as_sf = TRUE)

## aggregate prey capture events to location times & append
peng.ssm_sf <- merge.tracks.preds(peng.ssm_sf, lipe.pc)

## append move persistence estimates
peng.ssm_sf <- peng.ssm_sf %>% mutate(g = grab(fmp, "f")$g)
```

Plot move persistence time-series for 5-min prediction interval & map along SSM-predicted tracks

```
## plot move persistence time-series for all 4 penguins, drop legend
p <- plot(fmp, ncol = 2, pages = 1, pal = "Plasma") &
  theme(legend.position = "none",
        plot.title = element_blank(),
        axis.text = element_text(size = 6),
        panel.grid.minor = element_blank())

## adjust x-axis date labels for clean manuscript figure
p[[1]] <- p[[1]] &
  scale_x_datetime(date_breaks = "3 hours", date_labels = "%H:%M")
p[[2]] <- p[[2]] &
  scale_x_datetime(date_breaks = "3 hours", date_labels = "%H:%M")
p[[3]] <- p[[3]] &
  scale_x_datetime(date_breaks = "4 hours", date_labels = "%H:%M")
p[[4]] <- p[[4]] &
  scale_x_datetime(date_breaks = "5 hours", date_labels = "%H:%M")
```

Map SSM-predicted locations with move persistence & prey capture estimates

```
## use foieGras::map to merge SSM & MPM model fits (SSM = fit, MPM = fmp);
##  use map tiles for better coastline resolution (Montague Is not in
##  `rnaturalearthhires` polygon data)

## define bounding box for map & expand limits to get desired map boundary
bb <- sf::st_bbox(peng.ssm_sf)
bb["xmin"] <- bb["xmin"] - diff(bb[c(1,3)]) * 0.7/2
bb["xmax"] <- bb["xmax"] + diff(bb[c(1,3)]) * 0.3/2
bb["ymin"] <- bb["ymin"] - diff(bb[c(2,4)]) * 0.2/2
bb["ymax"] <- bb["ymax"] + diff(bb[c(2,4)]) * 0.2/2

## customize mapping aesthetics
my.aes <- aes_lst(conf = F, line = T, mp_pal = hcl.colors(n=100, "Plasma"))
my.aes$df$size[1] <- 1

m <- foieGras::map(
  fit,
  fmp,
  what = "p",
  aes = my.aes,
  map_type = "cartolight",
  zoomin = 1,
  normalise = FALSE,
  silent = TRUE
) +
  geom_sf(data=peng.ssm_sf %>% filter(preyCount > 0),
          aes(size = preyCount, fill = g),
          shape = 21,
          stroke = 0.3,
          inherit.aes = TRUE) +
  scale_size(breaks = c(1,10,20),
             range = c(1, 4),
             name = "prey\ncaptures",
             guide = "none") +
  scale_fill_viridis_c(option = "C",
                       begin = min(peng.ssm_sf$g),
                       end = max(peng.ssm_sf$g),
                       guide = "none") +
  ggspatial::annotation_scale(height = unit(0.15, "cm"),
                              aes(location = "br")) +
  xlab(element_blank()) +
  ylab(element_blank()) +
  coord_sf(xlim = bb[c(1,3)],
           ylim = bb[c(2,4)],
           expand = TRUE,
           crs = sf::st_crs(peng.ssm_sf)) +
  scale_x_continuous(breaks = pretty(seq(150.13, 150.26, l = 4), n = 3)) +
  scale_y_continuous(breaks = pretty(seq(-36.5, -36.24, l = 5), n = 4)) +
  theme(legend.position = c(0.25,0.05),
        legend.direction = "horizontal",
        legend.key.width = unit(5, "mm"),
        legend.title = element_text(size = 8),
```

```
        legend.text = element_text(size = 6),
        axis.text = element_text(size = 6),
        panel.grid = element_line(colour = "grey40"),
        panel.background = element_blank(),
        panel.ontop = TRUE)

## define track labels for map annotations
label.df <- data.frame(tag = c("a","b","c","d"),
                       x = c(0.3, 0.8, 0.15, 0.83) *
                         (bb["xmax"] - bb["xmin"]) + bb["xmin"],
                       y = c(0.85, 0.15, 0.4, 0.5) *
                         (bb["ymax"] - bb["ymin"]) + bb["ymin"])
names.df <- data.frame(tag = c("Montague\nIsland"),
                       x = 0.92 * (bb["xmax"] - bb["xmin"]) + bb["xmin"],
                       y = 0.91 * (bb["ymax"] - bb["ymin"]) + bb["ymin"])

m <- m +
  geom_text(data = label.df, aes(x,y,label=tag), size = 3) +
  geom_text(data = names.df, aes(x,y,label=tag), size = 2.5)

## make custom prey capture legend for location symbol size
pc.title <- data.frame(tag = "prey\ncaptures",
                       x = 0.05 *
                         (bb["xmax"] - bb["xmin"]) + bb["xmin"],
                       y = 0.1 *
                         (bb["ymax"] - bb["ymin"]) + bb["ymin"])
pc.df <- data.frame(x = c(0.15, 0.205, 0.26, 0.33) *
                         (bb["xmax"] - bb["xmin"]) + bb["xmin"],
                    y = rep(0.11, 4) *
                         (bb["ymax"] - bb["ymin"]) + bb["ymin"],
                    size = c(1, 1, 6, 15))
pc.labels <- data.frame(x = c(0.15, 0.205, 0.26, 0.33) *
                         (bb["xmax"] - bb["xmin"]) + bb["xmin"],
                    y = rep(0.08, 4) *
                         (bb["ymax"] - bb["ymin"]) + bb["ymin"],
                    tag = c("0", "1", "10", "20"))

m <- m +
  geom_text(data = pc.title,
            aes(x, y, label = tag),
            size = 2,
            inherit.aes = FALSE) +
  geom_point(data = pc.df[1,],
             aes(x, y),
             shape = 21,
             size = 1,
             fill = "#EDB300",
             colour = "#EDB300",
             inherit.aes = FALSE,
             show.legend = FALSE) +
  geom_point(data = pc.df[2:4,],
             aes(x, y, size = size),
             shape = 21,
```

```
              stroke = 0.3,
              fill = NA,
              inherit.aes = FALSE,
              show.legend = FALSE) +
  geom_text(data = pc.labels,
            aes(x, y, label = tag),
            size = 2,
            inherit.aes = FALSE)

## plot movement persistence 1-D time-series and map along 2-D tracks
(p | m) +
  plot_layout(widths = c(2.2, 3)) +
  plot_annotation(tag_levels = "a") &
  theme(plot.tag = element_text(size = 9))
```