Ecography

E7681

Schuster, R. and Arcese, P. 2012. Using bird species community occurrence to prioritize forests for old growth restoration. – Ecography 35: xxx-xxx.

Supplementary material

This supplementary material includes two Appendices. In Appendix 1 we include text provided to experts to describe habitats of interest; tables describing the Terrestrial Ecosystem Mapping (TEM) reclassification schemes used herein; a table including averaged model covariates for all species examined; and occupancy maps for 6 species not included in the main text. In Appendix 2 we provide the R code we developed for the stepwise model selection we used in combination with R package 'unmarked'.

Appendix 1.

Expert elicitation descriptions.

Introduction for experts:
Thank you for taking the time to assist us with our survey.

We are creating predictive occurrence maps for up to 18 bird species to aid in identifying areas within the Coastal Douglas Fir (CDF) zone of south-eastern Vancouver Island and the Southern Gulf Islands (see Figure) that are likely to support bird communities representing mature and older forest and woodland habitats. Once assembled, these and other maps of native and exotic plants, habitat types and human land use, will be used to identify existing forest and woodland stands likely to contribute positively to the restoration of 'old growth' CDF communities in future. We are especially interested in identifying bird species that, based on expert opinion, are likely to be present in mature or older CDF forest and woodland stands (e.g., stands with large diameter trees, well-vegetated light gaps, and multi-layer canopy structure).

We are requesting your help because detailed information on the dependence of individual species on old forest and woodland habitats are generally unavailable for the coastal Douglas fir zone. We are therefore reaching out to experienced birders to help us by filling out an online survey requiring perhaps 15-20 minutes of your time.

Habitat dependence questions:
(Photographs of associated habitats removed to avoid copyright issues)

Please read the following descriptions of habitats found in the CDF Biogeoclimatic Zone, then rank the listed bird species for each habitat type using the embedded drop-down menus.

Herbaceous: Early successional or herbaceous communities maintained by environment or disturbance (e.g., flooding, grazing, fire, agriculture); dominated by forbs, graminoids, ferns. Invading or residual shrubs and trees may be present (tree cover < 10%, shrubs < 20%), time since disturbance < 20 yrs via forest succession or non-forested communities maintained in this stage.

Shrub/Herb: Early successional or shrub communities maintained by environment or disturbance; dominated by shrubby vegetation that is <10m tall. Seedlings and advance regeneration may be abundant (tree cover < 10%, shrub cover > 20%), time since disturbance < 40 years via forest succession.

Pole/Sapling: Trees > 10 m tall, typically densely stocked, have overtopped shrub and herbaceous layers; younger stands are vigorous (usually > 10-15 years old); older stagnated stands (up to 100 years old) are also included. Self-thinning and vertical structure not yet evident in the canopy, time since disturbance < 40 years via forest succession and up to 100+ years for dense stagnant stands.

Young Forest: Self-thinning has become evident and the forest canopy has begun to differentiate into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in the Pole/Sapling stage, time since disturbance generally 40-80 years, depending on tree species and ecological conditions.

Mature Forest: Trees established after the last disturbance have matured; a second cycle of shade-tolerant trees may have become established; understories become well developed as the canopy opens up; time since disturbance generally 80-250 years.

Old Forest: Older, structurally complex stands comprised shade-tolerant and regenerating tree species, but often including long-lived, older seral stage trees sometimes dominating the upper canopy. Snags and coarse woody debris in all stages of decomposition, understory of deciduous and regenerating confers typical. Shrub layer well-developed and dense, especially in light gaps. Time since last stand-replacing disturbance generally > 250 years.

Please rank the following bird species in terms of their dependence (low/medium/high) on the before mentioned habitat types in the Coastal Douglas Fir Zone.
(followed by drop-down menus for selecting habitat associations)

Table A1a: Reclassification scheme for Terrestrial Ecosystem Mapping (TEM) structural stages.

Structural stage	description	forest class
1,2	open	0
3	shrub/herb	0
4	pole/sapling	1
5	young forest	1
6	mature forest	2
7	old forest	2

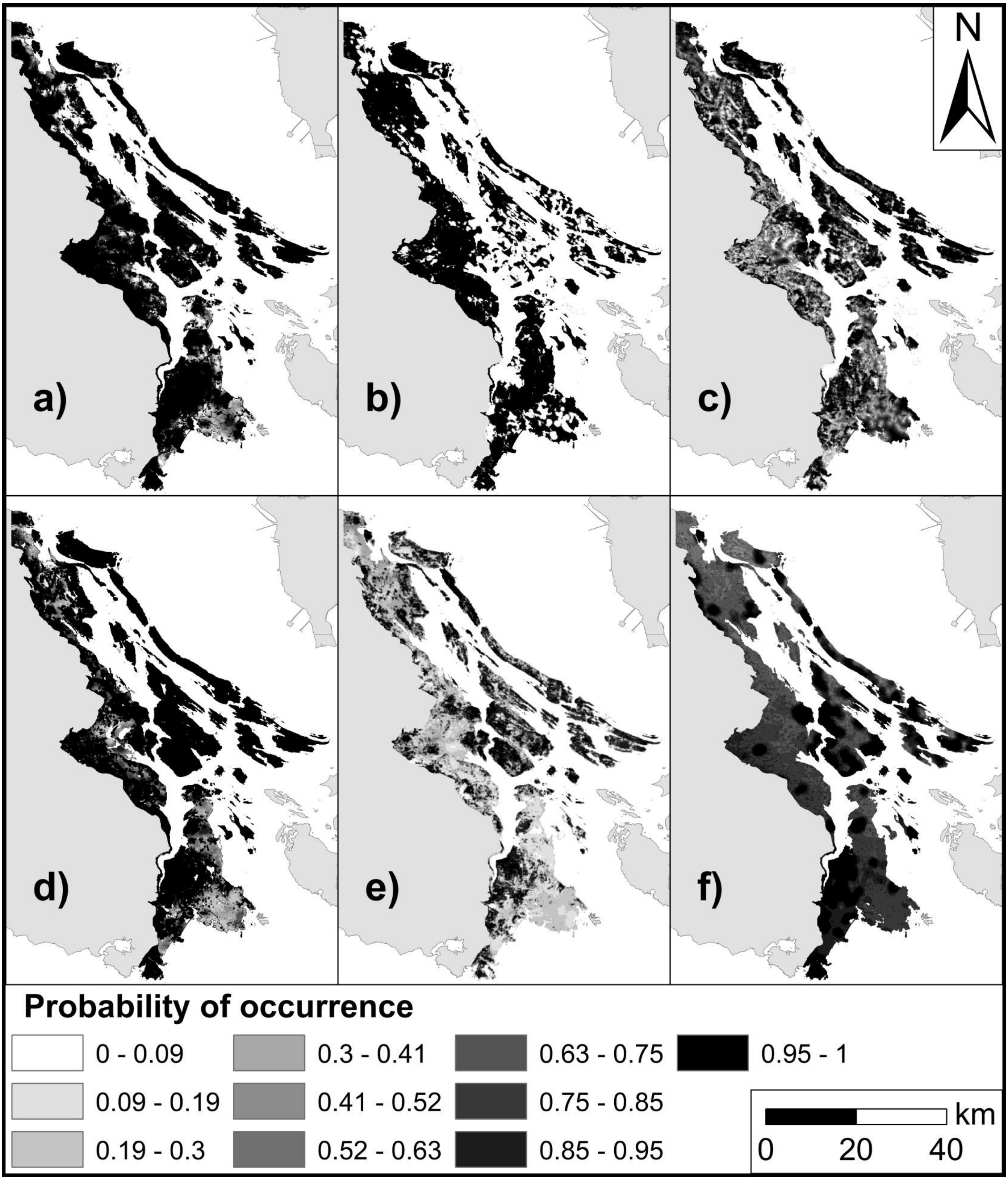
Table A1b: Reclassification scheme for Terrestrial Ecosystem Mapping (TEM) classes.

TEM code	Description	Reclass	TEM code	Description	Reclass	TEM code	Description	Reclass
CS	Cw-Slough sedge	Forest	OR	Oceanspray - Rose	Savannah	Wf52	Sweet gale - Sitka sedge	Shrub
DC	FdPl-Cladina	Forest	QB	Garry Oak - Brome/mixed grasses	Savannah	Wf53	Slender sedge - White beak-rush	Shrub
DF	Fd-Sword fern	Forest	RO	Rock Outcrop	Savannah	Wm04		Shrub
DG	FdBg - Oregon grape	Forest	SC	Cladina - Wallace's selaginella	Savannah	Wm05	Cattail	Shrub
DO	Fd - Oniongrass	Forest	TA	Talus	Savannah	Wm06	Great bulrush	Shrub
DS	FdHw-Salal	Forest	AS	Trembling aspen - Slough sedge	Shrub	Wm50	Sitka sedge - Hemlock -parsley	Shrub
HD	HwCw-Deer fern	Forest	BE	Beach	Shrub	Wm51	Three-way sedge	Shrub
HK	HwFd-Kindbergia	Forest	CD	Act - Red-osier dogwood	Shrub	Ws50	Hardhack (pink spirea) - Sitka sedge	Shrub
RB	Cw-Salmonberry	Forest	CW	Act-Willow	Shrub	Ws51	Sitka willow-Pacific willow-Skunk cabbage	Shrub
RC	CwSs-Skunk cabbage	Forest	Ed01	Tufted hairgrass - Meadow barley	Shrub	Ws52	Red alder - Skunk cabbage	Shrub
RF	Cw-Foamflower	Forest	Ed03	Arctic rush - Alaska plantain	Shrub	BK	Break water	Rural
RK	CwFd - Kindbergia	Forest	Em01	Widgeon-grass	Shrub	CF	Cultivated Field	Rural
RP	Cw - Indian-plum	Forest	Em02	Glasswort - Sea milkwort	Shrub	CO	Cultivated Orchard	Rural
RS	Cw-Sword fern	Forest	Em03	Seashore saltgrass	Shrub	CV	Cultivated Vineyard	Rural
RT	Cw-Black twinberry	Forest	Em05	Lyngbye's sedge	Shrub	GC	Golf Course	Rural
RV	Cw - Vanilla-leaf	Forest	GB	Gravel Bar	Shrub	RW	Rural	Rural
SS	Ss-Salmonberry	Forest	LA	Lake	Shrub	DM	Dam	Urban
AM	Arbutus-Hairy manzanita	Savannah	LS	Pl - Sphagnum	Shrub	ES	Exposed Soil	Urban
BA	Rock Outcrop	Savannah	MU	Mudflat Sediment	Shrub	GP	Gravel Pit	Urban
CB	Sand Clif	Savannah	OW	Shallow Open Water	Shrub	IN	Industrial	Urban
CL	Cliff	Savannah	PD	Pond	Shrub	MI	Mine	Urban
DA	FdPl - Arbutus	Savannah	RA	Nootka Rose - Pacific Crab Apple	Shrub	RN	Railway Surface	Urban
FC	Fescue-Common camas	Savannah	RE	Reservoir	Shrub	RZ	Road Surface	Urban
GO	Garry Oak - Ocean Spray	Savannah	RI	River	Shrub	TZ	Mine Tailings	Urban
LM	Dunegrass - Beach pea	Savannah	Wb50	Labrador tea - Bog-laurel -Peat-moss	Shrub	UR	Urban/ Suburban	Urban
OM	Garry Oak - Moss	Savannah	Wf51	Sitka sedge - Peat-moss	Shrub			

Table A2: Individual species model covariate averages.

Species	brown creeper	chestnut backed chickadee	golden-crowned kinglet	olive-sided flycatcher	pacific wren	pacific-slope flycatcher	pine siskin	purple finch	red-breasted nuthatch	townsend's warbler	Wilson's warbler	yellow-rumped warbler
Intercept	2.16	9.20	1.57	3.42	0.46	11.02	14.34	2.84	1.85	1.81	1.35	4.49
near_road	-	-	-0.05	-	0.06	-8.25	-	-	-	-2.04	-	-
near_frshw	-0.76	-	-	-	-	13.65	-	-	-	1.46	2.45	-2.84
near_saltw	-	1.53	-	-1.49	-	-	-0.08	-	-	-	-	-
URB_1KM	-	-	-	-4.59	-	-	-	-	-	-	-	-0.19
RUR_1KM	-	-1.99	-	-	-	-	-0.09	-	-	-	-3.63	-
FOR0_1KM	-	-	-	0.64	-	-	-	-	-	-	-	-
FOR1_1KM	-	-1.91	-	0.03	0.14	-4.79	-	-0.02	-	-0.44	1.25	-
FOR2_1KM	-1.25	-	-	-	-0.05	-	-	-	-	-	-	-2.41
SAV_1KM	-	0.13	-	-	-	-	-	-	-	0.28	-	-
SHR_1KM	-	-	-	-	-	8.17	-	-	-	-	-	-
URB_100	-	-1.23	0.01	-	-	-	-	-	-9.59	-	-	-0.20
RUR_100	-	-	-	-	-	-	-	-	-	-	0.11	-1.78
FOR0_100	-	0.61	-	-0.13	-	-	-	-	0.26	-	-0.52	-
FOR1_100	-	-	-0.67	0.63	-	-	-	0.01	1.72	-	-	-
FOR2_100	-	3.09	-	-2.48	-0.10	-	-	-	2.95	-	-	-0.03
SAV_100	-	0.40	-	-	0.07	-	-	-	-	0.07	-0.41	-
SHR_100	-	-	-	-	-	-	-1.42	-	-0.63	-	-	-
Near_Urb	-0.04	-1.17	-0.49	0.02	-	-	-	-	-	-	-2.56	-
CR_CL0	-	-4.20	-1.91	-	-	-	-	-0.21	-	-	0.13	-
CR_CL_2	3.51	-	-	1.55	1.69	-	11.15	-	-	1.73	-	-
CR_CL_3	-	-	-0.02	-	-	-0.06	-	-	-	-	-0.35	-
BRDLF	-	-	-	-	-	-0.89	-	-	-	-	6.34	-
OF_100	1.05	-	1.54	2.34	-	-	-	0.13	2.15	-	1.68	2.80
OF_1K	-	-	-	0.59	-	-3.58	-	2.06	-	-	0.07	2.62
Is_sie	-	-	-	1.21	-	3.38	-1.91	-	-	-	-	-
rd_up_100	-0.25	-	-	-	-0.01	-	-	0.21	-	-	1.58	-
rd_p_100	-	0.34	-	-	-	-	-	-0.02	-	-	-	-
rd_up_1k	-1.22	3.79	-	-	-0.54	2.91	1.04	-0.13	-	-	-	-
rd_p_1k	-	-	-	2.82	-	-6.88	-	-0.06	-	-	-	-
UTM_E	-	-	-	-	-0.07	-	-	0.62	-	-1.08	-	-
UTM_N	-	-	-	-	0.07	-	-	-0.25	-	0.10	-	-
UTM_E_UTM_N	-	-	-	-	-	-	-	-1.84	-	1.73	-	-
UTM_E2	-	-	-	-	-0.07	-	-	0.91	-	-0.53	-	-
UTM_N2	-	-	-	-	0.07	-	-	-0.25	-	0.25	-	-

Figure A1: Additional occupancy maps for 6 species: a) chestnut backed chickadee; b) pine siskin; c) townsend's warbler; d) pacific-slope flycatcher; e) pacific wren and f) purple finch.



Appendix 2.

Stepwise model selection code

```
f.b.occu.sig <- function(start.model, blocks, max.iter=NULL, forback, print.log=TRUE,
UMF=NULL){
# Stepwise model selection using occupancy models in R-package unmarked
# Author: Richard Schuster Date: 28 November 2010
# Built on a stepwise function for mixed effects models in R
# by Rense Nieuwenhuis (http://www.rensenieuwenhuis.nl/r-sessions-32/)
  zt <- 1.439531
  st.class <- class(start.model)
  modlst <- c(start.model)
  x <- 2
  best <- FALSE
        model.basis <- start.model
        if (is.null(max.iter) | max.iter > length(blocks)) max.iter <- length(blocks)
  for(i in 1:max.iter){
    models <- list()
    occup<- as.character(model.basis@formula[[1]])
    red <- 0
    for(j in 1:length(blocks)) {
      if (class(dummy <- try(update(model.basis, as.formula(paste("~. ~. + ", blocks[j]))))) ==
        st.class) {
        models[[j-red]] <- dummy
        modlst[x] <- models[[j-red]]
        x <- x + 1
      }
      else red <- red +1
    }
    LL <- unlist(lapply(models, function(x) {x@AIC}))
    LL <- -1 * LL
    for (j in order(LL, decreasing=TRUE)) {
      if(zt != FALSE) {
       b.model <- models[[j]]@estimates@estimates$state
       diff.par <- setdiff(names(b.model@estimates),
       names(model.basis@estimates@estimates$state@estimates))
       if (length(diff.par)==0) break
       sig.par <- FALSE

       for (k in 1:length(diff.par)) {
         if (!is.nan(SE(b.model)[[which(names(b.model@estimates) == diff.par[k])]]) &&
           !is.nan(SE(b.model)[[which(names(b.model@estimates) == diff.par[k])]])) {
            if(abs(coef(b.model)[[which(names(b.model@estimates) == diff.par[k])]]/
              SE(b.model)[[which(names(b.model@estimates) == diff.par[k])]]) > zt) {
               sig.par <- TRUE
```

```
              break
              }
           }
       }
      if(sig.par==TRUE) {
        model.basis <- models[[j]]
        blocks <- blocks[-j]
        best <- FALSE
        break
        }
       else best <- TRUE
       }
    }

    if (forback == TRUE) {
      param <- names(model.basis@estimates@estimates$state@estimates)[-1]
      z <- c(1:length(param))
      b.model <- model.basis@estimates@estimates$state
      rem <- FALSE

      for (k in 1:length(param)) {
        if (!is.nan(SE(b.model)[[which(names(b.model@estimates) ==  param[k])]]) &&
          !is.nan(SE(b.model)[[which(names(b.model@estimates) ==  param[k])]])) {
         z[k] <- abs(coef(b.model)[[which(names(b.model@estimates) ==  param[k])]]/
          SE(b.model)[[which(names(b.model@estimates) == param[k])]])
         if (z[k] < zt) {
          rem <- TRUE
          best <- FALSE
          }
        }
      }
      if (rem == TRUE) {
        if (class(dummy <- update(model.basis, as.formula(paste("~. ~. – ",
          param[which.min(z)])))) == st.class) {
          model.basis <- dummy
          blocks <- c(blocks, param[which.min(z)])
        }
      }
    }
    if(best == TRUE) break
  }
  fitlst <- fitList(fits = modlst)
  modsel <- modSel(fitlst,nullmod=NULL)
  return(list(model=model.basis, modlst=modlst, fitlst=fitlst, modsel=modsel))
}
```