Comparing VAST and sdmTMB GOA indices

Contents

```
#remotes::install_github("pbs-assess/sdmTMB", dependencies = TRUE)
library(VAST)
library(sp)
library(sdmTMB)
library(dplyr)
library(ggplot2)
library(here)

species <- "Sebastes_variabilis"

phase <- c("hindcast", "production")[1]
```

We will fit geostatistical spatiotemporal models with VAST and sdmTMB for the purposes of index standardization and compare the outputs given the same data. We will use data from the GOA AFSC GAP bottom trawl survey for the species specified above. The density units are kg/km^2.

```
dat_ll <- readRDS(here::here(paste0("data/GOA/", phase, "/dat_allspp.RDS"))) %>%
  filter(species == gsub("_", " ", species)) %>%
  select(year,
         lat = lat_dd,
         lon = lon_dd,
         catch_kg,
         effort = effort_km2,
         cpue_kg_km2) %>%
  mutate(vessel = "missing",
         pass = 0
  )
```

We begin by specifying the VAST model. To specify the mesh used to approximate the spatial process, which is used in the SPDE calculations, we use the k-means method in VAST. Rather than specifying the cutoff distance, meshes in VAST are typically generated by specifying only the number of knots, which we will later pass, along with other model settings to the function make_settings. We will use 750 knots, the same number in the mesh created in the existing production VAST index for this stock and region.

We will include a factor predictor that represents the mean estimate for each time slice. Settings used for index standardization are applied by specifying `purpose = "index2"`.

Unlike in sdmTMB, the fitting and predicting steps are all accomplished with the function `fit_model()` and thus we need to specify the prediction grid (referred to as the "extrapolation grid" in VAST). Here, X and Y are coordinates in UTM zone 5.

```
GOAgrid <- read.csv(here("extrapolation_grids", "GOAThorsonGrid_Less700m.csv"))
input_grid <- cbind(Lat=GOAgrid$Latitude,
```

```
                    Lon=GOAgrid$Longitude,
                    Area_km2=GOAgrid$Shape_Area/1000000)

settings <- make_settings(
  n_x = 750, # number of vertices in the SPDE mesh
  Region = "user",
  purpose = "index2", # index of abundance with Gamma for positive catches
  fine_scale = TRUE, # use bilinear interpolation from the INLA 'A' matrix
  zone = NA, # detects automatically
  Options = c("Calculate_Range" = TRUE, "Calculate_effective_area" = TRUE,
              "treat_nonencounter_as_zero" = FALSE),
  ObsModel = c(2, 1), # conventional logit-linked delta-Gamma; (2,4) if there are years with 100% encou
  bias.correct = TRUE,
  use_anisotropy = TRUE,
  max_cells = Inf, # use all grid cells from the extrapolation grid, production model used 2000
  knot_method = "grid", # or "samples"
  strata.limits = data.frame(STRATA = as.factor('All_areas')) # customize to sp.
)
```

Next we will fit a GLMM (generalized linear mixed effects model).

```
# create folder for saved output:
dir.create(paste0(here("species_specific_code", "GOA", species,
                       "index_comparison")), showWarnings = FALSE)

f <- here("species_specific_code", "GOA", species, "index_comparison",
          "VASTfit_catch_effort_offset.RDS")
if (!file.exists(f)) {
  fit <- fit_model(
    settings = settings,
    Lat_i = dat_ll[, "lat"],
    Lon_i = dat_ll[, "lon"],
    t_i = dat_ll[, "year"],
    b_i = dat_ll[, "catch_kg"],
    a_i = dat_ll[, "effort"],
    input_grid = input_grid,
    working_dir = paste0(here("species_specific_code", "GOA",
                              species, "index_comparison"), "/")
  )
  saveRDS(fit, file = f)
} else {
  fit <- readRDS(f)
  fit <- reload_model(fit)
}
#> Maximum absolute gradient of 5.5e-06: No evidence of non-convergence
```

We can look at parameter estimates. First we see estimates from the binomial component and second we see estimates from the positive Gamma component.

```
fit$parameter_estimates$diagnostics
#>           Param starting_value     Lower         MLE     Upper final_gradient
#> 1    ln_H_input     0.29351546 -5.000000  0.29346945  5.000000  -1.059339e-07
#> 2    ln_H_input     0.39948825 -5.000000  0.39946273  5.000000  -2.727626e-08
```

```
#> 3      beta1_ft     0.42219879      -Inf  0.42204862       Inf  -6.241321e-08
#> 4      beta1_ft     0.42915716      -Inf  0.42899570       Inf  -2.545885e-08
#> 5      beta1_ft     0.85863327      -Inf  0.85842793       Inf   9.444132e-08
#> 6      beta1_ft     0.90744754      -Inf  0.90726354       Inf   3.071726e-08
#> 7      beta1_ft     0.75560253      -Inf  0.75546759       Inf  -7.121172e-08
#> 8      beta1_ft     0.90666627      -Inf  0.90649766       Inf   2.292328e-09
#> 9      beta1_ft     0.91790088      -Inf  0.91773951       Inf  -2.035649e-08
#> 10     beta1_ft     0.84602060      -Inf  0.84584646       Inf   1.321053e-08
#> 11     beta1_ft     0.91570847      -Inf  0.91554281       Inf  -5.465795e-09
#> 12     beta1_ft     0.93105536      -Inf  0.93089948       Inf  -2.817762e-08
#> 13     beta1_ft     0.91023283      -Inf  0.91006228       Inf  -1.410593e-08
#> 14     beta1_ft     0.87792089      -Inf  0.87772769       Inf   5.248912e-08
#> 15     beta1_ft     0.91093745      -Inf  0.91081237       Inf  -9.736811e-08
#> 16     beta1_ft     1.00756359      -Inf  1.00736605       Inf   6.194937e-08
#> 17     beta1_ft     0.89280051      -Inf  0.89261835       Inf   2.400690e-08
#> 18     beta1_ft     0.95583186      -Inf  0.95564299       Inf   4.811562e-08
#> 19   L_omega1_z     4.39254304      -Inf  4.39258993       Inf  -2.625875e-08
#> 20 L_epsilon1_z     0.05850927      -Inf  0.05851071       Inf  -3.292228e-06
#> 21    logkappa1    -5.30722715 -6.765487 -5.30724636 -1.659642   7.606491e-08
#> 22     beta2_ft     4.05515220      -Inf  4.05518688       Inf  -6.857408e-08
#> 23     beta2_ft     4.19328907      -Inf  4.19326173       Inf   3.466909e-09
#> 24     beta2_ft     3.77243150      -Inf  3.77234612       Inf   6.939842e-08
#> 25     beta2_ft     3.41602808      -Inf  3.41603692       Inf  -2.711630e-08
#> 26     beta2_ft     3.74153864      -Inf  3.74154244       Inf  -3.094240e-08
#> 27     beta2_ft     3.77560238      -Inf  3.77547341       Inf   9.633629e-08
#> 28     beta2_ft     3.76067440      -Inf  3.76060555       Inf   4.534304e-08
#> 29     beta2_ft     3.72182832      -Inf  3.72178186       Inf   2.531156e-08
#> 30     beta2_ft     3.80087956      -Inf  3.80075975       Inf   9.630241e-08
#> 31     beta2_ft     3.80774508      -Inf  3.80762380       Inf   8.370911e-08
#> 32     beta2_ft     3.92710587      -Inf  3.92715065       Inf  -7.122938e-08
#> 33     beta2_ft     3.85739081      -Inf  3.85736508       Inf   3.668077e-09
#> 34     beta2_ft     3.52967073      -Inf  3.52958881       Inf   4.230317e-08
#> 35     beta2_ft     3.45493819      -Inf  3.45486272       Inf   4.211975e-08
#> 36     beta2_ft     3.65418714      -Inf  3.65412724       Inf   3.123425e-08
#> 37     beta2_ft     3.84501443      -Inf  3.84487497       Inf   7.969815e-08
#> 38   L_omega2_z     1.12016688      -Inf  1.12015107       Inf  -7.271392e-07
#> 39 L_epsilon2_z     1.06517900      -Inf  1.06516475       Inf  -1.400187e-06
#> 40    logkappa2    -2.35589656 -6.765487 -2.35594899 -1.659642   1.466808e-06
#> 41    logSigmaM     0.46962478      -Inf  0.46962267 10.000000  -1.739769e-06
```

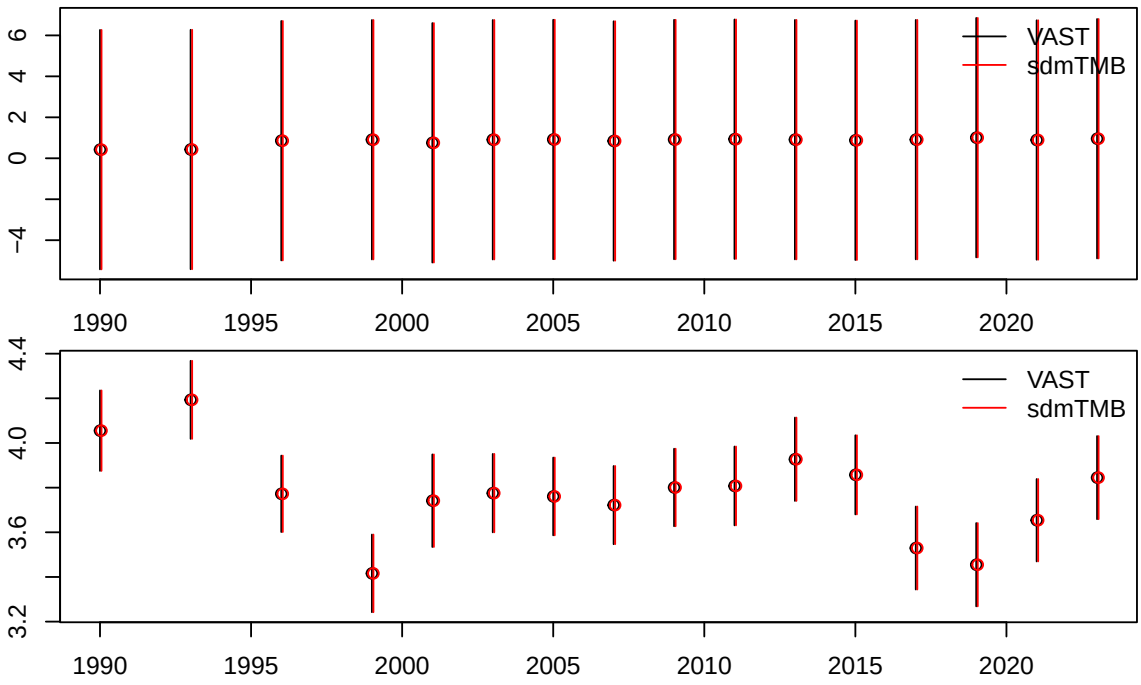
Now we fit the same model in sdmTMB:

```
dat <- dat_ll %>%
  rename(X = lon, Y = lat)

dat$year_f <- as.factor(dat$year)

coordinates(dat) <- ~ X + Y
proj4string(dat) <- CRS("+proj=longlat +datum=WGS84")
dat <- as.data.frame(spTransform(dat, CRS("+proj=utm +zone=5")))
# scale to km so values don't get too large
dat$X <- dat$coords.x1 / 1000
dat$Y <- dat$coords.x2 / 1000
```

```r
f1 <- here("species_specific_code", "GOA", species,
           "index_comparison", "fit_sdmTMB_catch_effort_offset.RDS")
if (!file.exists(f1)) {
# make mesh and fit model
mesh <-  make_mesh(dat, xy_cols = c("X", "Y"), mesh = fit$spatial_list$MeshList$anisotropic_mesh) #pass
#mesh <-  make_mesh(dat, xy_cols = c("X", "Y"), n_knots = 50, type = "kmeans") #coarser mesh for experi

fit_sdmTMB <- sdmTMB(
  catch_kg ~ 0 + year_f,
  data = dat,
  mesh = mesh,
  family = delta_gamma(type = "poisson-link"),
  time = "year",
  spatial = "on",
  spatiotemporal = "iid",
  offset = log(dat$effort),
  silent = FALSE,
  anisotropy = TRUE,
  do_fit = TRUE
  #, do_index = TRUE (to compute index at same time, requires passing args)
)
fit_sdmTMB
saveRDS(fit_sdmTMB, file = f1)
} else {
fit_sdmTMB <- readRDS(f1)
}

# diagnose estimation issues due to model structure
#TMBhelper::check_estimability(fit_sdmTMB$tmb_obj)
```

We wrote some custom code to extract comparable parameters (not shown above). Here are the annual mean estimates in link space with 95% confidence intervals for the two components to the delta model:

```r
par(mfrow = c(2, 1), cex = 0.8, mar = c(1.5, 1, 1, 1), oma = c(2, 3, 1, 1))
plot_betas(fit, fit_sdmTMB, "beta1_ft", sdmTMB_pars = 1)
plot_betas(fit, fit_sdmTMB, "beta2_ft", sdmTMB_pars = 2)
```



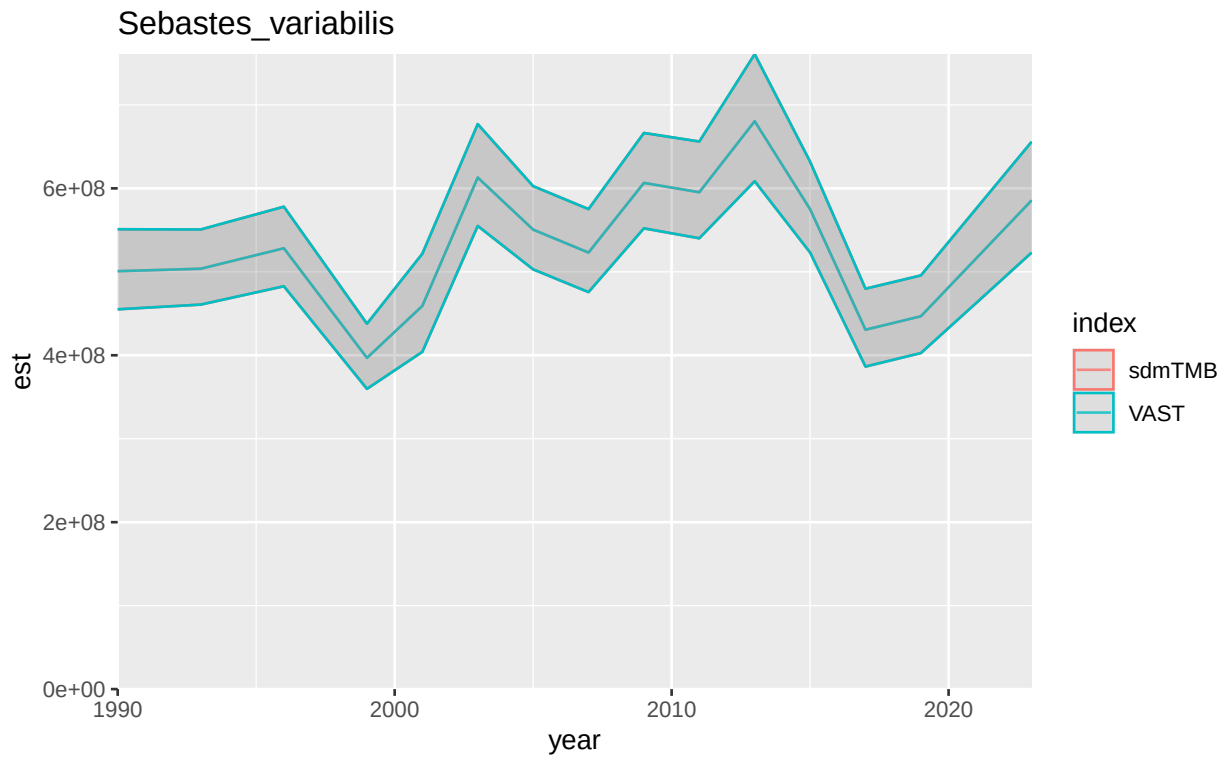
We can compare the index we would get using sdmTMB.

```
# prep prediction grid and transform to UTM projection
grid_ll <- as.data.frame(input_grid)
names(grid_ll) <- tolower(names(grid_ll))
coordinates(grid_ll) <- ~ lon + lat
proj4string(grid_ll) <- CRS("+proj=longlat +datum=WGS84")
grid <- as.data.frame(spTransform(grid_ll, CRS("+proj=utm +zone=5")))

# rename and scale to km so values don't get too large
grid$X <- grid$coords.x1 / 1000
grid$Y <- grid$coords.x2 / 1000

# or with sf:
# grid_ll <- sf::st_as_sf(
#   x = grid_ll,
#   coords = c("lon", "lat"),
#   crs = "+proj=longlat +datum=WGS84"
# )
# grid <- sf::st_transform(grid_ll, crs = "+proj=utm +zone=5")

# replicate extrapolation grid for each year in data
pred_grid <- replicate_df(grid, "year_f", unique(dat$year_f))
pred_grid$year <- as.integer(as.character(factor(pred_grid$year_f)))

# make predictions and get index
f2 <- here("species_specific_code", "GOA", species,
           "index_comparison", "predictions_catch_effort_offset.RDS")
if (!file.exists(f2)) {
```

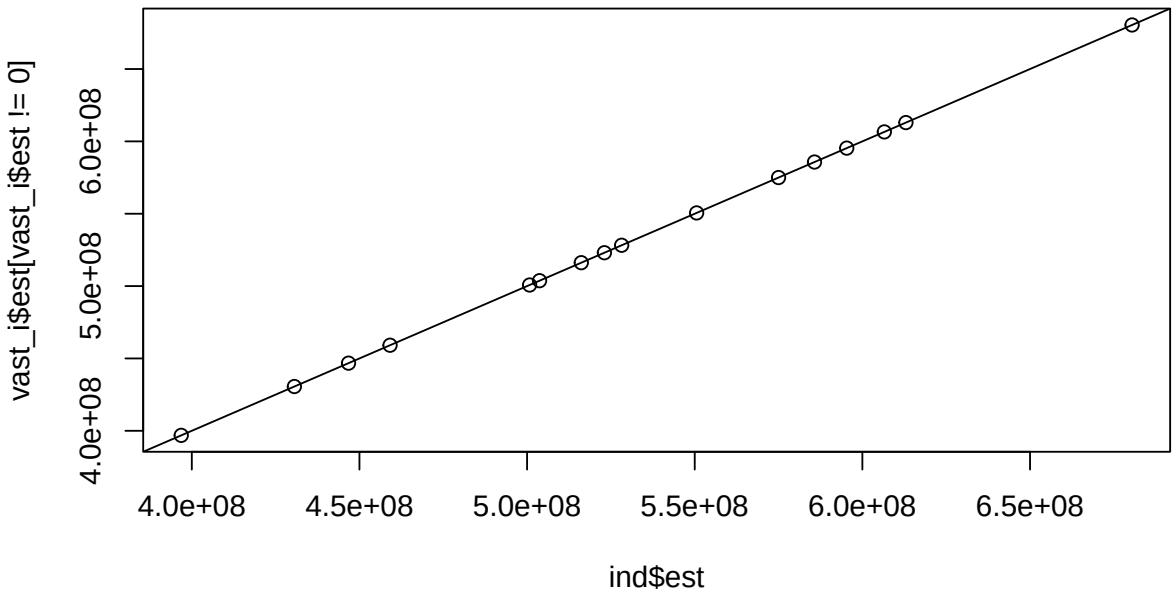
```
p <- predict(fit_sdmTMB, newdata = pred_grid, return_tmb_object = TRUE)
saveRDS(p, file = f2)
} else {
p <- readRDS(f2)
}

f3 <- here("species_specific_code", "GOA", species,
           "index_comparison", "index_catch_effort_offset.RDS")
if (!file.exists(f3)) {
ind <- get_index(p, bias_correct = TRUE, area = p$data$area_km2)
saveRDS(ind, file = f3)
} else {
ind <- readRDS(f3)
}
```

Now, we can compare the indices.

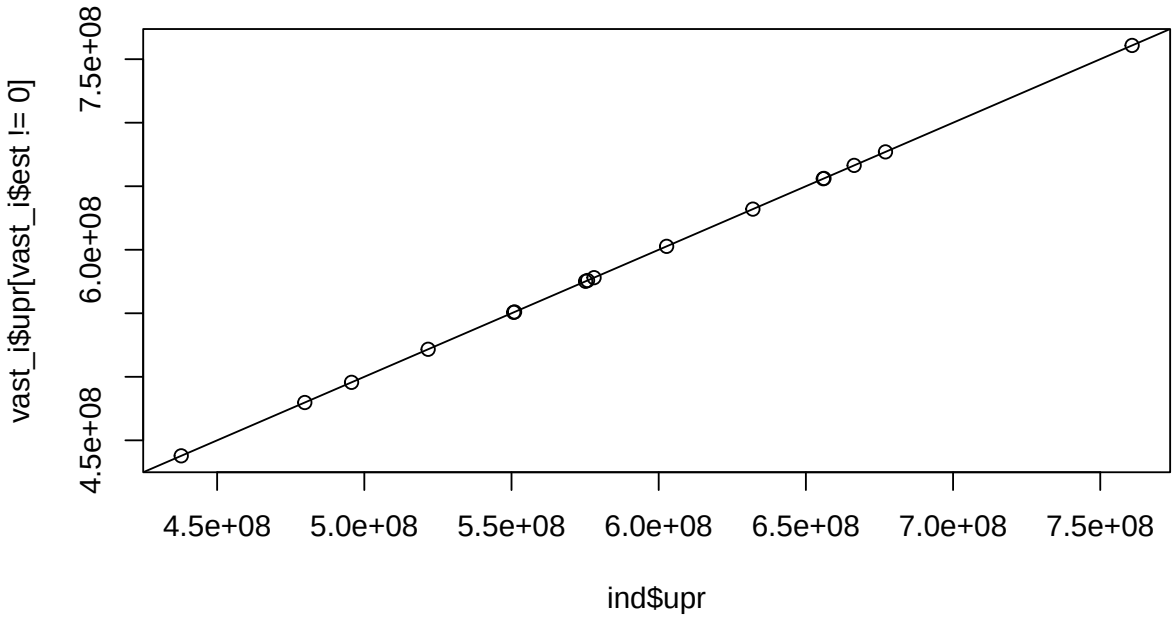
```
sdm_i <- ind %>% mutate(index = "sdmTMB")
vast_i <- read.csv(here("species_specific_code", "GOA", species,
                        "index_comparison", "Index_catch_effort_offset.csv")) %>%
  mutate(index = "VAST", year = as.numeric(Time), est = Estimate,
    se = Std..Error.for.ln.Estimate.) %>%
  select(index, year, est, se) %>%
  filter(year %in% unique(sdm_i$year)) %>%
  mutate(lwr = exp(log(est) + qnorm(0.025) * se)) %>%
  mutate(upr = exp(log(est) + qnorm(0.975) * se))
both_i <- bind_rows(sdm_i, vast_i) %>% filter(est > 0)

ggplot(both_i, aes(x = year, y = est, ymin = lwr, ymax = upr, colour = index)) +
  geom_ribbon(alpha = 0.1) +
  geom_line(alpha = 0.8) +
  ylim(0, max(both_i$upr)) +
  ggtitle(species) +
  coord_cartesian(expand = FALSE)
```



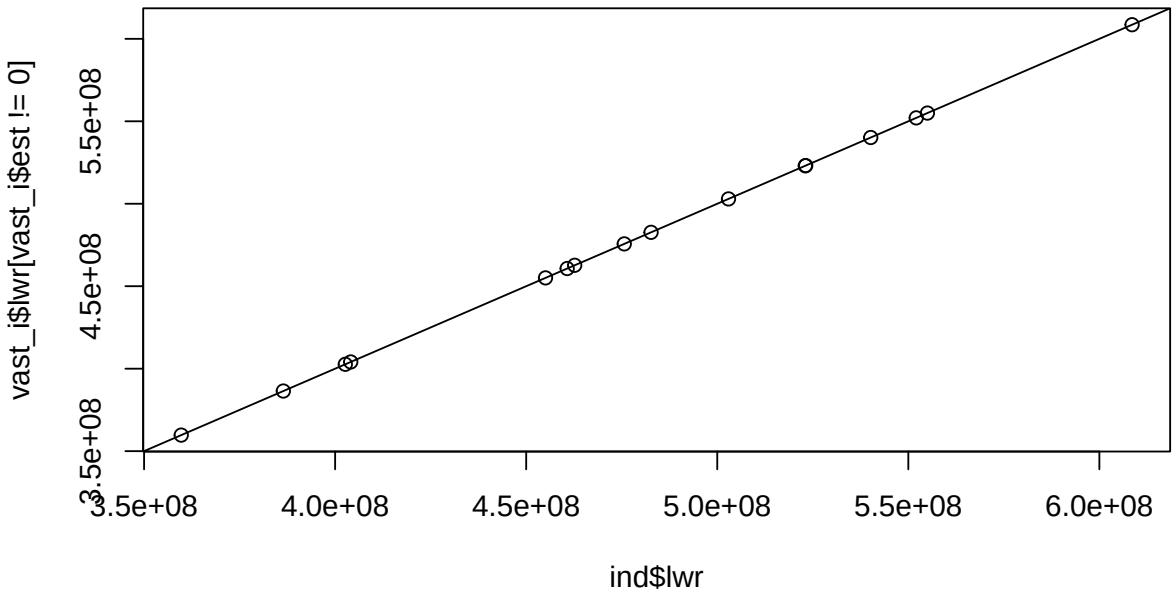

```
plot(ind$est, vast_i$est[vast_i$est != 0]);abline(0, 1)
```




```
plot(ind$upr, vast_i$upr[vast_i$est != 0]);abline(0, 1)
```




```
plot(ind$lwr, vast_i$lwr[vast_i$est != 0]);abline(0, 1)
```




```
(ind$est - vast_i$est[vast_i$est != 0]) / vast_i$est[vast_i$est != 0]
```

```
#>  [1]  1.349487e-10  3.489466e-10  1.929027e-11 -3.611859e-10  8.923694e-10
#>  [6]  3.524434e-10  5.111255e-10  6.090364e-10 -2.246860e-10 -5.427516e-10
#> [11] -6.160997e-10  2.027832e-10 -8.180828e-12  1.865313e-10  4.561185e-10
#> [16]  4.549860e-10
(ind$upr - vast_i$upr[vast_i$est != 0]) / vast_i$upr[vast_i$est != 0]
#>  [1] -4.843841e-10  2.818773e-09  5.195027e-10 -2.783029e-09 -2.759503e-09
#>  [6]  3.593911e-09  1.727855e-09 -2.043688e-09 -4.022377e-11 -4.271642e-10
#> [11]  8.802505e-09  9.338130e-10  4.078689e-09  2.524356e-09  2.657561e-09
#> [16]  1.983836e-10
(ind$lwr - vast_i$lwr[vast_i$est != 0]) / vast_i$lwr[vast_i$est != 0]
#>  [1]  7.542768e-10 -2.120878e-09 -4.809202e-10  2.060656e-09  4.544244e-09
#>  [6] -2.889024e-09 -7.056044e-10  3.261757e-09 -4.091447e-10 -6.583392e-10
#> [11] -1.003470e-08 -5.282495e-10 -4.095053e-09 -2.151293e-09 -1.745324e-09
#> [16]  7.115872e-10
```

This document was built using:

```
R.Version()$version.string
#> [1] "R version 4.3.0 (2023-04-21 ucrt)"
packageVersion("VAST")
#> [1] '3.11.2'
packageVersion("FishStatsUtils")
#> [1] '2.13.1'
```