Plausible bounds for availability of and net efficiency for northern shortfin squid in the US fishery & Northeast Fishery Science Center Bottom Trawl Survey

Co-Authors:
John P Manderson. OpenOcean Research
Brooke Lowman. NEFSC Cooperative Research Branch
Ben Galuardi, NOAA GARFO
Anna Malek Mercer. NEFSC Cooperative Research Branch

Disclosure: Manderson serves as science advisor for 3 major shore side facilities & some independent owner operators in the illex fishery.

Part of a larger collaborative to develop products valuable to the 2021 Research Track Assessment (RTA)
(Lowman, Mercer, Manderson, Rago on RTA Working Group)

1) Technical and economic aspects of northern shortfin squid (*Ilex illecebrosus*) processing and marketing essential for interpreting fishing effort and catch as indicators of population trend and condition *(Completed)*

2) Harvester perspectives on ecological, economic and social factors driving *Ilex illecebrosus* landings in US waters *(Ongoing)*

3) Analysis of pulses of immigration of *Ilex illecebrosus* into the fishery within framework of a generalized depletion model with an open population assumption *(Ongoing)*

4) Standardized fishery LPUE/CPUE developed using standard FDD and NOAA Cooperative research study fleet data *(Ongoing)*

5) Mental model of ecological & human dimensions of Illex fishery system. *(Ongoing)*

6) Plausible bounds to availability & net efficiency for fishery & survey (*this work*)

Why focus on the availability (v) of & net efficiency (q) for Illex to the NEFSC survey & US fishery?

“Rago 2021. Indirect Methods for Bounding Biomass and Fishing Mortality for Illex Squid and Implications of an Alternative Quota in 2022. Rept. to SSC”

Provide Rago with plausible bounds for $v_{fishery}$, $q_{fishery}$, v_{survey}, q_{survey}

Rago 2021; Table 2.1. Data sources, input parameters and outputs for the various models used to derive bounds on biomass and fishing mortality for Illex squid.

Method/Model	*Data*	*Years*	*Input Parameters*	*Output*	*Comments*
Depletion Model	• Landings by week • Effort by week for trips, days fished, days absent • Ave wt/indiv by week	1997-2018. Exclude 2006-2007.	None	• Estimated q for Effort • Initial Pop Size • Proportional depletion	• Violation of assumptions evident in most years • Lack of fit suggests low intensity of fishing mortality and high level of migration/recruitment into the fishing area
Envelope	• Fall Survey swept area biomass • Landings	1997-2019	Min and Max F Min and max M Min and Max q Min and Max v	• Upper limit Biomass • Lower Limit Biomass	• Constrained upper and lower bounds of biomass suggest feasible range of population behavior for any population dynamics model.
Escapement	• Fall Survey swept area biomass • Landings	1997-2019	Min and max M Min and Max q Min and Max v	• Realized fraction escapapement by year • Evaluation of alternative harvest scenarios	• Evaluate likelihood of exceeding target escapement for alternative quotas over historical period. • Compare with other management, eg with 50% escapement.
Mass Balance	• Min swept area Spring survey • Min Swept area Fall survey • Total Catch	1997-2019	• Ratio of F/M • Min and Max qv	• Estimates of migration, growth and recruitment necessary to balance catch and natural Mortality	• Uses simple mass balance to illustrate potential magnitude of inshore and offshore movements and growth.
VMS	• VMS locations of fishing speeds and durations • Average net width by permit number	2017-2019	• Availability • Move along rule—acceptable rate of depletion during fishing • Area of fishing activity relative to total habitat area. • Ratio of density in fished to unfished areas	• Maximum F • Area weighted average F	• Fishing mortality estimates are for entire season. Divide by 24 to obtain weekly F for comparisons

frontiers in Marine Science | Marine Conservation and Sustainability

SECTION ABOUT ARTICLES RESEARCH TOPICS FOR AUTHORS EDITORIAL BOARD ARTICLE ALERTS

‹ Articles

THIS ARTICLE IS PART OF THE RESEARCH TOPIC
Habitat and Distribution Models of Marine and Estuarine Species: Advances for a S

ORIGINAL RESEARCH article
Front. Mar. Sci., 23 February 2021 | https://doi.org/10.3389/fmars.2021.631657

Northern Shortfin Squid (*Illex illecebrosus*) Fishery Footprint on the Northeast US Continental Shelf

Brooke A. Lowman[1,2*], Andrew W. Jones[3], Jeffrey P. Pessutti[3], Anna M. Mercer[3], John P. Manderson[4] and Benjamin Galuardi[2,5]

[1]ERT, Inc. under Contract to Northeast Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Narragansett, RI, United States
[2]School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, MA, United States
[3]Northeast Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Narragansett, RI, United States
[4]OpenOcean Research, Philadelphia, PA, United States
[5]Greater Atlantic Regional Fisheries Office, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Gloucester, MA, United States

Expanded update to Lowman's 2021 work on availability to the fishery

(framework developed at Industry organized & hosted November 2019 Illex summit)

Feature	Lowman et al. 2021	Manderson et al. 2021
Surveys for training & testing	US surveys & NOAA Study fleet	US + DFO Canada FI trawl surveys
Modeling Framework	VAST (Delta model with binomial GLMM)	binomial GAMM
Evaluation of prediction accuracy		10 fold cv + ROC
Availability estimate	v_f	v_f & v_s
Net efficiency estimate (expert opinion)		q_f & q_s

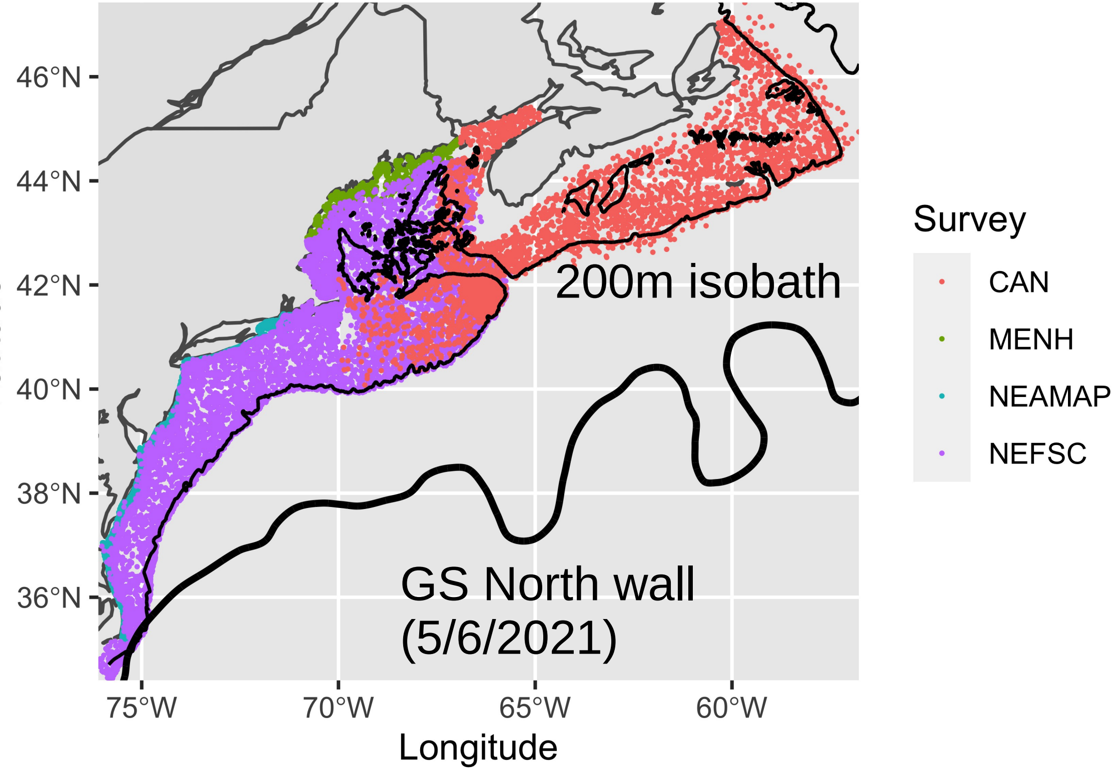
Availability Estimates

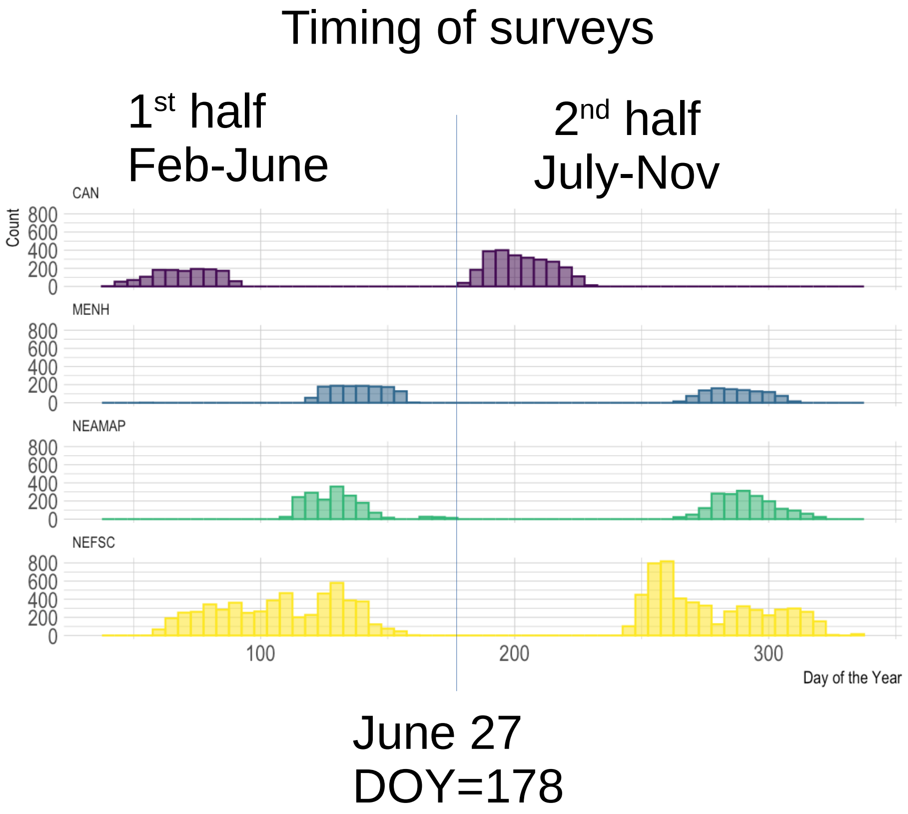
Approach

- Develop Species Distribution Model (SDM) using available US & Canadian fishery independent bottom trawl survey data
- Evaluate prediction accuracy of SDM & determine thresholds for classification of species distribution areas (SDAs)
- Use SDAs along with fishery and survey footprints to estimate availability to fishery (v_f) and the NEFSC survey (v_s)

Survey data used to train & evaluate SDM

(2008-2019: All surveys performed 2008. 2019 pre-covid)





Squid abundant slope sea where there is no survey data (Rathjen, 1981; Vecchione & Pohle, 2002; Harrop et al, 2014; Shea et al, 2017)

ICES Journal of Marine Science

ICES CIEM International Council for the Exploration of the Sea / Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2020), 77(2), 539–552. doi:10.1093/icesjms/fsz254

Original Article

Combining fisheries surveys to inform marine species distribution modelling

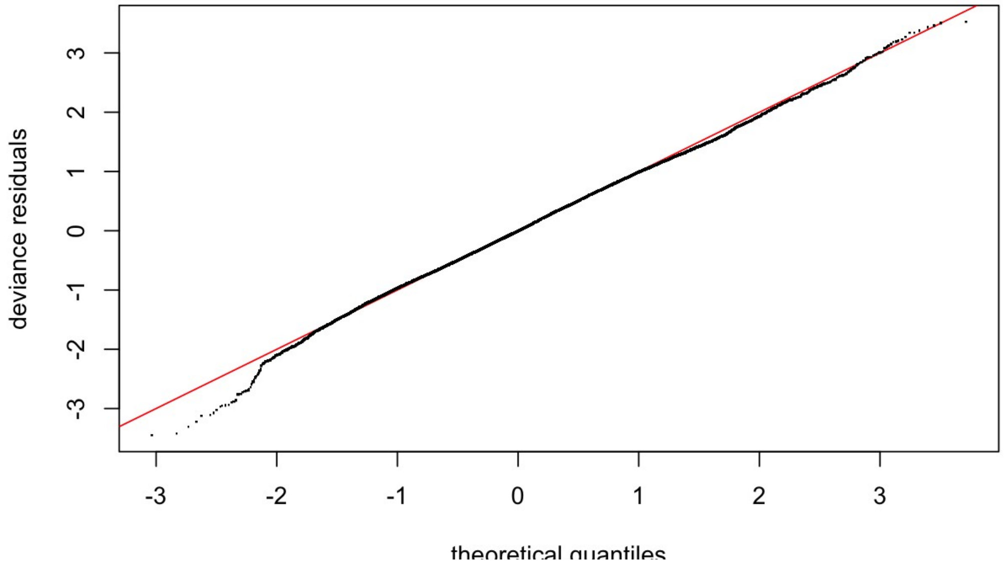
Meadhbh Moriarty[1,2,3,4]*, Suresh A. Sethi[3,5], Debbi Pedreschi[6], T. Scott Smeltz[2,3], Chris McGonigle[1], Bradley P. Harris[3], Nathan Wolf[3], and Simon P. R. Greenstreet[4]

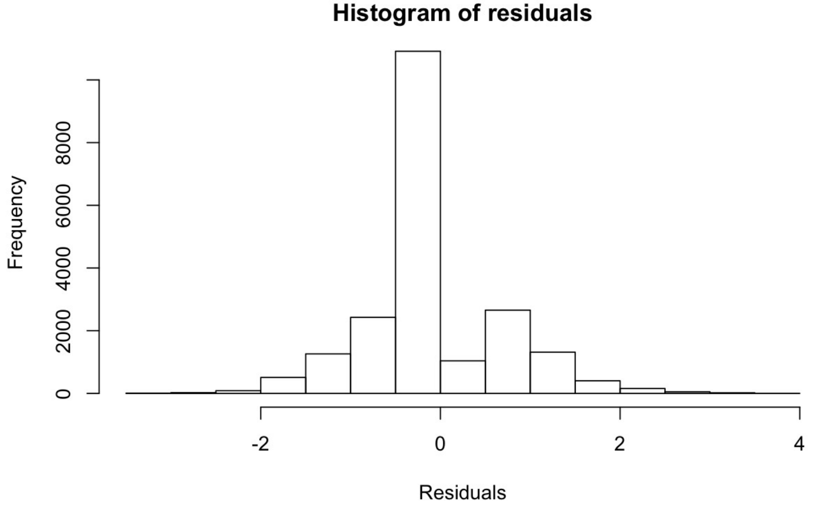
Use generalized additive mixed models with survey as random effect to integrate data from multiple surveys.

Final GAMM model with lowest AIC

```
Family: binomial
Link function: logit

Formula:
Total.Count > 1 ~ s(Survey, bs = "re", by = dum) + offset(logAreasw) +
    s(altitude, by = Survey, bs = "cc") + te(x.utm, y.utm, yr,
    by = seas, bs = "cs")

Parametric coefficients:
            Estimate Std. Error z value Pr(>|z|)
(Intercept)  -7.7728     0.5325   -14.6   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Approximate significance of smooth terms:
                               edf Ref.df   Chi.sq  p-value
s(Survey):dum             2.740645      3  183.669  < 2e-16 ***
s(altitude):SurveyCAN     0.008599      8    0.006  0.48695
s(altitude):SurveyMENH    3.517151      8  112.050 6.33e-08 ***
s(altitude):SurveyNEAMAP  4.409370      8   88.891 1.19e-07 ***
s(altitude):SurveyNEFSC   2.225924      8   11.370  0.00168 **
te(x.utm,y.utm,yr):seas  80.096403    125 4844.023  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

R-sq.(adj) =  0.403   Deviance explained = 40.1%
-REML = 5390.4  Scale est. = 1          n = 20877
```

GAMM Residuals



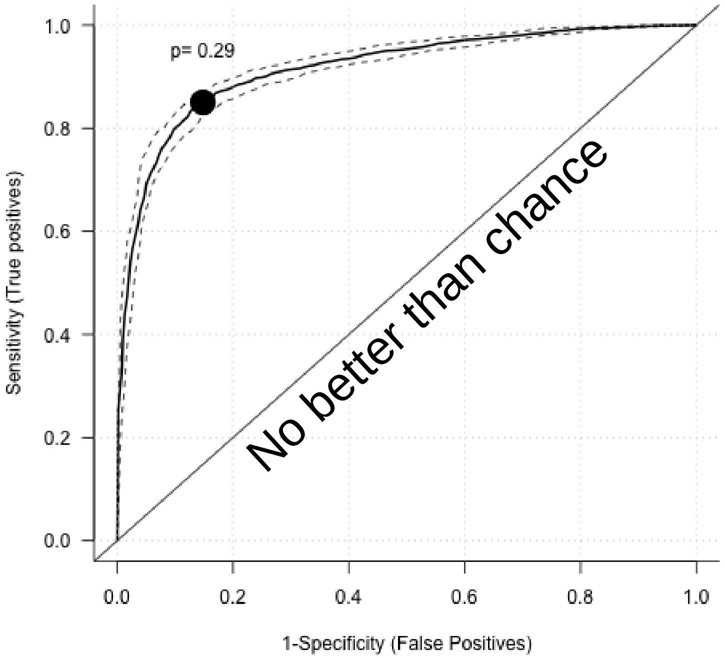


Are basis dimensions (=wiggliness) of smoothers appropriate?

```
Method: REML   Optimizer: outer newton
full convergence after 8 iterations.
Gradient range [-0.001293864,0.0001167029]
(score 5390.423 & scale 1).
Hessian positive definite, eigenvalue range [0.00130545,8.830364].
Model rank =  162 / 162

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                                 k'      edf k-index p-value
s(Survey):dum                4.0000   2.7407      NA      NA
s(altitude):SurveyCAN        8.0000   0.0086    0.97    0.14
s(altitude):SurveyMENH       8.0000   3.5171    0.97    0.08 .
s(altitude):SurveyNEAMAP     8.0000   4.4094    0.97    0.13
s(altitude):SurveyNEFSC      8.0000   2.2259    0.97    0.14
te(x.utm,y.utm,yr):seas    125.0000  80.0964    0.86  <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

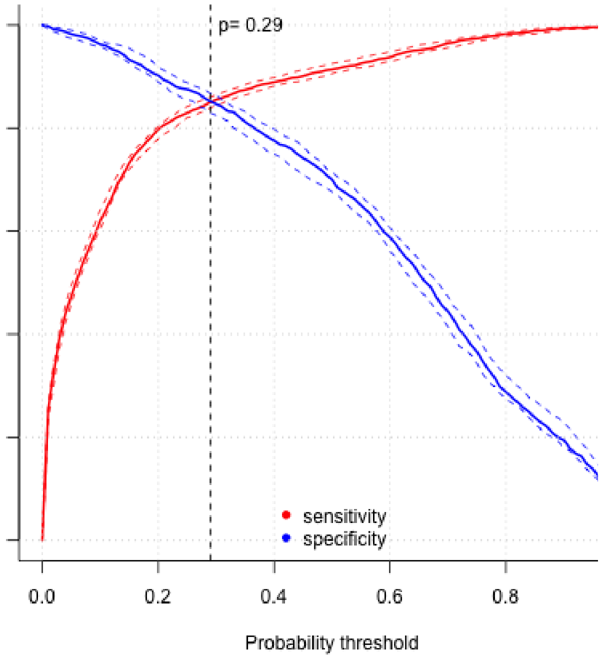
Model cross validation-evaluation

ROC curve



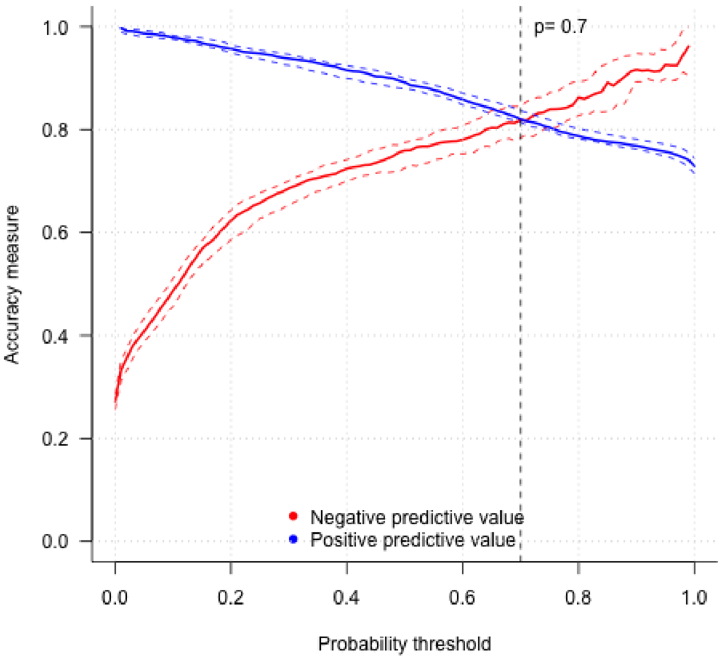
Sensitivity-Specificity

$$\frac{\#\text{ true pred.}}{\#\text{ obs in class}}$$



Negative-positive Predictive value

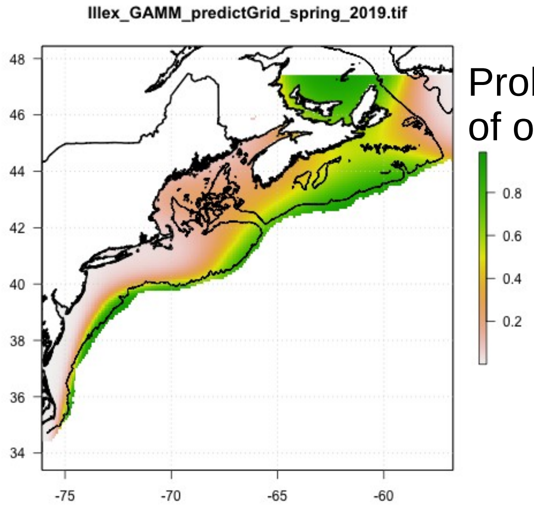
$$\frac{\#\text{ true pred.}}{\#\text{ obs in class} + \#\text{ false pred}}$$



10 fold cross validation: Train model with random selection of 90% of the data. Use remaining 10% to compare prediction against observations. Perform Receiver Operator Characteristic (ROC) analysis of confusion matrix developed over range of occupancy probability thresholds. Repeat 10 x's

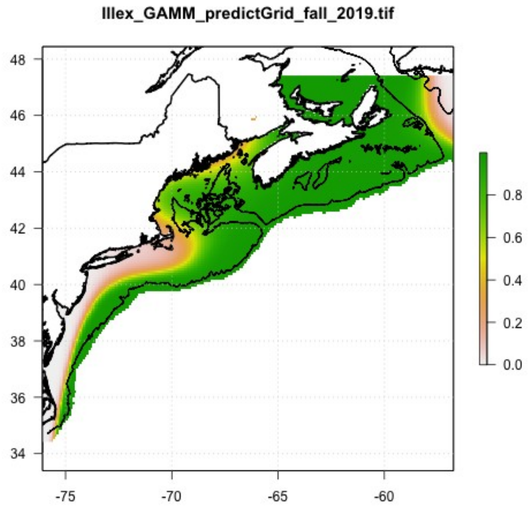
Predictions

1st half 2019

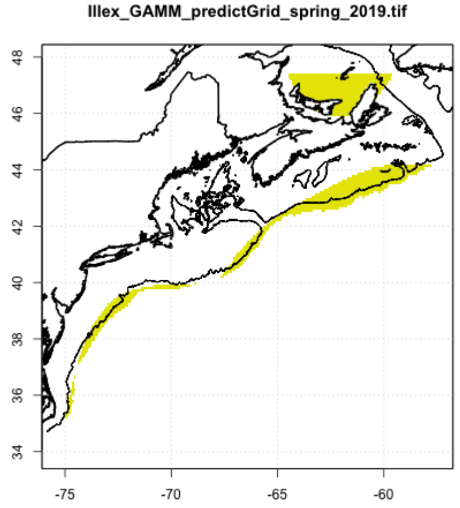


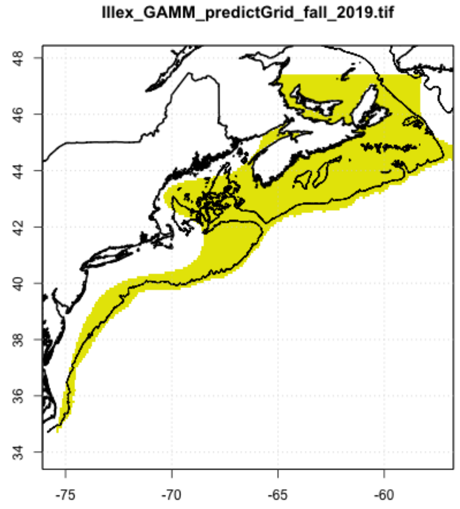
Probability of occupancy

2nd half 2019



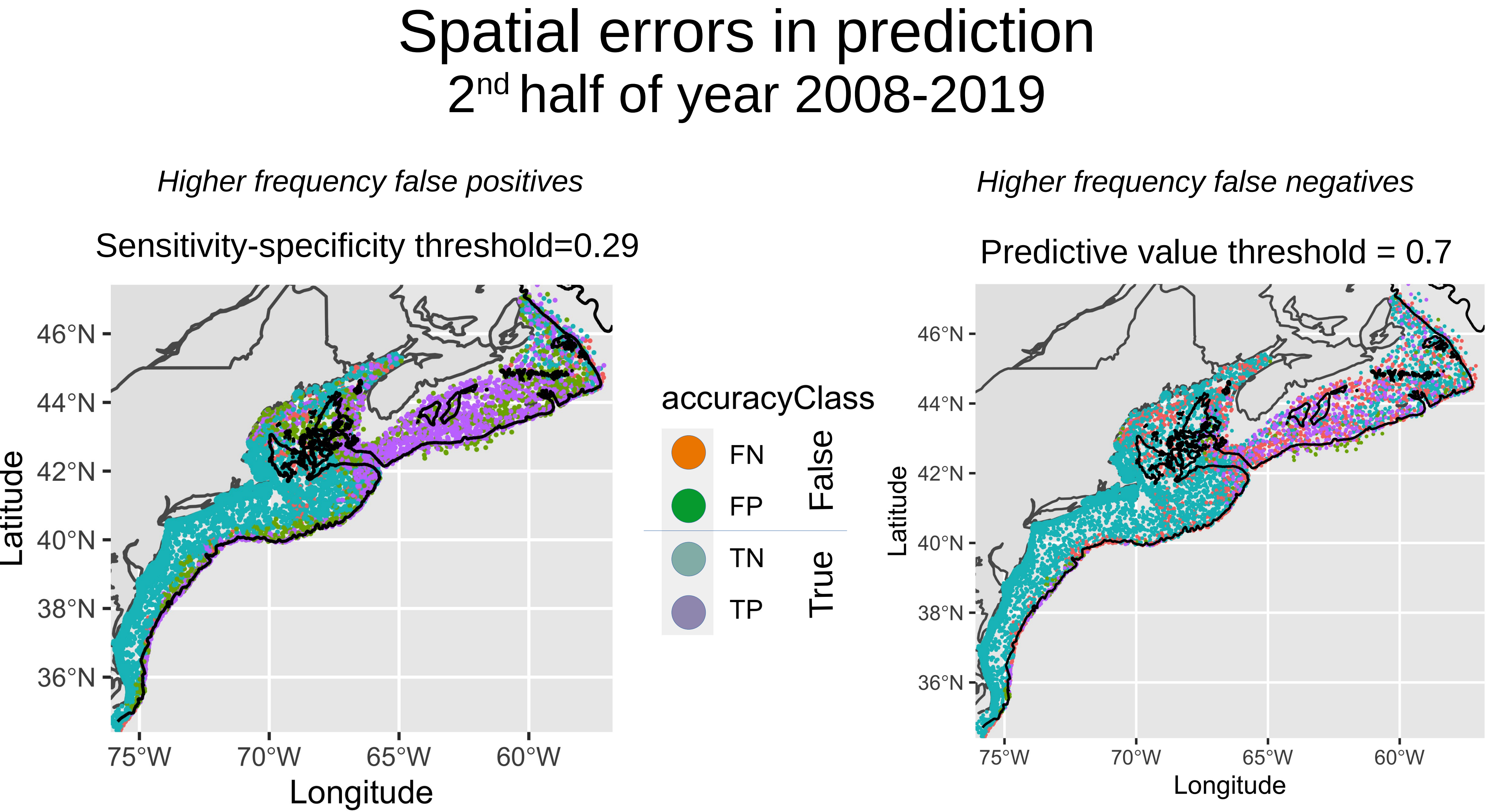
Predictions classified using predictive value threshold (0.7)





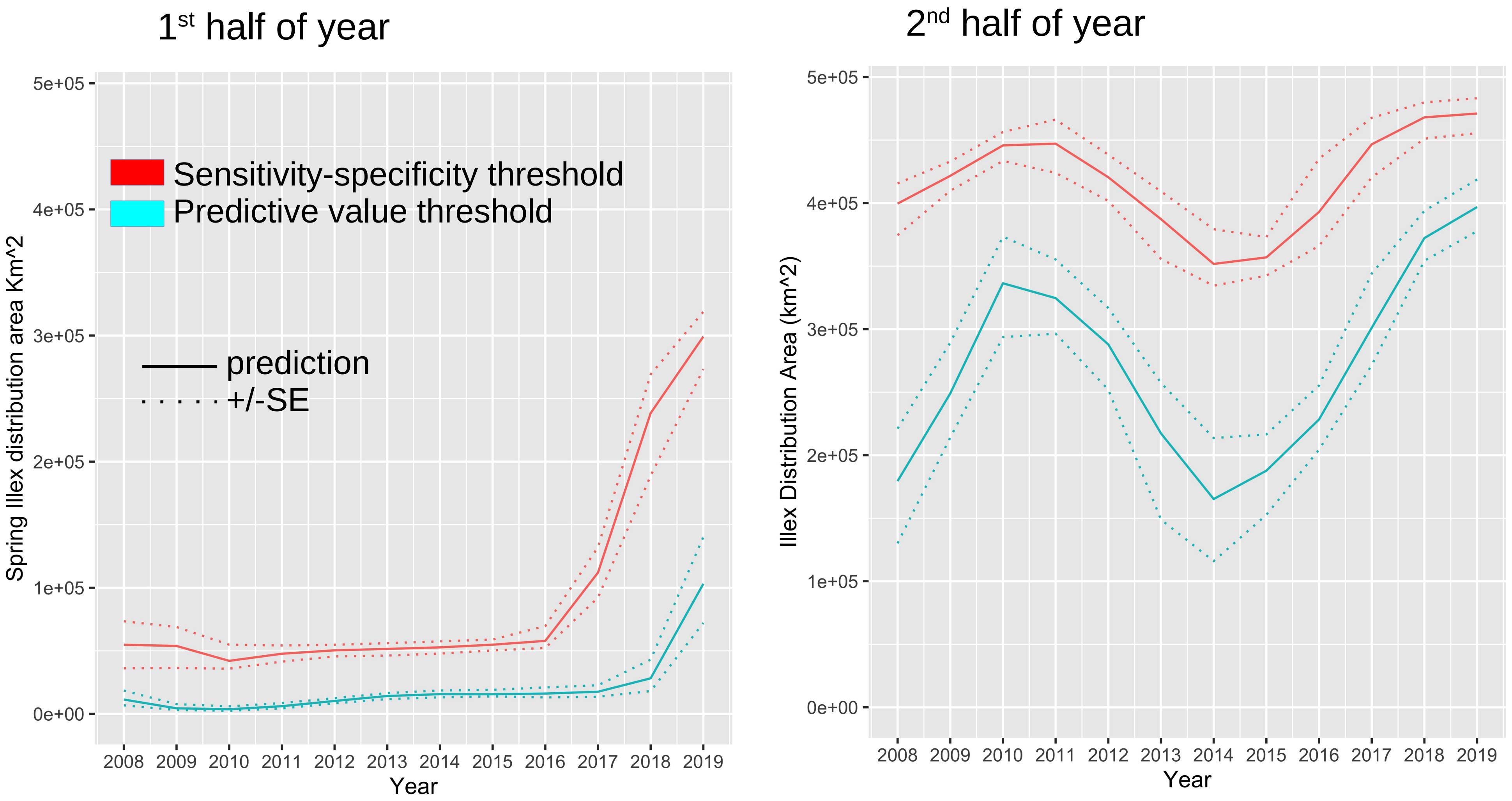
Developed distribution areas using
Sensitivity-specificity &
Predictive value threshold

Predictions
Prediction - SE
Predictions + SE

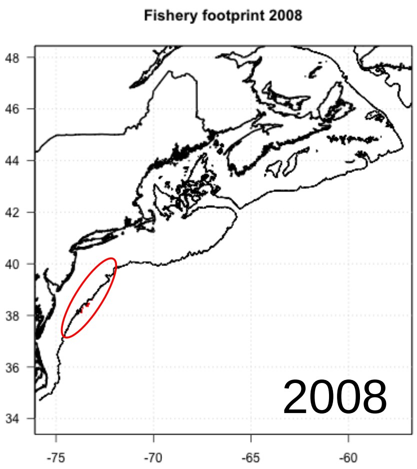


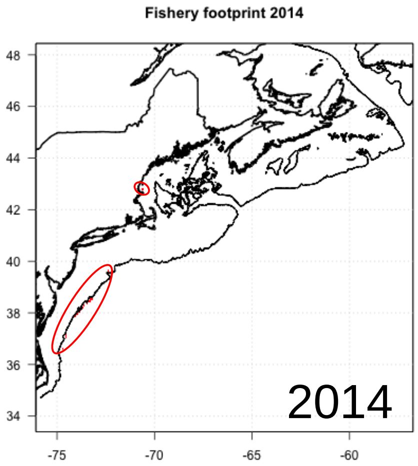
Spatial errors in prediction
2nd half of year 2008-2019
Higher frequency false positives
Sensitivity-specificity threshold=0.29
Higher frequency false negatives
Predictive value threshold = 0.7
accuracyClass
FN
FP
False
TN
TP
True
Latitude
Longitude
46°N
44°N
42°N
40°N
38°N
36°N
75°W
70°W
65°W
60°W

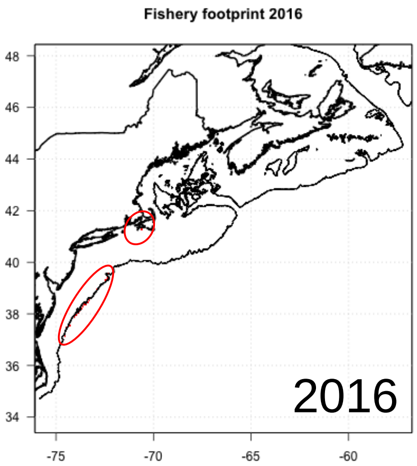
Estimates of species distribution area from SDM using thresholds

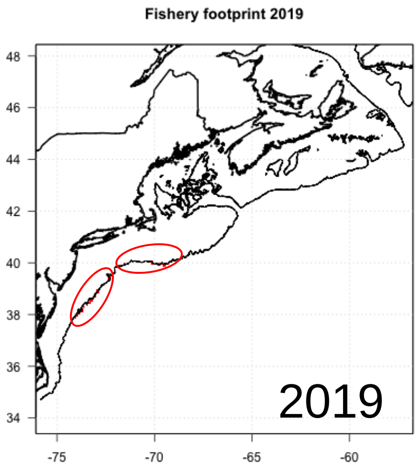


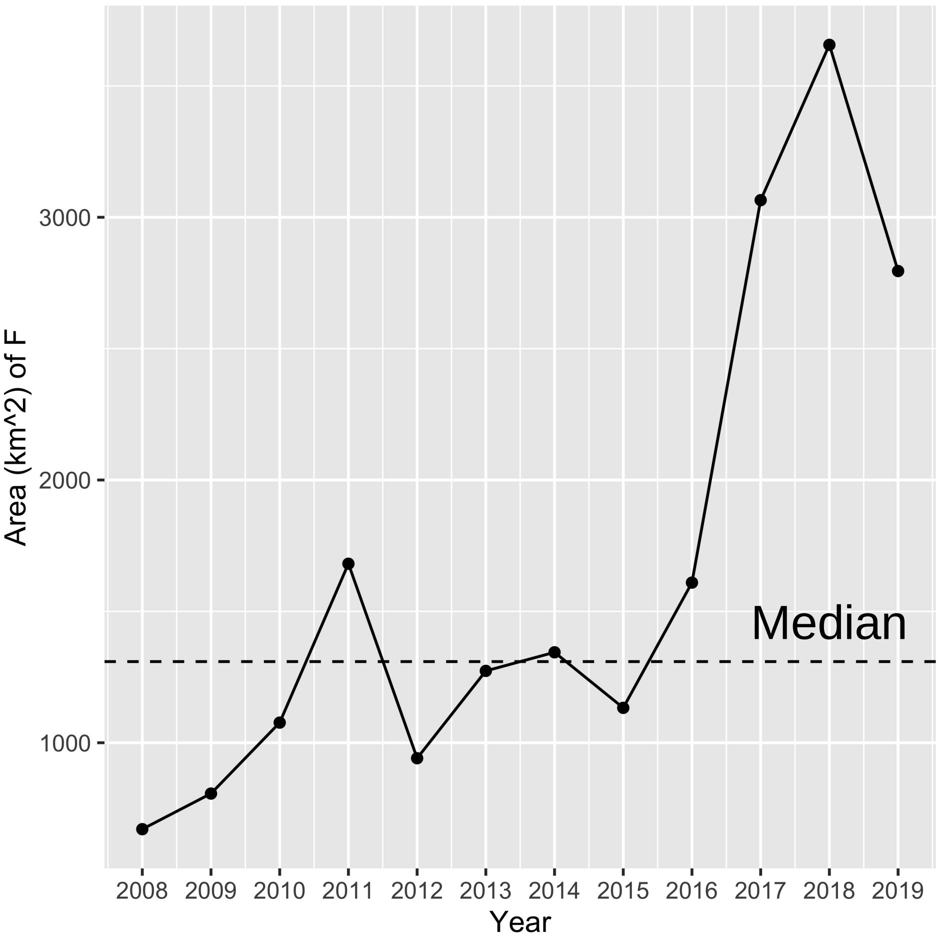
Footprint of directed fishery & incidental catch estimated using VTR data
(Any cell with directed or incidental catches of illex)





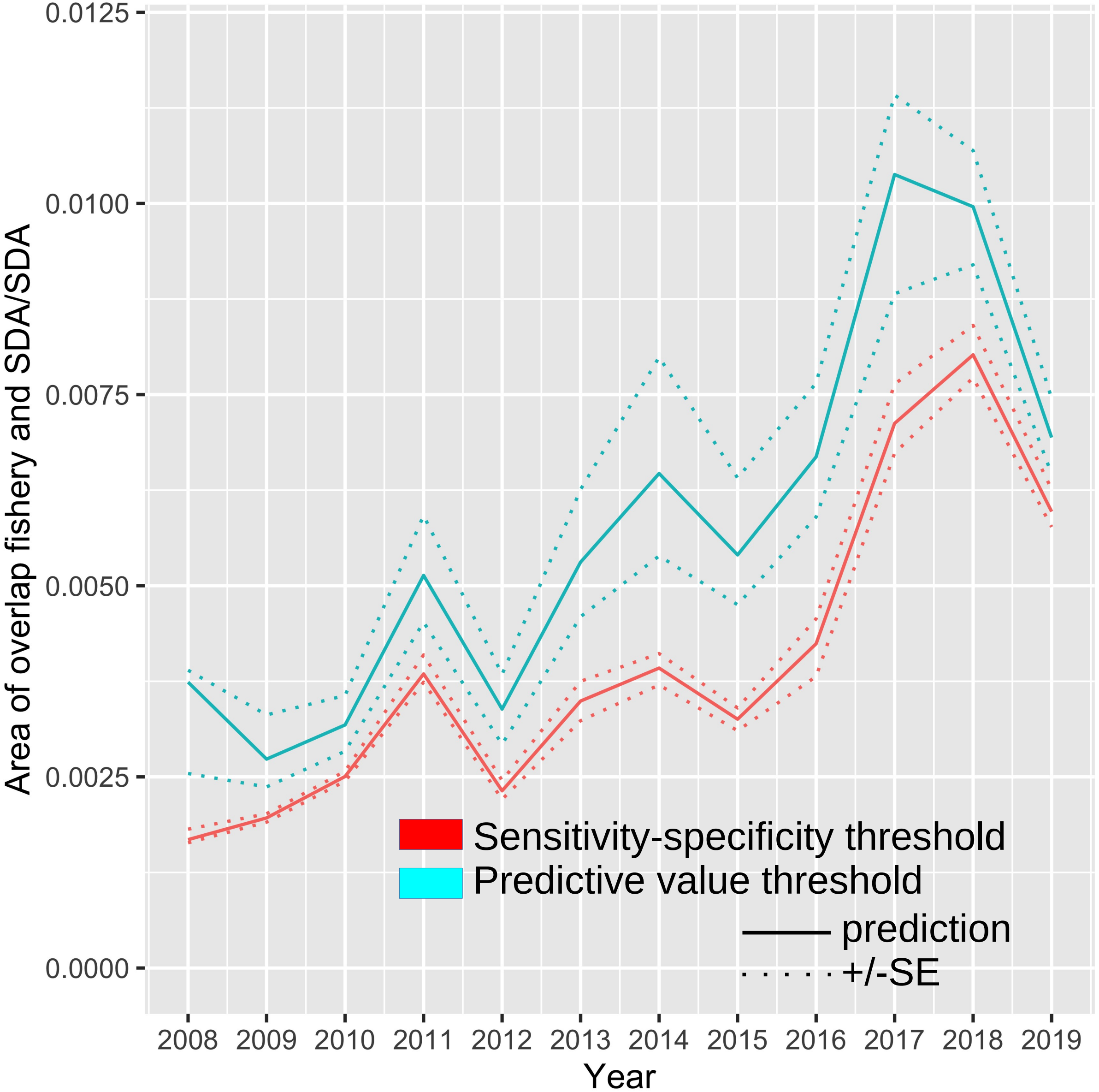




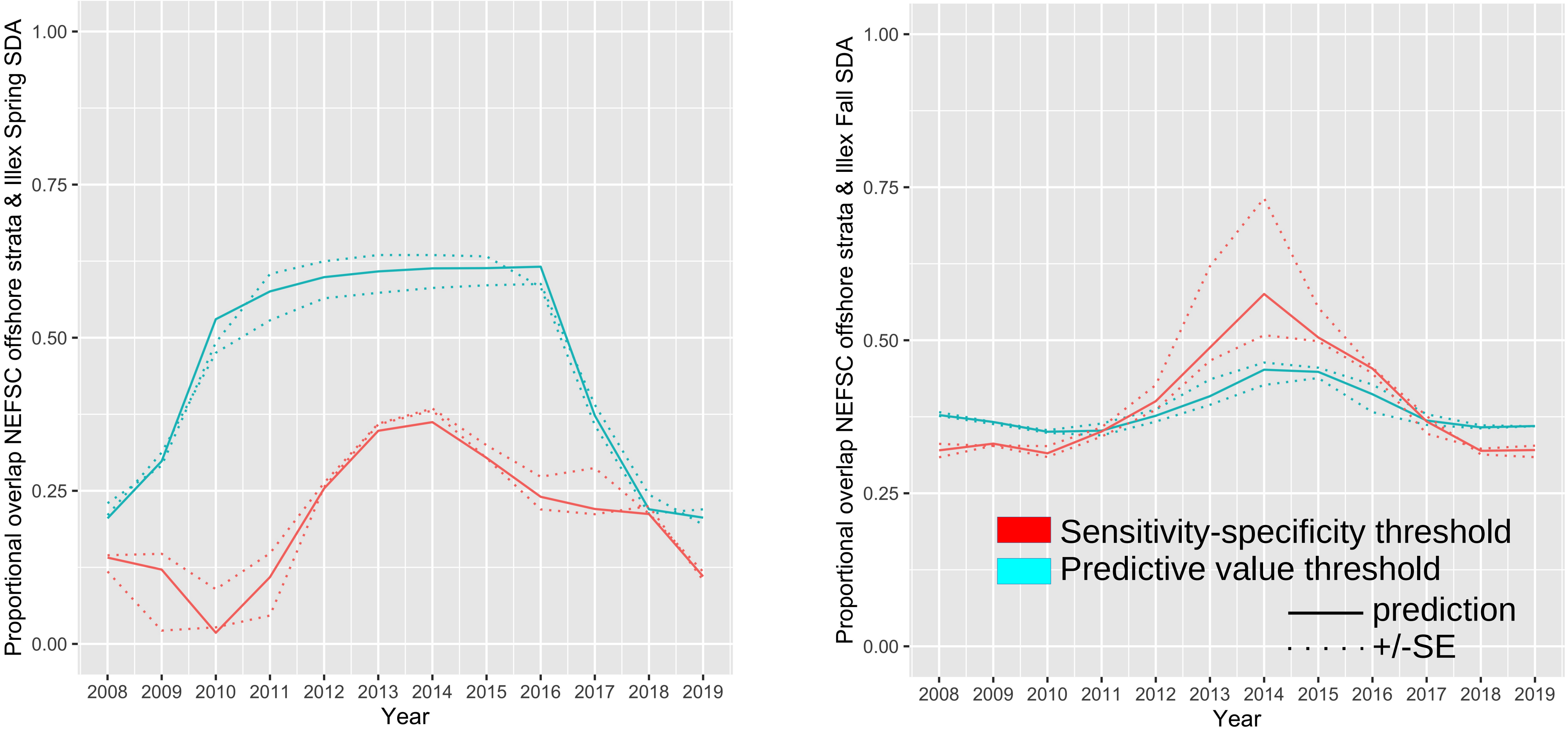


Estimated availability to the Fishery (Vf)

Developed with classified “fall” projections of SDM



Estimated availability to NEFSC survey (“Spring” and “Fall” V_s) offshore strata 1-30, 350, 351, 36-40 and 61-76 (Area estimate 209,670km^2).



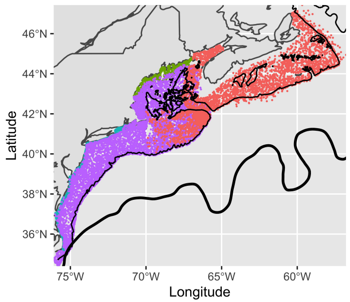
Net efficiency estimates in the fishery (q_f) and NEFSC survey (q_s) developed using expert opinion

- Question:“What percent of squid under the boat do you think you catch in your cod end”
- $q_{fishery}$ (N=13 experts in fishery: Goodwin’s, Axelson’s, Ruhle’s (N=3), Knight, Lackner, Bright, Conrad, Sawyer, Wise)
  - Median = 0.25; 95% CI= 0.178, 0.363; Range=0.02-0.85
- q_{survey} (N= 5 experts. Worked in Illex fishery, part of NTAP, worked with Bigelow net in field. Roebuck, Ruhle’s (N=2), Gartland, Knight)
  - Median = 0.075; 95% CI=0.0318, 0.121; Range=0.02-0.2

Parameter	Plausible upper bound
$V_{fishery}$	0.011
V_{survey} fall	0.427
V_{survey} spring	0.288
$q_{fishery}$	0.363
q_{survey}	0.121

(Lowman 2021: $v_{fishery}$ = 0.014 to 0.363, using US survey data alone in VAST)

Why v_s & v_f are overestimated here



- SDM not inclusive of shelf slope sea or areas to north east of Scotian Shelf squid are known to occupy

- Illex are pelagic: Ours is a 2 dimensional approach to a 3 dimensional problem

- Plausible upper bounds calculated using areas developed with predictive value threshold

- US fishery area calculated using cells where any directed or incidental catch of squid was reported

(Note: Canadian fishery not considered but available information indicates it is primarily an artisanal jig fishery conducted with small boats (<36ft) in Newfoundland)

Acknowledgments

to those who generously provided survey data

- Phil Grayson & Nancy Shackle from DFO
- James Gartland, VIMS, NEAMAP
- Rebecca Peters, Maine DNR