# Chapter 8
# Assessment of the northern rock sole stock in the Bering Sea and Aleutian Islands

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## Executive Summary

Northern rock sole (*Lepidopsetta polyxystra*) are assessed on a biennial stock assessment schedule as part of the National Marine Fisheries Service assessment prioritization plan implemented in 2017. For Bering Sea/Aleutian Islands partial assessments, an executive summary is presented to recommend harvest levels for the next two years. Please refer to last year's full stock assessment report for further information regarding the stock assessment model (Wilderbuer and Nichol, 2018, available online at https://www.afsc.noaa.gov/REFM/Docs/2016/BSAIrocksole.pdf). A full stock assessment document with updated assessment and projection model results is scheduled to be presented in next year's SAFE report.

A statistical age-structured model is used as the primary assessment tool for the Bering Sea/Aleutian Islands northern rock sole assessment, a Tier 1 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. The data sets used in this assessment include total catch biomass, fishery age compositions, trawl survey abundance estimates and trawl survey age compositions. In a partial assessment year, the full assessment model is not rerun but instead a Tier 1 projection model with an assumed future catch is used to estimate the stock level in the next two years. This incorporates the most current catch information for ABC and OFL recommendations without re-estimating model parameters and biological reference points.

The Tier 1 projection operates within the full assessment model by projecting estimates of the female spawning biomass, age 6+ total biomass, ABC and OFL ahead two years. Since the full assessment model is not rerun in this assessment, the projected values from the 2018 assessment are used to provide ABC and OFL.

### Summary of Changes in Assessment Inputs

*Changes in the input data*: There were no changes made to the assessment model inputs since this was not a full assessment year. New data including updating the fishery catch in 2018 and 2019 and the 2019 survey biomass are summarized below but were not used to determine harvest specifications.

*Changes in the assessment methodology*: There were no changes in assessment methodology.

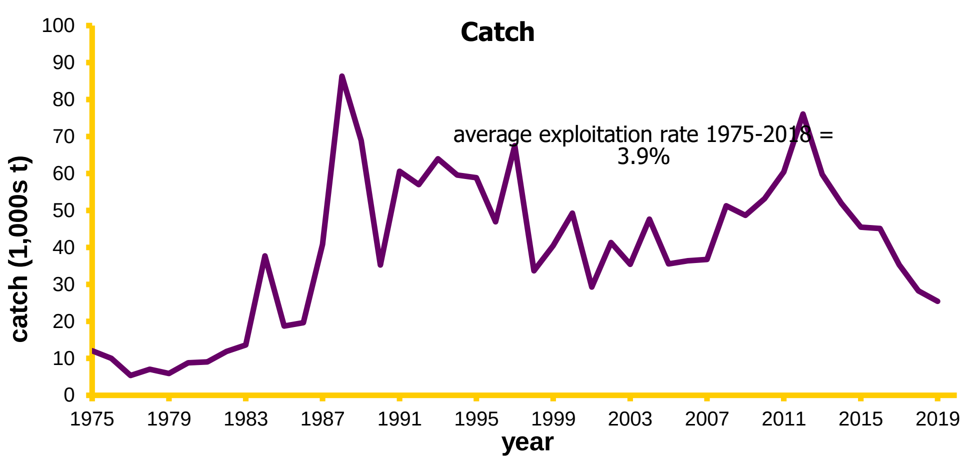
### Summary of Results

For the 2020 fishery, the recommend harvest is the maximum allowable ABC of 153,300 t from the Tier 1 projection model. This ABC is 28% more than year's ABC of 118,900 t. Reference values for BSAI northern rock sole are summarized in the following table, with the recommended ABC and OFL values for 2020 in bold.

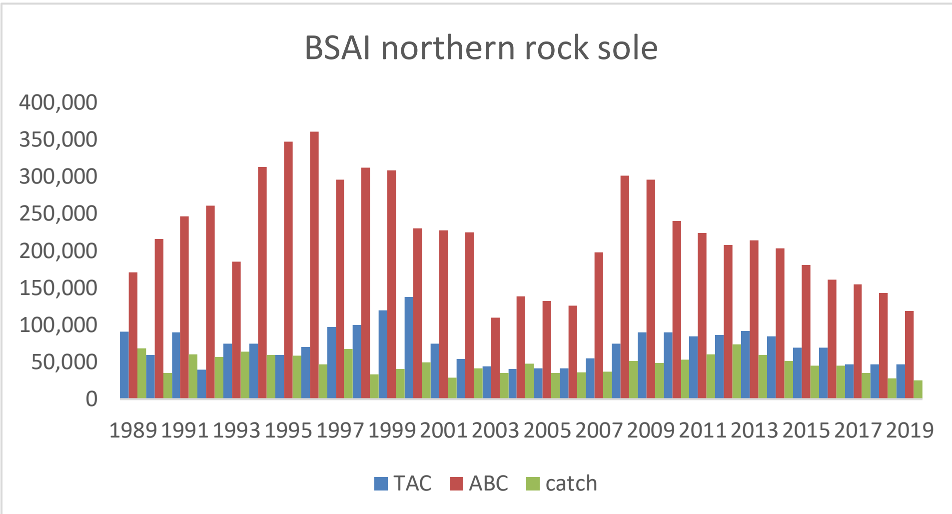
| **Quantity** | As estimated or *specified last* year for: 2019 | 2020 | As estimated or *recommended this* year for: 2020 | 2021 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.15 | 0.15 | 0.15 | 0.15 |
| Tier | 1a | 1a | 1a | 1a |
| Projected total (age 6+) | 828,000 | 1,001,400 | 1,068,000 | 1,608,000 |
| Female spawning biomass (t) | 417,800 | 380,600 | 380,600 | 356,000 |
| Projected | | | | |
| $B_0$ | 515,680 | | 515,680 | |
| $B_{MSY}$ | 186,000 | 186,000 | 186,000 | 186,000 |
| $F_{OFL}$ | 0.147 | 0.147 | 0.147 | 0.147 |
| $maxF_{ABC}$ | 0.144 | 0.144 | 0.144 | 0.144 |
| $F_{ABC}$ | 0.144 | 0.144 | 0.144 | 0.144 |
| OFL (t) | 122,000 | 157,300 | **157,300** | 236,800 |
| maxABC (t) | 118,900 | 153,300 | **153,300** | 230,700 |
| ABC (t) | 118,900 | 153,300 | **153,300** | 230,700 |
| **Status** | As determined *last* year for: 2017 | 2018 | As determined *this* year 2018 | 2019 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. The tests for evaluating these three statements on status determination require examining the official total catch from the most recent complete year and the current model projections of spawning biomass relative to $B_{MSY\%}$ for 2018 and 2019. The estimated total catch for 2018 is 28,275 t, far below the 2018 OFL of 147,300 t; therefore, the stock is not being subjected to overfishing. The estimates of spawning biomass for 2018 and 2019 from the 2018 stock assessment are 417,800 t and 380,600 t, respectively. Both estimates are well above the estimate of $B_{MSY\%}$ at 186,000 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

*Fishery Trends*

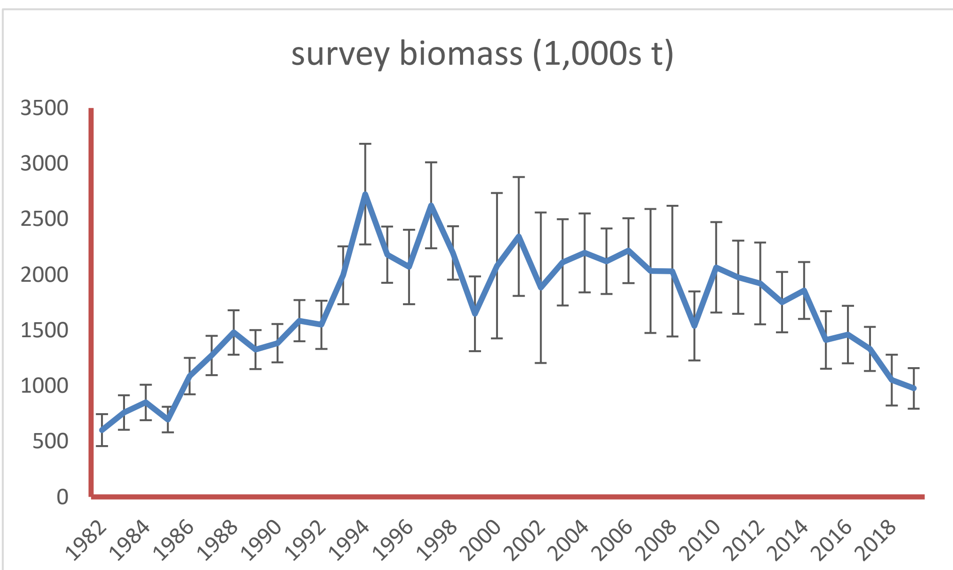


The northern rock sole catch in 2019 of 25,435 t (as of October 19) is below the 1975-2019 long term average of 39,300 t, and well below the annual ABC in every year. Historically, catches occurred during a late-winter/early spring roe fishery and also as bycatch in the yellowfin sole fishery. Retention rates are high, estimated at 96% in 2018.

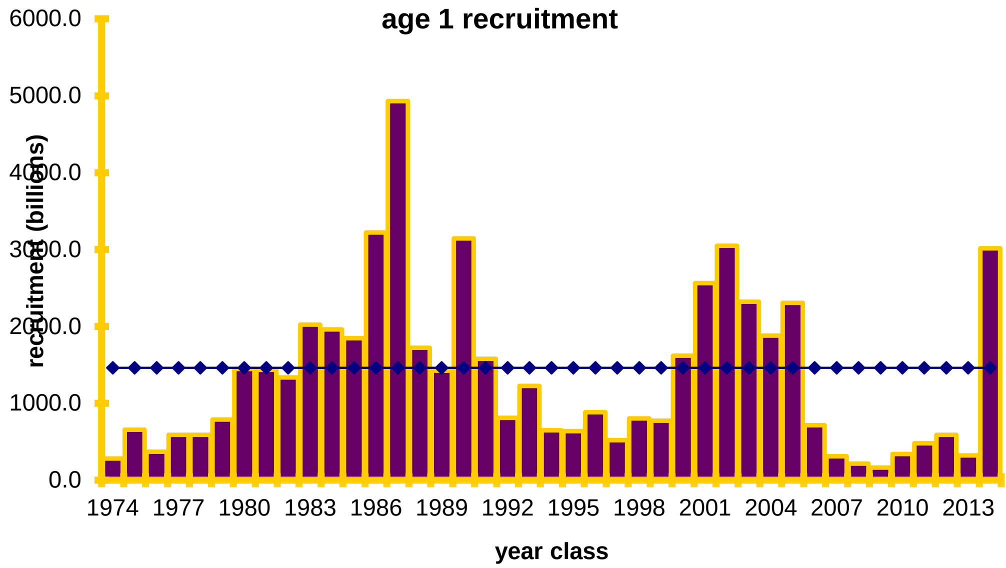


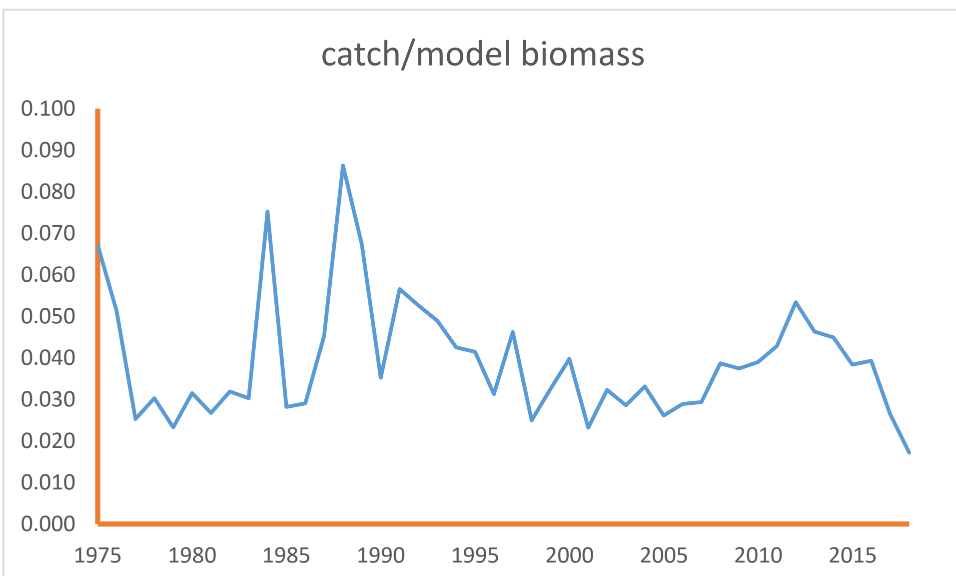

*Survey Trends*

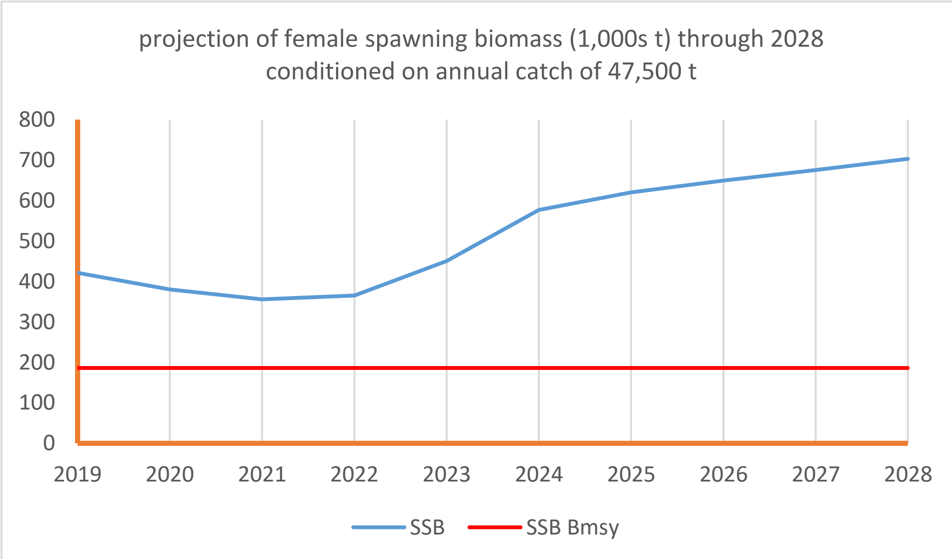
The 2019 shelf trawl survey abundance estimate decreased about 7% from the 2018 estimate and has been in a downward trend since about 2008, currently the resource is estimated at about half of the peak value estimated for 1994.




The northern rock sole stock is projected to remain above the $B_{MSY}$ level of female spawning biomass while declining through 2024.


age 1 recruitment
recruitment (billions)
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013
year class


catch/model biomass
0.100
0.090
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1975 1980 1985 1990 1995 2000 2005 2010 2015




The northern rock sole stock is projected to remain above the $B_{MSY}$ level of female spawning biomass while declining through 2021. Projection is conditioned on an annual harvest of 47,500 t.

# Appendix

Estimating Northern Rock Sole recruitment using environmental covariates
Lauren Rogers, Dan Cooper and Tom Wilderbuer

Difficulties exist in estimating northern rock sole recruitment at young ages since they do not appear in BSAI survey catches until age 3 and not well-sampled in the bottom trawl surveys until ages 4 or 5. They are estimated to be 25 and 40% selected by the trawl survey (males and females respectively) at age 3 and 95 and 98% selected at age 5. The age 4 and 5 fish that are present in the survey age samples are quite rare, typically only 7 fish out of 500 on an annual basis. Therefore, there is not a lot of information to inform the stock assessment model estimates of year class strength for fish 1 to 6 years old. Here we propose to use two environmental covariates to estimate the unknown recruitment, and compare the performance of a suite of regression models for predicting recruitment from environmental conditions. Ultimately, these predictions can be compared with future estimates derived from fitting full age composition data in the stock assessment model to evaluate the skill of the regression models. This is the fourth year we have provided this analysis as an appendix to the stock assessment, and the second year we have provided predictions for the most recent year classes. This recruitment prediction effort is described in more detail in Cooper et al., (In Press).

Studies on the influence of environmental variables on BSAI northern rock sole recruitment have shown that both on-shelf springtime winds (Wilderbuer et al. 2002, Wilderbuer et al. 2013) and above average water-temperatures in nursery areas (Cooper et al. 2014, Cooper and Nichol 2016) are positively correlated with northern rock sole recruitment.
This analysis seeks to answer the following questions using multiple models.

Q1: Do onshore winds and the size of the cold pool (as a percentage of the nursery area) affect recruitment of northern rock sole?
Q2: Does the effect of the cold pool on recruitment depend on the presence of favorable winds? (i.e. is there a significant interaction?)
Q3: Does including wind and cold pool covariates in the stock-recruitment model improve predictions of age-4 recruitment?

We assessed the performance of a suite of models, ranging from a simple Ricker stock-recruit model, to Ricker models with environmental covariates, to models with only environmental covariates. For parsimony, we also assessed simpler forecasting models that used the previous year recruitment or running mean recruitment. We also tested for an interaction between the cold pool effect and winds, because nursery habitat conditions may only matter if winds were favorable for onshore transport (i.e. the fish have to get there in the first place).

We assessed 13 models. Estimates of female spawning biomass and recruitment at age-4 were available for the 1982–2014 year classes.

1) Ricker model
2) Ricker model with % cold pool covariate
3) Ricker model with wind covariate
4) Ricker model with % cold pool covariate + wind covariate
5) Ricker model with an interaction between % cold pool and wind (hypothesis is that the thermal conditions on the nursery grounds only matter if winds are favorable)
6) Ricker model with both cold pool index as a categorical variable (hypothesis is that there is some amount of coverage by the cold pool which inhibits use of the northern nursery area and precludes high recruitment) + wind
7) Regression model with % cold pool
8) Regression model with wind
9) Regression model with % cold pool + wind
10) Regression model with interaction between % cold pool and wind
11) ColdPool Cat + wind. This is a model with a threshold low temperature for recruitment success, and the categorical wind term.
12) Previous year recruitment (t-1)
13) Running mean recruitment (t:(t-1))

Spring wind direction was obtained from the Ocean Surface Current Simulation Model (OSCURS) and was classified as either on- or across-shelf or off-shelf, depending on the ending longitude position after 90 days of drift starting from a locale in a known spawning area (Wilderbuer et al., 2002 and 2013). Water temperature effects were calculated from the percent of the known northern rock sole nursery area (Cooper et al. 2014) that is covered by the cold pool each year from annual trawl survey bottom temperature data. For most models, percentage of the northern nursery area covered by the cold pool was used as a continuous variable. In two models, the percent cold pool was used a categorical variable, dividing years into cold and not-cold categories under the hypothesis that there is some amount of cold pool coverage of the northern nursery area that inhibits use of the northern nursery area and precluded high overall recruitment for the EBS in that year. Both indices extend back to 1982 for this analysis. Estimates of female spawning stock biomass were also included in the analysis for model runs when recruitment was estimated from a Ricker stock-recruitment model with environmental variables.

We compared model performance using traditional statistical methodology on all data (AICc), as well as by using two prediction methods. First we used a leave-one-year out (LOYO) analysis: we left out one year of data, fit the model to the remaining 32 years of data, and then compared the prediction for the left-out year to the observed value. Second, we did a one-step-ahead forecast: beginning with year 11 (1992), we used the data collected up to that year to fit the model, and then compared the prediction for that year with the observation. We repeated for all remaining years. We calculated the mean squared error (MSE) for each prediction: (Observed – Predicted)^2. Models were fit using log(recruitment) as the response, so the mean squared error is for the difference between the observed and predicted log(recruitment).

In this assessment, we also use models #1-13 to predict recruitment for the 2015 through 2019 year classes using the environmental covariates and estimated spawning stock biomass.

The Previous Year Model had the lowest (best) MSE for both the one step ahead and LOYO prediction methods (Table 1), indicating some autocorrelation in recruitment; however, the Previous Year Model is capable of predicting recruitment only one year class into the future, limiting its utility.

The recruitment models based on environmental factors that performed the best included both the wind and cold pool indices. Of these models, the ColdpoolCat + Wind model had the lowest AICc and the lowest prediction error using both the one-step-ahead and LOYO prediction methods, and explained 49% of the variance in log recruitment (Table 1). After the Coldpool Cat + Wind model, the environmental-factors based models with the lowest prediction errors were the Coldpool*Wind and Coldpool+Wind using the LOYO method, and the Coldpool+Wind using the one-step-ahead method (Table 1).

All of the Ricker models with environmental covariates performed worse than their corresponding models without Ricker terms. Ricker models had the highest AICc scores and the highest MSE of all models, except for the Wind model evaluated using the one-step-ahead prediction method (Table 1). Notably, all but one Ricker + environment model performed worse than predictions based on only the historical mean recruitment (Running Mean model). At the observed biomass levels in this study, the models do not provide evidence that recruitment is strongly related to spawning stock size. The Ricker + ColdpoolCat + Wind model did perform better than many models, but performed worse than the simpler ColdpoolCat + Wind model.

Recruitment predictions from models with environmental covariates suggest that conditions were conducive to relatively strong recruitment in 2015 and 2018, and moderate to weak recruitment in 2016, 2017, and 2019 (Table 2, Figure 1). As recruitment estimates become available from the stock assessment model, we will continue to assess the suitability of these models for forecasting northern rock sole recruitment.

Table 1. Mean squared error (MSE) is the mean of the squared prediction errors for each model. LOYO = Leave one year out. Lower values for MSE indicate lower prediction errors. The three best (lowest) AICc and MSE scores are in bold.

| | Model | df | AICc | MSE (LOYO, log-scale) | MSE (1 step ahead, log-scale) | $R_2$ |
|---|---|---|---|---|---|---|
| 1 | Ricker | 3 | 90.9 | 0.76 | 0.91 | 0.09 |
| 2 | Ricker + coldpool | 4 | 88.1 | 0.80 | 0.91 | 0.23 |
| 3 | Ricker + wind | 4 | 92.5 | 0.77 | 0.91 | 0.11 |
| 4 | Ricker + coldpool + wind | 5 | 88.1 | 0.78 | 0.85 | 0.28 |
| 5 | Ricker + coldpool*wind | 6 | 89.0 | 0.78 | 0.93 | 0.32 |
| 6 | Ricker + ColdpoolCat + wind | 6 | **75.0** | **0.59** | 0.67 | **0.50** |
| 7 | coldpool | 3 | 83.1 | 0.74 | 0.82 | 0.18 |
| 8 | wind | 3 | 88.6 | 0.77 | 0.86 | 0.04 |
| 9 | coldpool + wind | 4 | **82.3** | 0.70 | **0.77** | 0.26 |
| 10 | coldpool*wind | 5 | 82.9 | 0.70 | 0.84 | 0.31 |
| 11 | ColdpoolCat + Wind | 4 | **70.1** | **0.51** | **0.60** | **0.49** |
| 12 | Previous Year | NA | NA | **0.50** | **0.52** | **0.49** |
| 13 | Running Mean | NA | NA | 0.75 | 0.89 | 0.12 |

Table 2. Predicted recruitment (thousands) for selected models for the 2014–2019 year classes.

| Year | coldpool + wind | coldpool*wind | ColdpoolCat + wind | Previous Year | Running Mean |
|---|---|---|---|---|---|
| 2014 | 1,345,000 | 1,275,000 | 1,412,000 | 203,000 | 675,000 |
| 2015 | 1,345,000 | 1,275,000 | 1,412,000 | 1,922,000 | 697,000 |
| 2016 | 792,000 | 1,026,000 | 822,000 | NA | 697,000 |
| 2017 | 717,000 | 762,000 | 822,000 | NA | 697,000 |
| 2018 | 1,345,000 | 1,275,000 | 1,412,000 | NA | 697,000 |
| 2019 | 792,000 | 1,026,000 | 822,000 | NA | 697,000 |

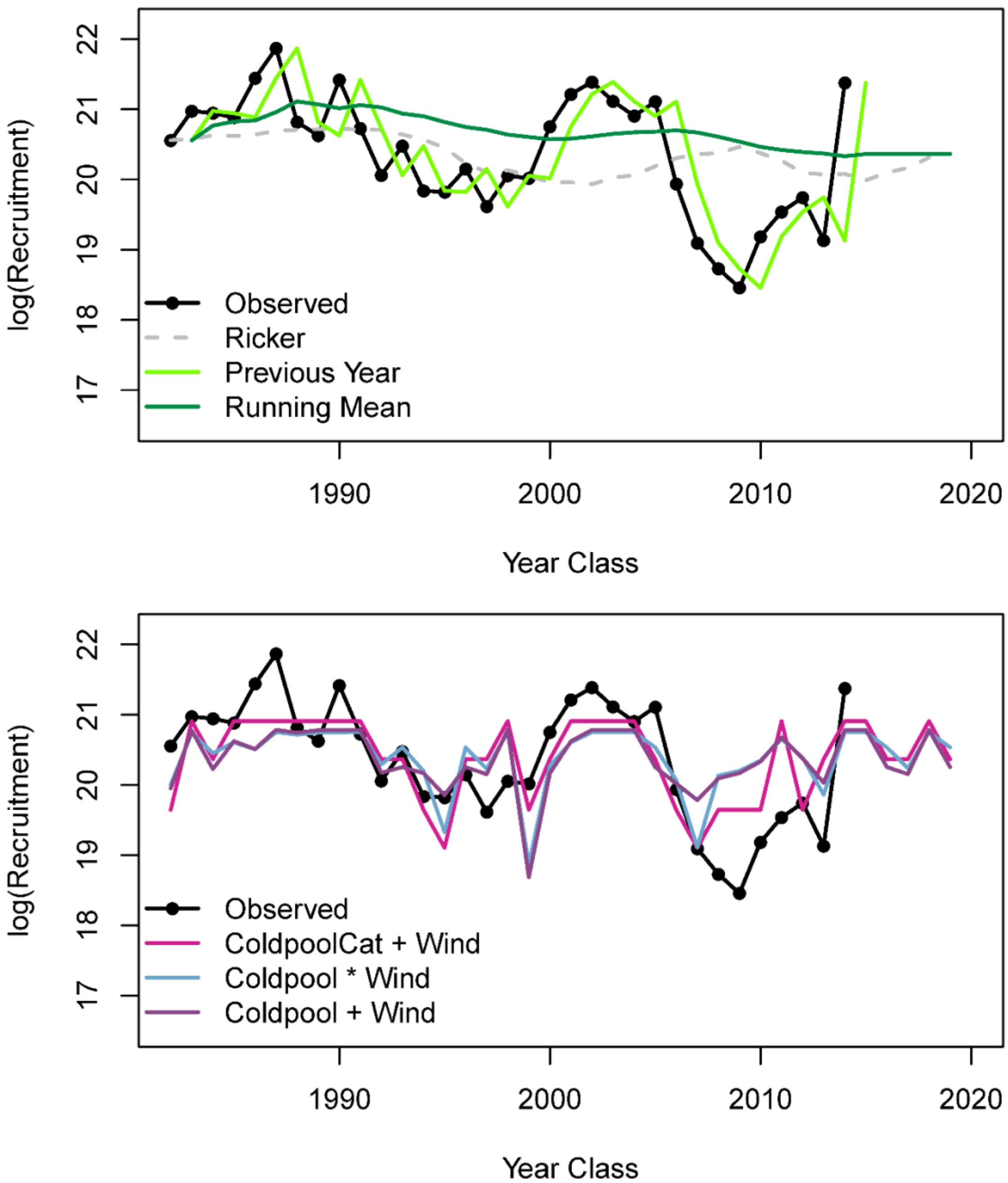



Figure 1. Observed (estimated from stock assessment model) and predicted recruitment from selected models for the 1982 through 2014 northern rock sole year classes, and predicted recruitment for the 2015 through 2019 year classes.

**Literature Cited**

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