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, 2016, 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 run to estimate the stock level in the next two years. This incorporates the most current catch information without re-estimating model parameters and biological reference points. A Tier 1 partial projection rule is implemented to estimate the 2019 ABC and OFL.

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, only the projected values from the 2016 assessment are available (2017 and 2018) whereby values for 2019 are not estimated. The 2019 values are determined by a linear fit to the 2017 and 2018 estimates. If the trend is increasing, then the 2019 values are a roll-over of 2018. If the trend is decreasing, the projected proportional decrease from 2017 to 2018 is applied to 2018 to get 2019.

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 added to the Tier 3 projection model, used to forecast stock condition out to year 2030, included an updated 2016 catch estimate (45,006 t) and new catch estimates for 2017. The 2017 catch was estimated by setting the catch as of October 21, 2017 as the final 2017 catch (35,069 t). To estimate future catches through 2030, the catches that corresponded to the average F of the most recent 5 years were used.

Changes in the assessment methodology: There were no changes in assessment methodology since this was an off-cycle year.

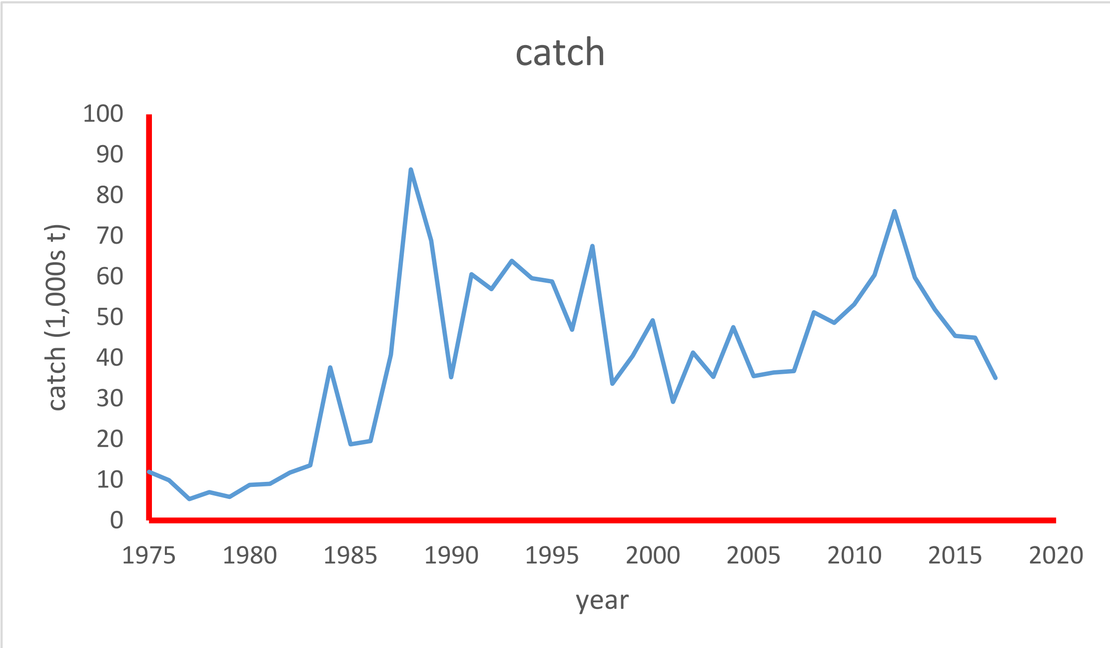
Summary of Results

For the 2018 fishery, the recommend harvest is the maximum allowable ABC of 143,100 t from the Tier 1 projection model. This ABC is 14% less than year's ABC of 155,100 t. Reference values for BSAI RE/BS rockfish are summarized in the following table, with the recommended ABC and OFL values for 2018 in bold.

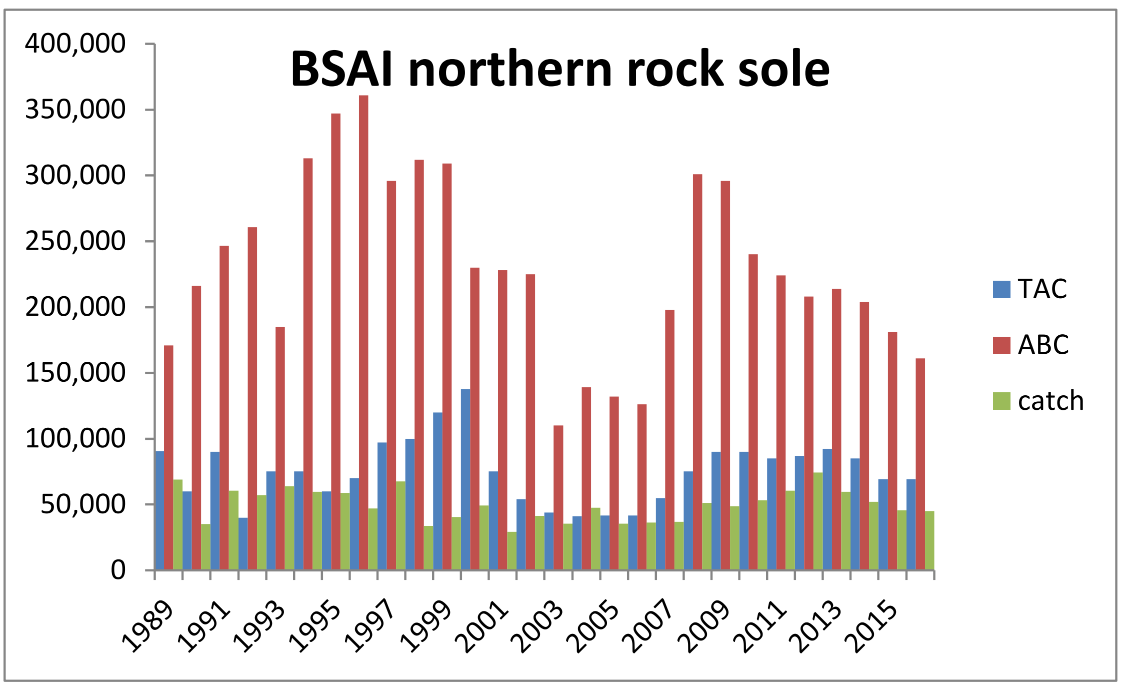
	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2017	2018	2018	2019
M (natural mortality rate)	0.15	0.15	0.15	0.15
Tier	1a	1a	1a	1a
Projected total (age 6+)	1,000,600	923,200	923,200	852,000
Female spawning biomass (t)	539,500	472,200	472,200	413,300
Projected				
B_0	678,310		678,310	
B_{MSY}	257,000	257,000	257,000	257,000
F_{OFL}	0.160	0.160	0.160	0.160
$maxF_{ABC}$	0.155	0.155	0.155	0.155
F_{ABC}	0.155	0.155	0.155	0.155
OFL (t)	159,700	147,300	**147,300**	136,000
maxABC (t)	155,100	143,100	**143,100**	132,000
ABC (t)	155,100	143,100	**143,100**	132,000
	As determined *last* year for:		As determined *this* year	
Status	2015	2016	2016	2017
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 2017 and 2018. The estimated total catch for 2017 is 35,069 t, far below the 2017 OFL of 159,700 t; therefore, the stock is not being subjected to overfishing. The estimates of spawning biomass for 2017 and 2018 from the 2016 stock assessment are 539,500 t and 472,200 t, respectively. Both estimates are well above the estimate of $B_{MSY\%}$ at 257,000 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

Fishery Trends

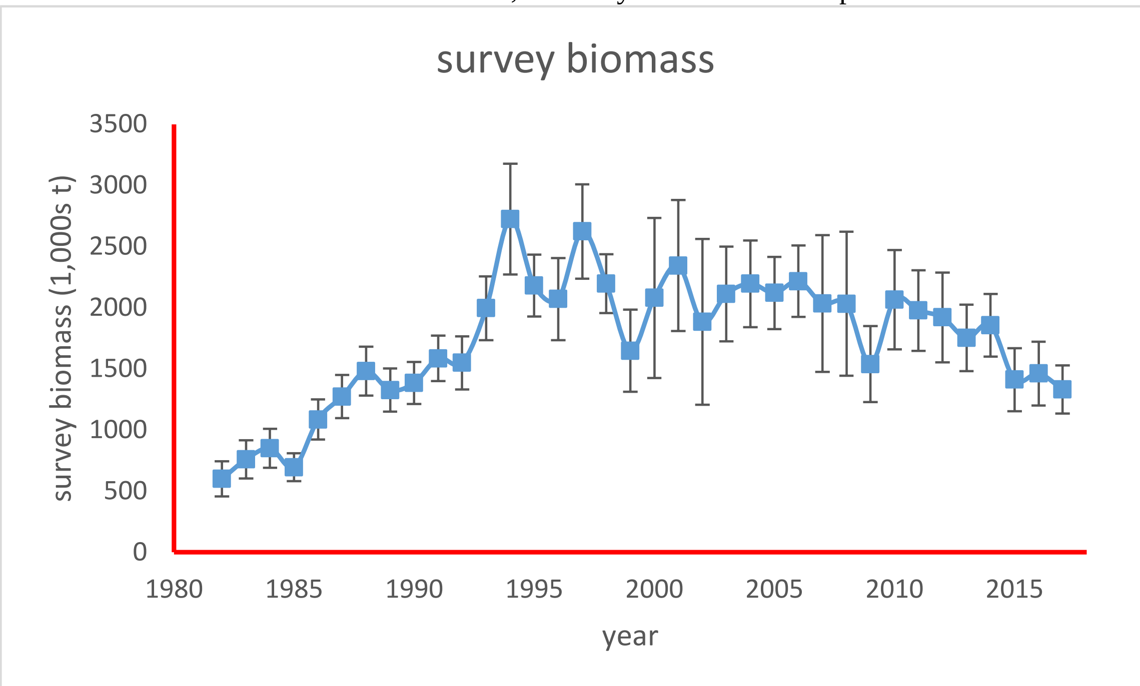


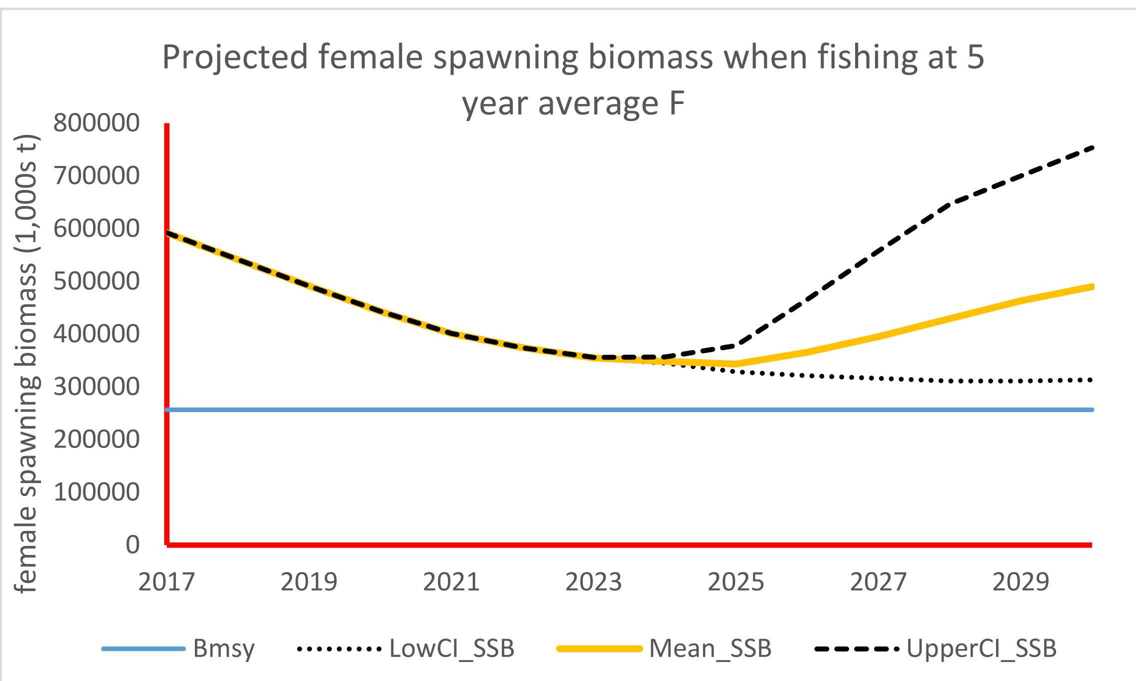
The northern rock sole catch in 2017 of 35,069 t is below the 1975-2017 long term average of 40,000 t, and well below the annual ABC in every year. Catches primarily are made during a late-winter/early spring roe fishery and also as bycatch in the yellowfin sole fishery. Retention rates are high, estimated at 98% in 2015.



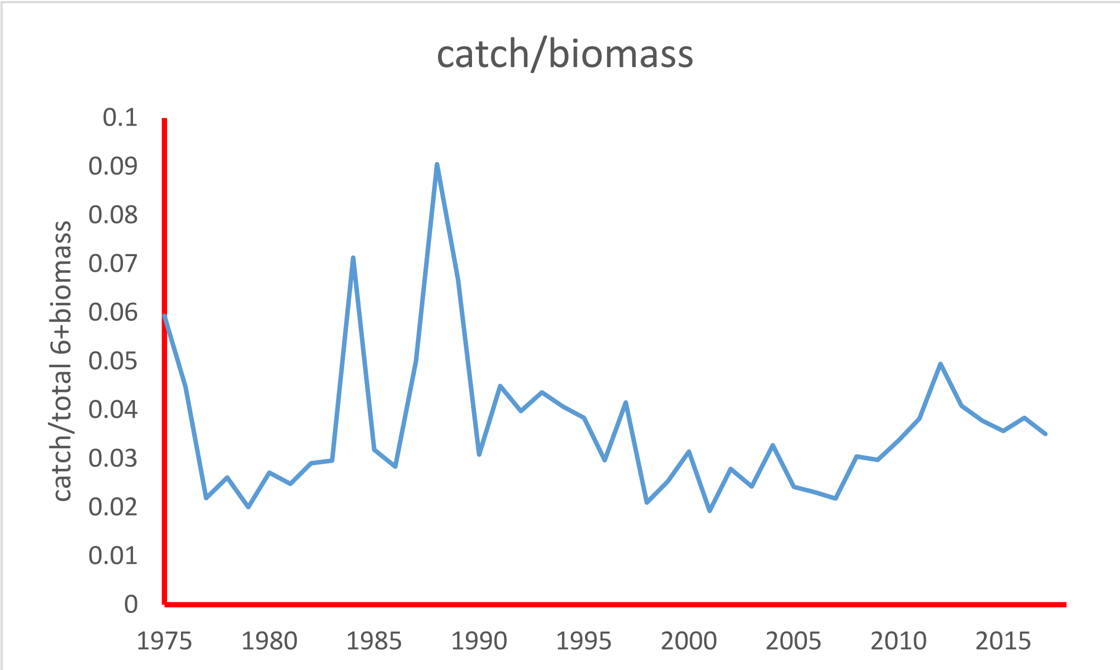
Survey Trends

The 2017 shelf trawl survey abundance estimate decreased about 11% from the 2016 estimate and has been in a downward trend since about 2008, currently 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.



Appendix

Estimating Northern Rock Sole recruitment in the last (most recent) 6 years of the assessment using environmental covariates

Dan Cooper, Lauren Rogers 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 in survey age sampling until age 4 or 5. They are estimated to be 25 and 40% selected by the survey trawl (males and females respectively) at age 3 and 95 and 98% selected at age 5. The age 4 and 5 fish that do end up in the 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 the last (most recent) 6 years. Some assessments provide estimates for the last 3 years by using an average of the estimated values to provide more credible values of year class strength. Here we propose to use two environmental covariates in regression modeling to estimate the unknown recruitment, and then compare those estimates with future estimates derived from fitting full age composition data in the stock assessment model.

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. 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. Water temperature effects were calculated from the percent of the known northern rock sole nursery area (Cooper et al. 2014) that is in 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 one model, 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.

The 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 14 models. Thirteen are the same models from the 2016 stock assessment appendix, and we present one new model, the categorical model.

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) Same as above, but cold pool slope set to 0 if unfavorable winds
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) Same as above, but cold pool slope set to 0 if unfavorable winds
12) Categorical model with threshold low temperature for recruitment success (hypothesis is that there is a some amount of coverage by the cold pool which inhibits use of the northern nursery area and precludes high recruitment)
13) Previous year recruitment (t-1)
14) Running mean recruitment (t:(t-1))

We compared model performance using traditional statistical methodology on all data (AIC), as well as by using two prediction methods. First we used a leave-one-year out analysis: we left out one year of data, fit the model to the remaining 27 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 for each prediction: (Observed – Predicted)^2. Models were initially fit using log(recruitment) as the response, so the mean squared error is for the difference between the observed and predicted log(recruitment). However, the mean squared error can also be calculated based on the predicted recruitment on the real scale. In this case, Duan's smearing estimate for the lognormal re-transformation bias was used to adjust the mean of the exponentiated log(recruitment) to be equal to the mean recruitment. Both results are given in Table 1.

In the 2016 northern rock sole SAFE appendix, we presented modeled and observed recruitment from 1982 through 2009. In this assessment, we also use models #1-12 to predict recruitment for the 2010 through 2016 year classes using the environmental covariates and estimated spawning stock biomass (Figure 1).

The environmental-factors based recruitment models with the lowest prediction errors included both the winds and cold pool indices (Table 1). The Categorical Model had the lowest AIC score and the lowest MSE in both the LOYO log scale and LOYO real scale prediction methods (Table 1). Other environmental-factors based models with the best predictive scores include the Coldpool + Wind model and the Coldpool*Wind model. While the model with an interaction between the Coldpool and Wind had reasonable predictive ability, the interaction term was not statistically significant. The Previous Year Model had the lowest (best) MSE for the 1 step ahead prediction method for both log and real scales, and had the second best score in the LOYO log scale, 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 six models including a Ricker spawning biomass term had the highest (worst) AIC scores and generally had poor MSE scores relative to the other models.

Recruitment predictions from models with environmental covariates suggest that conditions were conducive to relatively strong recruitment in 2011, 2014, and 2015, and moderate to weak recruitment in 2010, 2012, 2013 and 2016 (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) AIC and MSE scores are in bold.

	Model	df	AICc	MSE (LOYO, log-scale)	MSE (1 step ahead, log-scale)	MSE (LOYO, real scale)	MSE (1 step ahead, real scale)
1	Ricker	3	67.8	0.69	0.85	725	635
2	Ricker + coldpool	4	66.5	0.73	0.86	678	539
3	Ricker + wind	4	67.9	0.67	0.81	703	625
4	Ricker + coldpool + wind	5	63.9	0.66	0.78	635	509
5	Ricker + coldpool*wind	6	65.0	0.64	0.85	622	514
6	Ricker + coldpool*wind (slope=0)	5	66.0	0.69	0.81	655	536
7	coldpool	3	57.8	0.60	0.69	545	600
8	wind	3	60.9	0.58	0.69	585	631
9	coldpool + wind	4	**54.9**	0.55	0.61	**531**	**504**
10	coldpool*wind	5	**55.7**	**0.53**	0.71	**522**	570
11	coldpool*wind (slope=0)	4	57.2	0.58	0.64	552	533
12	Categorical	4	**45.5**	**0.41**	**0.47**	**456**	**412**
13	Previous Year	NA	NA	**0.46**	**0.45**	533	**382**
14	Running Mean	NA	NA	0.62	0.74	637	638

Literature Cited

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