

Data Accessibility Paper

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- Abstract

- Importance

- Incentivize authors to publish/make available their original data
- Publishing data helps get more use out of research
- Helps eliminate file drawer effect as it shows negative data

- Keywords

- Data accessibility
- Data reproducibility

Introduction

Data availability (DA) is the practice of making raw experimental data and analyses publicly accessible, often via upload in maintained databases. DA is a newly emerging and yet deeply important component of the scientific process in the digital age. With the latest and greatest methodologies available across fields, increasing amounts of data are being generated each day, especially in the biological sciences. Availability of these large quantities of study data and metadata (data about data) is a necessary resource for appropriate use and re-use of data and protocols as well as the recreation of analyses. We believe that policies of data “available on request” are not sufficient to be considered available data. One example was published in *Microbiome*, that a reader

in search of data may email the corresponding author, with varying results ((1)). We believe that this is simply unacceptable, and set out to determine rates of published raw data in the biological sciences, specifically microbiology, by examining the American Society for Microbiology's (ASM) library of published primary research journals.

25 **Scientific Data as a Public Good**

The United States Government spent over two hundred million dollars (USD) in 2024 on research expenditures ((2)). The result of all of these investments are data, paid for in part by taxpayers. Therefore, data is a public good, and best used as a benefit to those who provided the funds for it. Once data has been generated, it can be used not only for initial analyses, but over and over
30 again in future studies or meta analyses. Additionally, data can be used to eliminate possible solutions to a problem by the publishing of "negative data." Thinking of data as a public good, if negative data is published, it can help researchers avoid sinking time and financial resources into the investigation of non-viable hypotheses. This lack of publication of non-fruitful investigation is more commonly known as the "file drawer effect." Data as a public good also is subject to the
35 tragedy of the commons. If no one contributes to the public "commons", data that is available for public use, how can we advance our understanding of our study systems?

Current DA Policies

Current data availability guidelines have been informed by a number of policies created by funding agencies, peer-review journals, conference and special task groups, as well as community interest
40 groups. In 2011, after the Future of Research Communication (FoRC) conference in Germany to establish FORCE11, a community interest group which seeks to encourage and promote data availability standards ((3)) . Also in 2011, the Genomic Standards Consortium (GSC) published the MIMARKS/MiXs standards in *Nature Biotechnology* to promote the publication of the "minimum information about a marker gene sequence" (MIMARKS) or "minimum information about x sequence"

45 (MIxS) ((4)). These standards are checklists usable by data generators and uploaders towards inclusion of relevant data with sequence uploads in the International Nucleotide Sequence Database Collaboration (INSDC).

In 2014 the group published the Joint Declaration of Data Citation Principles (JDDCP), a document towards the standardization of data citation and its future availability((5)). The Findable, Accessible, 50 Interoperable, and Reuseable (FAIR) data science guiding principles were put forth in 2016 in *Nature Scientific Data* urges readers to “improve the infrastructure supporting the reuse of scholarly data” ((6)). Neither the JDDCP nor the FAIR principles are enforceable by any agency. In 2021, a *Nature Medicine* publication put forth the “Strengthening the Organization and Reporting of Microbiome Studies” (STORMS) checklist to help authors identify report-worthy elements of their data and 55 metadata ((7)). Finally, the National Institutes of Health (NIH) began enforcing the “Policy for Data Management and Sharing” (NOT-OD-21-013) in January of 2023, requiring NIH funded studies to submit a data management and sharing plan (DMS) with their funding applications, and comply with their DMS plan after generation and publication of the funded work((8)). Non-compliance with NOT-OD-21-013 is identified by funding agencies during annual Research Performance Progress 60 Reports (RPPRs), and may impact future funding decisions ((8)).

ASM Journals

With the advent of next generation sequencing, microbiology research has generated large amounts of sequencing data, and it is common to upload sequence data to a public repository as well as to include data in research publications. The American Society for Microbiology(ASM) is the major 65 professional body recognized by microbiologists. They have eighteen journals, thirteen primary research journals, three review journals, and two archive journals. In addition, several journals have been folded into others or renamed over time. The ASM family of journals requires that authors “make data fully available, without restriction, except in rare circumstances” ((9)). They have adapted this policy from journals *Microbial Genomics* and *PLOS*. In the ASM open data policy 70 they describe the use of a “Data Availability Statement” which includes “data description, name(s)

of the repositories, and digital object identifiers (DOIs) or accession numbers” and encourages publishing data on relevant public repositories ((9)). Consequences of non-compliance to the ASM open data policy include contacting research article authors to inform of non-compliance, publication of an “Expression of Concern” for the author and their compliance issues, sanctions on publication in ASM journals, as well as contacting the affiliated research institution and/or funding agencies of the authors ((10)). We endeavor to evaluate how well the microbiology community is using reproducible data practices as we believe that this group of researchers will be early adopters of the technologies available as a result of both the ASM and NIH policies towards data availability.

Nucleic Acid Sequencing Efforts

Beginning in 1996 with the International Strategy Meeting on Human Genome Sequencing in Bermuda, researchers have prioritized the release of all human genome sequencing information so that it may “maximize its benefit to society” ((11)). The meeting participants agreed that “primary sequence data should be rapidly released”, with “sequence assemblies [to] be released as soon as possible, in some centres, assemblies of greater than 1 kb would be released automatically on a daily basis”, and that “finished annotated sequence should be submitted immediately to public databases” ((11)). The “Bermuda Principles,” as they became known, have been embraced by the large scale Human Genome Project (HGP) since 1998. In 2003, another meeting, held in Ft. Lauderdale, FL, re-affirmed the 1996 Bermuda Principles, expanded upon them to apply more broadly towards sequencing data, and called for further support of these practices ((11)). These foundation agreements set the stage for both the HGP and the Human Microbiome Project (HMP) to generate and share massive amounts of data over the course of their studies ((12), (13), (14)).

Starting with projects such as the HGP and HMP, nucleic acid sequencing efforts have been commonly uploaded and released using public databases. There are three major databases worldwide to support sequencing and sharing efforts. The National Library of Medicine’s (NLM) National Center for Biotechnology (NCBI) in the United States, the Research Organization of Information Systems’ (ROIS) National Institute of Genetics (NIG) in Japan, and the European

Molecular Biology Lab's (EMBL) European Bioinformatics Institute (EBI) in Europe. These three databases are part of the International Nucleotide Sequence Database Collaboration (INSDC). These large databases make research by comparison possible. Genetic lineages of microbes are determined by creating phylogenetic trees which compare a new sequence to existing sequences. Phylogenetic trees show how closely related a new microbial genetic sequence is related to others studied before both in terms of evolution and mutation and in structure and function. An important tool for creating phylogenies is the NCBI Basic Local Alignment Search Tool (BLAST) ((altschul1990?)). The BLAST algorithm allows users to compare a nucleic acid or protein sequence to the NCBI database of over 1TB of data to find similar and related sequences. Without the upload of sequences to the NCBI database, the use and success of BLAST would not be possible, despite the effort required on part of the researcher to upload of sequences to one of the INSDC databases.

Examples of Data Availability

A key tenet of the scientific method is the ability to replicate scientific findings to ensure that they are not due to error. One way that scientific findings can be replicated is by re-completing the same analyses by another researcher. This is only possible if the data used to complete the original analyses is available for use. The availability of datasets also allows new questions to be answered with existing data or the combination of multiple datasets, such as the use of the Human Microbiome Project's (HMP) sequencing data by researchers to create over 650 scientific publications ((15)), and the completion of metadata studies. Availability of data contributed to the rapid sequencing of the SARS-CoV-2 virus during the 2020 pandemic and subsequent expedition of vaccine development ((16)).

With microbiologists commonly uploading nucleic acid sequences to public databases, the aim of this study was to determine the current state of data availability in twelve primary research journals from the ASM family of journals. Primary research articles were classified with using two machine learning models to answer two questions; "Does this paper contain new sequence data?", and "Is

the data available?” Once these questions were answered, we moved to analyses to answer further questions, “How does making my data available impact my citation metrics over time?”

Results

General Description of the Experiment

We set out to determine the current state of data availability in twelve primary research journals from the ASM family of journals. This objective was completed by first acquiring all papers published in the journals of interest between 2000 and 2024 using the Crossref database and command line tools. We then trained random forest machine learning models to differentiate if each paper contained “New Sequencing Data” (NSD) and then if the paper had “Data Available” (DA). To avoid overfitting the model, we trained each model multiple times, performing validations on a subset of data after each iteration. This allowed us to have a greater number of papers in the training dataset, as well as to have great accuracy and precision within our models. Using our trained models, we were able to classify over 150,000 papers from the whole dataset to determine if they were NSD or DA. After this, we could perform statistical modeling to describe the data, and generate summary statistics. We were especially interested in the ways in which NSD and DA impact citation metrics.

ASM Journals

We used twelve of the ASM primary research journals in this study. Of note, several journals had changes to their publication goals during the 2000-2024 time period. The *Journal of Bacteriology* was the primary place to publish new genome announcements until 2013 when ASM announced journal *Genome Announcements* as a more permanent place for this type of data. *Genome Announcements* was active from 2013 until 2018, when it was re-branded to *Microbiology Resource Announcements*, which has been active from 2018 until present . These two journals appear separately in our analyses as a result of the Crossref database. New genome announcements have a high percentage of NSD papers, and a high percentage of DA within those papers. As a

result, the *Journal of Bacteriology* has had fewer NSD papers, and fewer papers with DA since 2013. Another journal of note is *Microbiology Spectrum* and its re-brand. From 2013 until the fall of 2021, *Microbiology Spectrum* was a review journal. After this point, *Microbiology Spectrum* became a primary research journal ((17)). Review journals are less likely to publish articles with NSD, and to have DA. Several journals, including *Microbiology Spectrum*, do not span the entire time period for the study. Journals *mBio* (b.2010), *Microbiology Spectrum* (b. 2013, re-brand 2021), *mSphere* (b. 2016), *mSystems* (b. 2016), and *Genome Announcements* (2013-2018). Not all journals are equally likely to contain NSD and have sequencing DA as a result of their field of interest. Journals *Antimicrobial Agents and Chemotherapy*; *Infection and Immunity*; and the *Journal of Microbiology and Biology Education*; are all less likely to contain NSD and have DA than the other journals in the dataset.

Descriptive Statistics:

Table 1: Summary Statistics of Model Training Dataset

container.title	n_total	n_fract	n_nsd	fract_nsd	n_da	fract_da
Antimicrobial Agents and Chemotherapy	82	7.8469	23	28.0488	10	43.4783
Applied and Environmental Microbiology	92	8.8038	38	41.3043	28	73.6842
Genome Announcements	30	2.8708	29	96.6667	29	100.0000
Infection and Immunity	76	7.2727	16	21.0526	9	56.2500
Journal of Bacteriology	75	7.1770	25	33.3333	15	60.0000
Journal of Clinical Microbiology	77	7.3684	23	29.8701	14	60.8696
Journal of Microbiology & Biology Education	60	5.7416	0	0.0000	0	NaN
Journal of Virology	87	8.3254	21	24.1379	6	28.5714
mBio	63	6.0287	17	26.9841	11	64.7059
Microbiology Resource Announcements	155	14.8325	146	94.1935	145	99.3151

container.title	n_total	n_fract	n_nsd	fract_nsd	n_da	fract_da
Microbiology Spectrum	111	10.6220	49	44.1441	38	77.5510
mSphere	57	5.4545	25	43.8596	20	80.0000
mSystems	80	7.6555	45	56.2500	45	100.0000

Table 2: Summary Statistics of All Data

container.title	n_total	n_fract	n_nsd	fract_nsd	n_da	fract_da
Antimicrobial Agents and Chemotherapy	20297	13.1550	2765	13.6227	897	32.4412
Applied and Environmental Microbiology	21853	14.1635	7261	33.2266	2546	35.0640
Genome Announcements	6714	4.3515	6628	98.7191	6546	98.7628
Infection and Immunity	14490	9.3913	1287	8.8820	264	20.5128
Journal of Bacteriology	16806	10.8924	3734	22.2183	1412	37.8147
Journal of Clinical Microbiology	18421	11.9391	3713	20.1563	499	13.4393
Journal of Microbiology & Biology Education	1305	0.8458	4	0.3065	1	25.0000
Journal of Virology	29761	19.2889	3079	10.3458	972	31.5687
mBio	7705	4.9938	2283	29.6301	1473	64.5204
Microbiology Resource Announcements	5878	3.8097	5744	97.7203	5734	99.8259
Microbiology Spectrum	6119	3.9659	2787	45.5467	2174	78.0050
mSphere	2615	1.6948	971	37.1319	751	77.3429
mSystems	2327	1.5082	1430	61.4525	1268	88.6713

Whole Dataset

160 Using the Crossref database, with validation from WOS, NCBI, and Scopus databases, we downloaded N = 154720 unique records of papers published in ASM journals between 2000 and 2024. After downloading the HTML content of each paper, we cleaned the HTML content and readied it

to apply our machine learning models to classify each paper. Overall, 26.9429% of papers had NSD, and 58.8615% of papers with NSD, had DA. See table 1 for percentages of NSD and DA for each journal. The journal with the highest rate of NSD was Genome Announcements at 98.7191%, and the lowest was Journal of Microbiology & Biology Education at 0.3065%. The journal with the highest rate of DA was Microbiology Resource Announcements at 99.8259%, and the lowest was Journal of Clinical Microbiology at 13.4393%. This was expected as Genome Announcements publishes mainly new genomic sequence data and makes the data available. On average, papers in the dataset had a median of 25 citations/article. This number varies by journal, see table YYYY for data by journal. The journal with the highest median rate of citations/article was Applied and Environmental Microbiology at 38%, and the lowest was Microbiology Resource Announcements at 1%. The journals in the dataset span years 2000-2024. See table YYYYYY for the distribution of papers per year in the dataset.

Training Dataset (pretty much the same as the above paragraph, but with stats for the training dataset)

*XX - add italics for journal names even when they're variables, do this in not visual mode

We created a subset of the whole dataset to train our machine learning models. The training dataset initially had N = 500 papers, but was increased over time due to gaps in the dataset, and after subsequent validation of the trained models (see below), with a total of N = 1045. See table 2 for the distribution of papers per journal in the training dataset. The journals in the dataset also span years 2000-2024. See table 3 for the distribution of papers per year in the training dataset. Overall, 43.7321% of papers had NSD, and 80.9628% of papers with NSD, had DA. See table 2 for percentages of NSD and DA for each journal. The journal with the highest rate of NSD was Genome Announcements at 96.6667%, and the lowest was Journal of Microbiology & Biology Education at 0%. The journals with the highest rate of DA in NSD papers were Genome Announcements and mSystems at 100%, and the lowest was Journal of Virology at 28.5714%. On average, papers in the dataset had median 10 citations/article. This number varies by journal, see table YYYY for data

by journal. The journal with the highest rate of citations/article was Infection and Immunity at 40%,
 190 and the lowest was Microbiology Resource Announcements at 0%.

Year Published Distribution Table

Table 3: Distribution of Year Published for Whole and Training Dataset

year.published	n_whole_dataset	n_training_dataset
2000	6009	30
2001	5825	43
2002	5807	23
2003	6170	22
2004	6461	21
2005	6961	36
2006	5873	29
2007	5911	18
2008	5476	12
2009	5561	13
2010	5622	21
2011	6206	41
2012	6609	24
2013	6618	29
2014	6875	31
2015	6745	34
2016	6417	38
2017	5893	40
2018	5899	40
2019	5964	63

year.published	n_whole_dataset	n_training_dataset
2020	5886	65
2021	6268	119
2022	6824	70
2023	6199	57
2024	6212	116
NA	429	10

Descriptive Statistics about the Trained Models

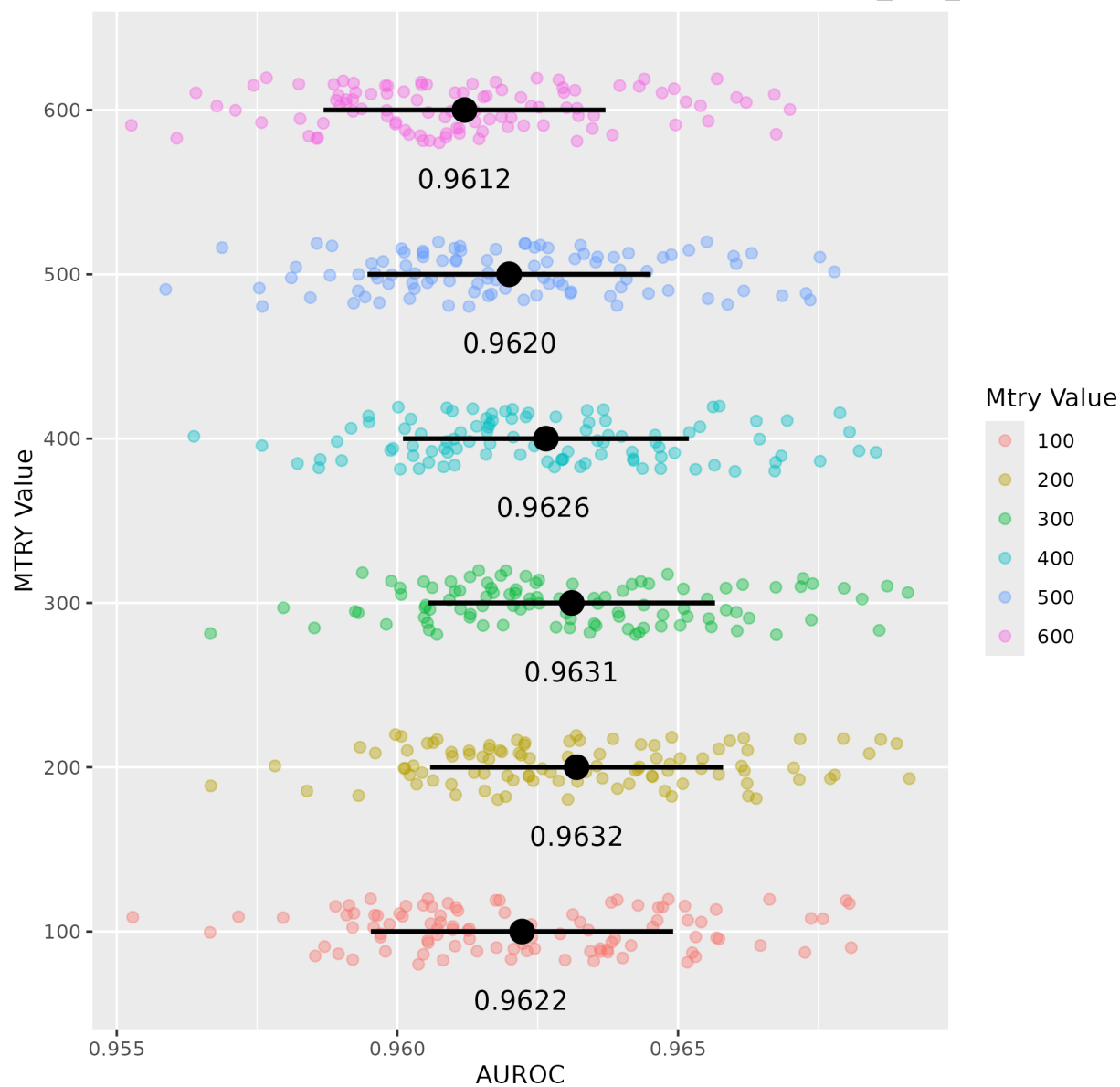
Table 4: Trained Model Summary Statistics

key	da_model	nsd_model
mtry	300.0000	200.0000
logLoss	0.1864	0.2848
AUC	0.9878	0.9645
prAUC	0.9468	0.9465
Accuracy	0.9464	0.9036
Kappa	0.8826	0.8029
F1	0.9586	0.9160
Sensitivity	0.9610	0.9350
Specificity	0.9199	0.8631
Pos_Pred_Value	0.9565	0.8984
Neg_Pred_Value	0.9290	0.9128
Precision	0.9565	0.8984
Recall	0.9610	0.9350
Detection_Rate	0.6204	0.5257

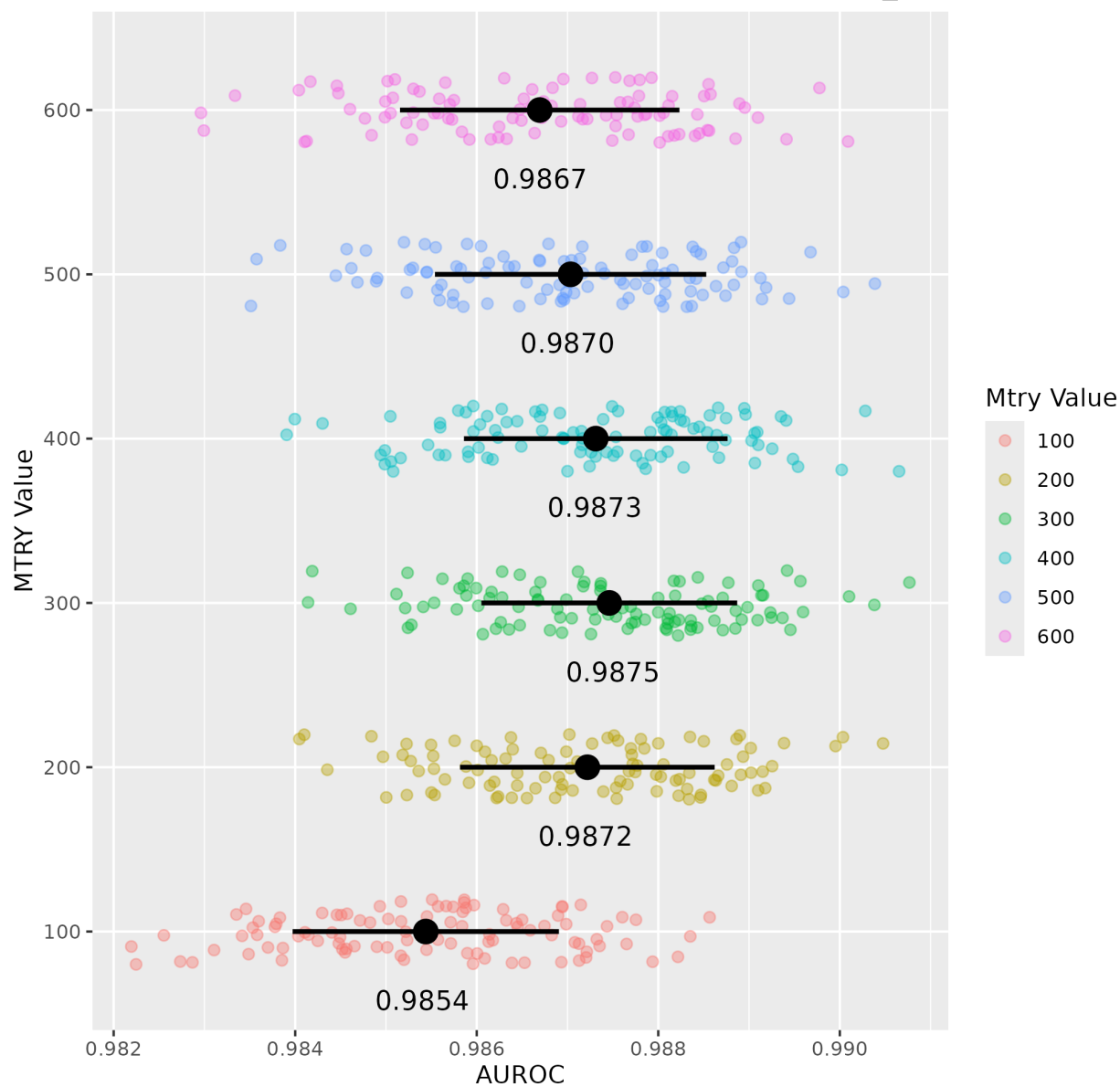
key	da_model	nsd_model
Balanced_Accuracy	0.9404	0.8991
logLossSD	0.0153	0.0206
AUCSD	0.0051	0.0107
prAUCSD	0.0131	0.0127
AccuracySD	0.0145	0.0189
KappaSD	0.0317	0.0388
F1SD	0.0112	0.0162
SensitivitySD	0.0163	0.0233
SpecificitySD	0.0294	0.0364
Pos_Pred_ValueSD	0.0152	0.0240
Neg_Pred_ValueSD	0.0277	0.0283
PrecisionSD	0.0152	0.0240
RecallSD	0.0163	0.0233
Detection_RateSD	0.0105	0.0133
Balanced_AccuracySD	0.0165	0.0199

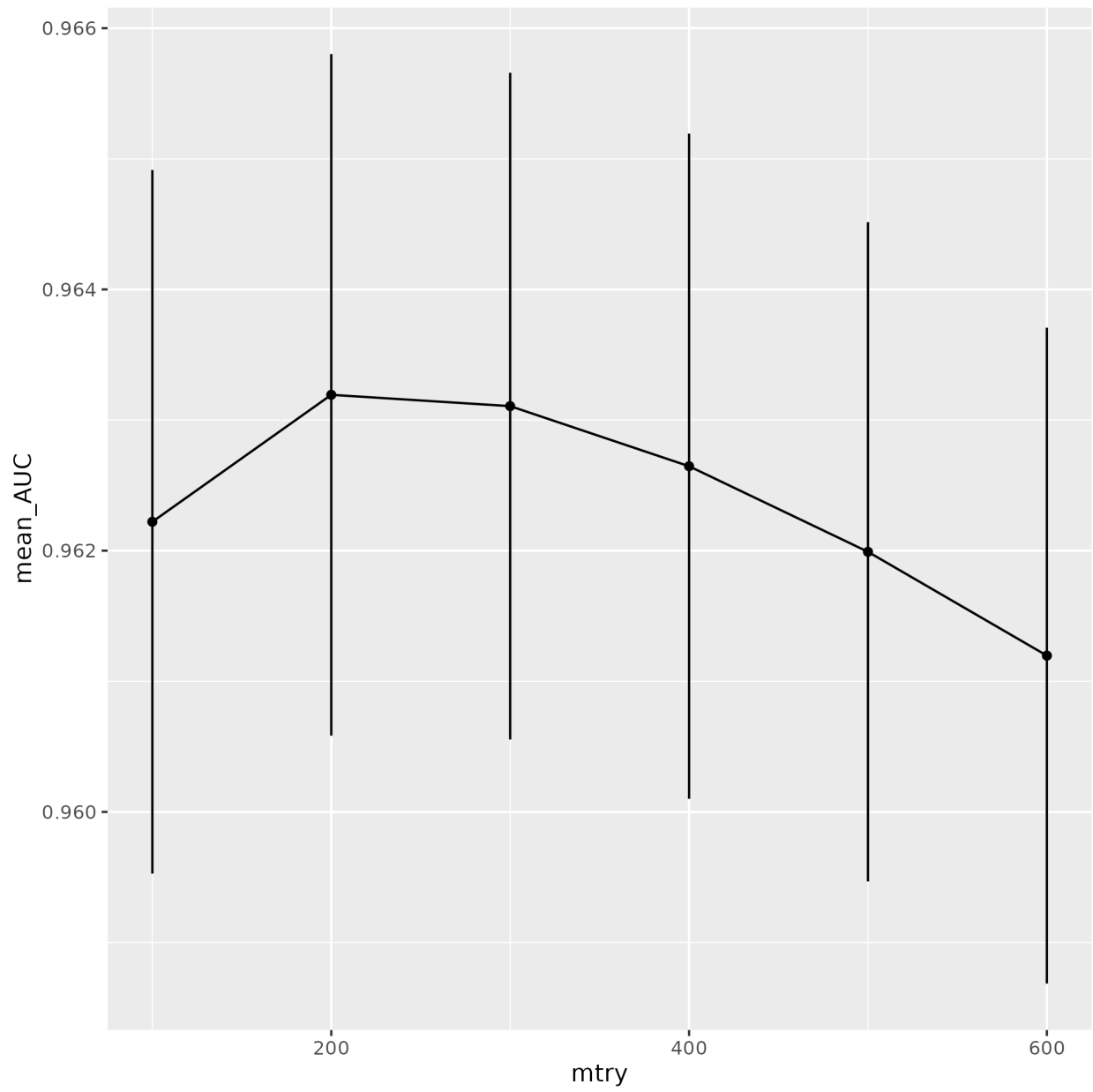
Figures for trained models

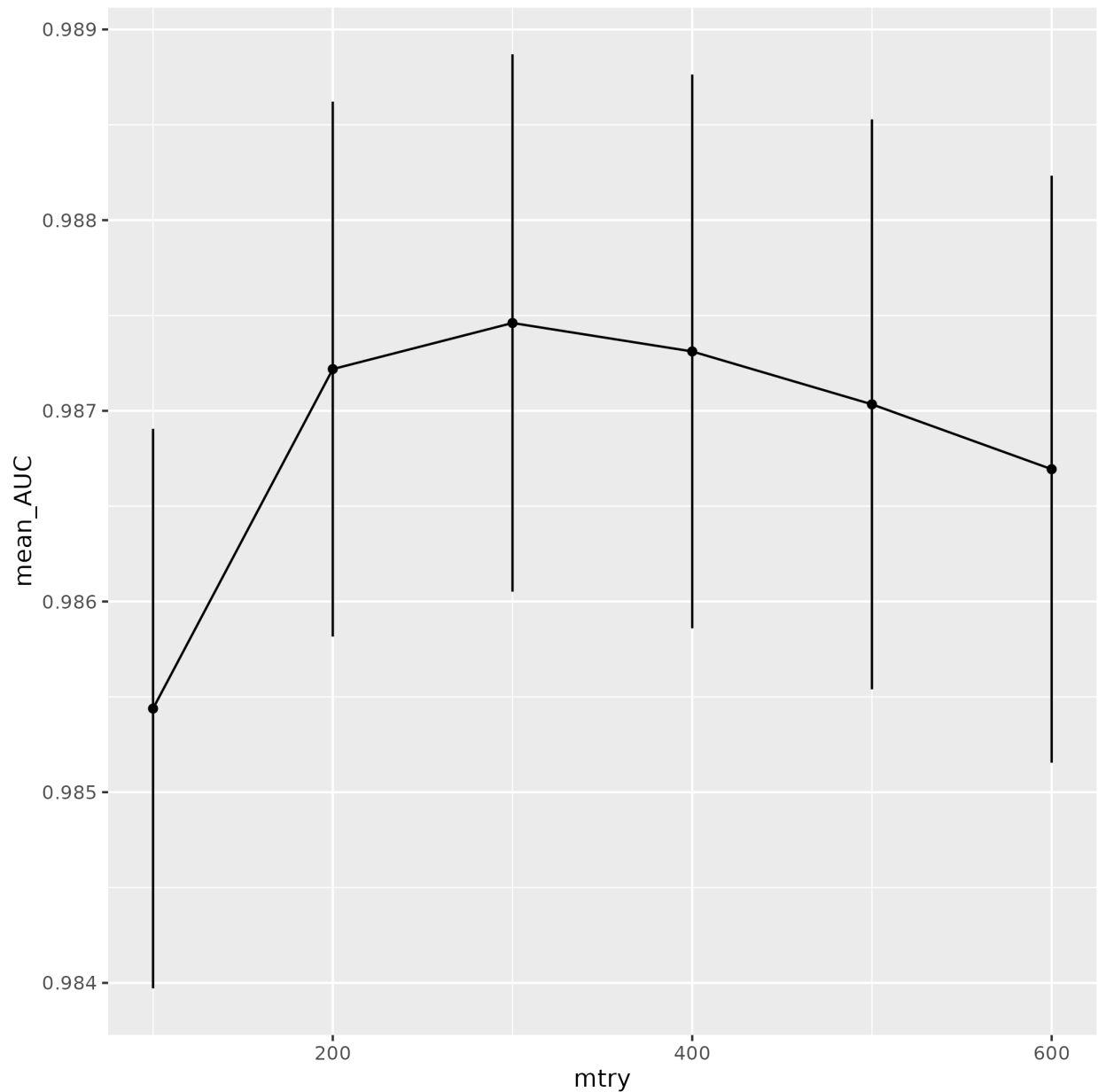
AUROC of Training Set by MTRY Value for model new_seq_data



AUROC of Training Set by MTRY Value for model data_availability







Two random forest models were trained to predict if published scientific papers “contained new sequence data” (NSD), and if the paper “had data available” (DA), one model for each variable.

200 Other models such as generalized linear regression and boosted trees were explored, but were ultimately discarded in favor of the random forest model (data not shown). Random forest models were chosen to aid in this classification problem as the creation of many decision trees helps to improve accuracy and precision. This type of model has one hyperparameter, ‘mtry’ or the number of predictors to be sampled at each decision. During iterative model training, a subset of papers

205 were validated after each completed training and deployment of each model. Papers from each journal, and extras from certain journals were hand-validated against model predictions to generate confusion matrices. Confusion matrices for the final version of each trained model are available in YYYY table(supplement?). The NSD model used an mtry value of 200 had an Area Under the Curve(AUC) of 0.9645 and an accuracy of 0.9036. The sensitivity of the NSD model was 0.935, 210 and the specificity of the model was 0.8631. The DA model used an mtry value of 300 had an AUC of 0.9878 and an accuracy of 0.9464. The sensitivity of the DA model was 0.961, and the specificity of the model was 0.9199 (See table 4 for more information on trained machine learning models). This shows that the models fit the data well, and can provide classifications on new data with an expected error rate of less than 10%. We deemed this as acceptable, accounting for variability in 215 papers and data, as well as the large size of the dataset on which we deployed the models.

Regression Model using Negative Binomial Models

Table 5: Coefficients for Negative Binomial Modeling

coefficients	full_nsd_yes	full_nsd_yes_pvalue
rsquared	0.6914	NA
(Intercept)	-1.1007	0.0000
da_factorYes	-1.6780	0.0000
log(age.in.months)	1.0193	0.0000
container.titleApplied and Environmental Microbiology	-0.7625	0.0002
container.titleGenome Announcements	-1.3780	0.6459
container.titleInfection and Immunity	-0.3405	0.2905
container.titleJournal of Bacteriology	-0.9194	0.0003
container.titleJournal of Clinical Microbiology	0.4635	0.0645
container.titleJournal of Microbiology & Biology Education	3.0029	0.5597
container.titleJournal of Virology	-0.3446	0.1051

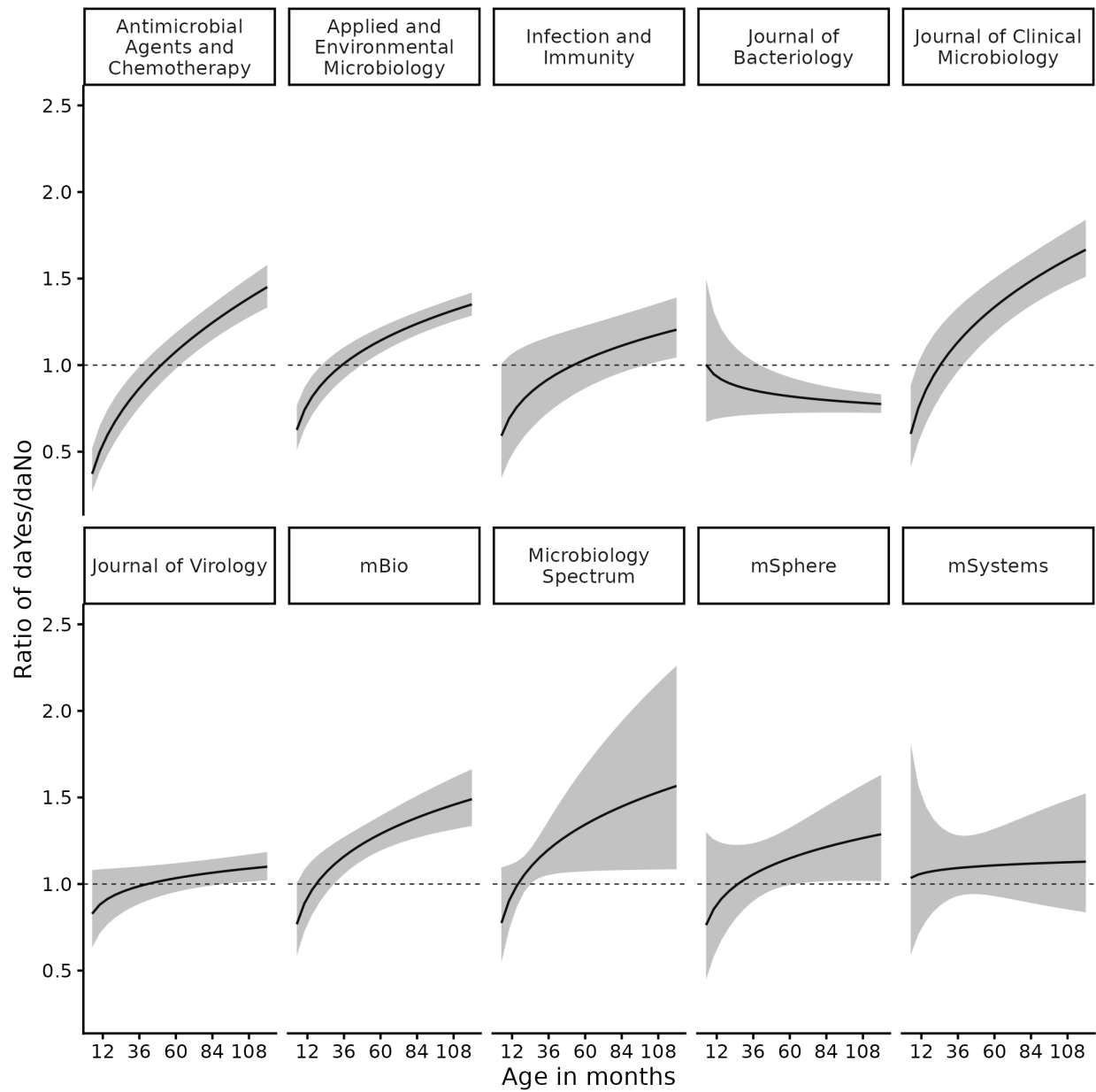
coefficients	full_nsd_yes	full_nsd_yes_pvalue
container.titlemBio	-1.4953	0.0000
container.titleMicrobiology Resource Announcements	2.3844	0.1270
container.titleMicrobiology Spectrum	-3.3128	0.0000
container.titlemSphere	-2.0889	0.0000
container.titlemSystems	-3.0742	0.0000
da_factorYes:container.titleApplied and Environmental Microbiology	0.8197	0.0063
da_factorYes:container.titleGenome Announcements	-1.0988	0.7162
da_factorYes:container.titleInfection and Immunity	0.7932	0.0976
da_factorYes:container.titleJournal of Bacteriology	1.8107	0.0000
da_factorYes:container.titleJournal of Clinical Microbiology	0.6567	0.0923
da_factorYes:container.titleJournal of Microbiology & Biology Education	-20.8893	0.9989
da_factorYes:container.titleJournal of Virology	1.3455	0.0000
da_factorYes:container.titlemBio	1.0788	0.0015
da_factorYes:container.titleMicrobiology Resource Announcements	-4.5437	0.0040
da_factorYes:container.titleMicrobiology Spectrum	1.0664	0.0144
da_factorYes:container.titlemSphere	1.1419	0.0277
da_factorYes:container.titlemSystems	1.6684	0.0025
da_factorYes:log(age.in.months)	0.4282	0.0000
log(age.in.months):container.titleApplied and Environmental Microbiology	0.1606	0.0001
log(age.in.months):container.titleGenome Announcements	-0.0672	0.9142
log(age.in.months):container.titleInfection and Immunity	0.0045	0.9407
log(age.in.months):container.titleJournal of Bacteriology	0.1231	0.0110
log(age.in.months):container.titleJournal of Clinical Microbiology	-0.1240	0.0100

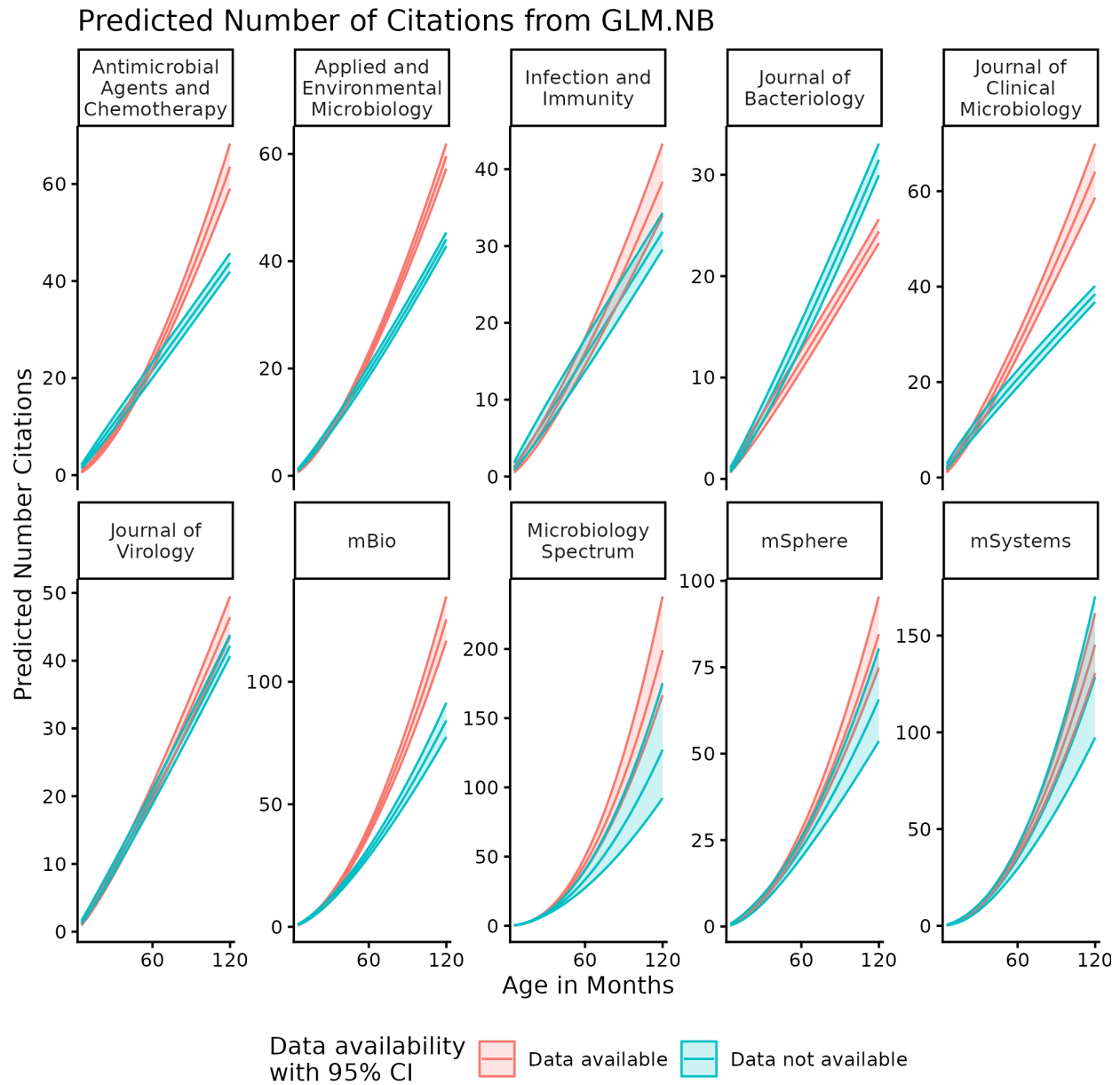
coefficients	full_nsd_yes	full_nsd_yes_pvalue
log(age.in.months):container.titleJournal of Microbiology & Biology Education	-1.2224	0.3434
log(age.in.months):container.titleJournal of Virology	0.0643	0.1261
log(age.in.months):container.titlemBio	0.4489	0.0000
log(age.in.months):container.titleMicrobiology Resource Announcements	-1.1018	0.0108
log(age.in.months):container.titleMicrobiology Spectrum	0.9146	0.0000
log(age.in.months):container.titlemSphere	0.5210	0.0000
log(age.in.months):container.titlemSystems	0.8673	0.0000
da_factorYes:log(age.in.months):container.titleApplied and Environmental Microbiology	-0.1861	0.0037
da_factorYes:log(age.in.months):container.titleGenome Announcements	0.1571	0.8029
da_factorYes:log(age.in.months):container.titleInfection and Immunity	-0.2045	0.0431
da_factorYes:log(age.in.months):container.titleJournal of Bacteriology	-0.5091	0.0000
da_factorYes:log(age.in.months):container.titleJournal of Clinical Microbiology	-0.1082	0.1950
da_factorYes:log(age.in.months):container.titleJournal of Microbiology & Biology Education	NA	NA
da_factorYes:log(age.in.months):container.titleJournal of Virology	-0.3389	0.0000
da_factorYes:log(age.in.months):container.titlemBio	-0.2198	0.0045
da_factorYes:log(age.in.months):container.titleMicrobiology Resource Announcements	1.1682	0.0074
da_factorYes:log(age.in.months):container.titleMicrobiology Spectrum	-0.2067	0.0953
da_factorYes:log(age.in.months):container.titlemSphere	-0.2635	0.0369

da_factorYes:log(age.in.months):container.titlemSystems	-0.4009	0.0040
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In this study we sought to investigate the effect of NSD and DA on the number of citations received by a given paper. We focused on NSD papers to determine the effect of having DA. This led us to the use of a negative binomial regression model to best describe our data. All regression data was NSD yes. We focused on the continuous outcome of “number of citations” with predictor variables journal (categorical), age in months (continuous), and DA status (dichotomous). Due to the number of citations being bell shaped with a long right tail (very few papers at advanced age with many citations), the model that best described our data was the negative binomial regression model. A negative binomial model is appropriate for data that begins at zero and has a long ‘tail’ of data. This model also includes a dispersion parameter to describe the spread of the data. We applied a log transformation to our age variable (age.in.months) to better describe the relationship between time and number of citations received. See table XXX6? for model coefficients. In general, we found that NSD papers that made DA received more citations over time than those that did not. See figure YYYY for trends in each major journal. ??XX insert some kind of metrics about % more citations over time? per journal? ??XX Describe figure emmeans contrast plot that i cannot get to insert in the document for the life of me??? In all journals excepting the *Journal of Bacteriology*, papers with DA have a greater number of citations at time point 60 months after publication, if not sooner via ratio plot. Over time this ratio increases further, demonstrating increased citations for papers with DA available over time.

Figures for Negative Binomial yay! come back to theseXX





Discussion

We investigated the impact of data availability on citation metrics in new sequencing papers by deploying machine learning models on over 150,000 papers from the ASM family of journals. Overall, making data available increases citation metrics over time.

On average, more than half of papers with NSD had DA (58.8615%), showing that authors of NSD

papers are more often than not, making their data publicly available. This is in line with recent NIH policy requiring that data be made available using the Data Management and Sharing Plan (DMS plan) outlined in the NIH's NOT-OD-21-013 ((8)). Expectedly, journals *Genome Announcements* and *Microbiology Resource Announcements* had the highest rates of DA in NSD papers. These journals publish primarily new genomic sequences and are required by ASM to make data available. Journals such as the *Journal of Microbiology and Biology Education* and *Infection and Immunity* which publish fewer NSD papers, have lower rates of DA in their journals.

Next, we looked further into the impact of DA on citation metrics using a negative binomial regression model. Using this model we found that over time, papers with DA receive more citations than those without up to well over 1.5x in some journals (*Journal of Clinical Microbiology*). This effect intensifies over time, with the greatest differences in citations occurring at the 108 months since publication time point. This is great news to manuscript authors, that simply making DA can give as much as 50% increase in citations over time. We believe that this more than justifies the work of making data available. We hope that these data will help to incentivize authors to make data available.

We acknowledge the limitations of our study data, focusing only on papers published in the ASM family of journals. We understand that this relationship between DA and citation metrics may not be as strong in other families of journals, but we hope with the newest NIH funding policies, these trends will continue. Another limitation is the availability of paper metadata from various databases, with crossref's metadata having the most complete metadata available for each paper. We were also not able to see specific time points, only having access to citation data for papers at time of dataset download (February 2025), and no intermediate time points for any given paper.

While DA in publications has a citation advantage, we hope that is not the only reason authors choose to make their data available. The need for reproducibility in science and demand for large datasets are additional reasons. We hope that authors recognize the need to contribute to the data "commons", to further work done by others, and that even their negative results have value and power to stop others from continuing down dead ends.

270 **Materials and Methods**

Creation of the Training set

To train our random forest machine learning model, we first created an appropriate training data set. Using the crossref database, we first downloaded all papers from the selected ASM family of journals from the time period beginning January 1st, 2000, and ending on December 31st, 2024.

275 The data was updated as of February 10th, 2025 with all citation counts frozen at that date. For our initial training set, we chose N = 500 papers from across each journal and time period, adding special emphasis to include papers that were part of our desired set of interest (i.e. contained published data) to ensure that our two models could adequately characterize each paper as a new sequencing paper and if it published raw sequencing data or not. After creating our initial
280 dataset, it was necessary to identify the status of both variables by hand and determine if each paper contained “new sequencing data” (NSD), and if each one had “data available” (DA). This was completed by opening each paper in an internet browser window, and searching for a “data availability” or similar statement. See table XXX for specific cases and how each of these cases were identified for the purpose of this study.

Table 6: Possible Data Scenarios

Scenario	NSD Status	DA Status
Paper is not about generating new sequencing data	No	No
Paper is about generating new sequencing data but has no data available	Yes	No
Paper is about generating new sequencing data and has data available	Yes	Yes

Scenario	NSD Status	DA Status
Paper uses sequencing as a confirmation of experimental technique (i.e. confirmation of plasmid insertion)	No	No
Paper discusses new computational or experimental tools	No	No
Paper has microarray data	No	No
Papers using MLST ONLY	No	No
Papers using qPCR ONLY	No	No
Papers about protein sequencing that have nucleotide sequencing	Yes	Yes/No depending on DA
Papers using iRNA techniques	No	No
Papers using pyrosequencing/454 techniques	Yes	Yes/No depending on DA

Adding Additional Training Set Papers

After initial trainings of our random forest models, a random sampling of papers was collected for each journal to audit the efficacy of the models. To audit the efficacy of the models, we hand identified the status of both variables of interest, NSD and DA. We looked for weaknesses in the models, and updated methodology to reflect important areas of interest. For example, in 2023 the ASM journals changed their formatting to include the data availability statement of a paper in a sidebar of the webpage. We identified this by noticing that all papers from journal *Microbiology Resource Announcements* from 2023-2024 were incorrectly characterized by the model as DA = No. The sidebar of the webpage was not included in the text the model was considering, and code had to be updated to include all sidebar data for all papers. These improvements to the model created a larger and more comprehensive training set of N = 1045. These validations allowed us to

create confusion matrices for each model. Confusion matrices for the final version of each trained model are available in YYYY table(XXsupplement?).

Descriptive Statistics about the Training Set

I think this is covered earlier but i will leave it for now just to make sure that i can move the sentences around if i need to

There were XXX papers in the training data set from 12 ASM journals. These papers came from journals *Applied and Environmental Microbiology*; *Antimicrobial Agents and Chemotherapy*; *Infection and Immunity*; *Journal of Clinical Biology*; *Journal of Virology*; *Journal of Bacteriology*; *Journal of Microbiology and Biology Education*; *Microbiology Resource Announcements* (formerly known as *Genome Announcements*); *mSystems*; *mSphere*; *mBio*; and *Microbiology Spectrum*. See table XXXX for the number of papers from each journal in the training dataset. The training dataset includes journal articles published between January 1st, 2000 and December 31st, 2024. See table XXXXX for the number of papers included from each year from 2000-2024. XXX% of training set data was NSD = Yes, and XXX% of training set data was DA = Yes.

Creation of the Training Data from Training dataset

To perform the computational steps required for these experiments, we used the python tool Snakemake ((18)), and the University of Michigan's high performance computing cluster (see acknowledgements). Using our selected papers from the training dataset, we downloaded the entirety of each paper's source HTML using the command line tool wget. This allowed us to use the source HTML multiple times for updated analyses without the need to re-query the ASM web servers numerous times. Next, we performed cleaning of the HTML using R packages rvest ((19)) and xml2 ((20)) to get the desired portions of the paper from the HTML including the abstract, the body of paper, all tables and figures with captions, as well as the side panels for all papers, but especially those containing the data availability statements in papers published after the 2023

change in webpage format (see above). Then we removed unnecessary text using R packages `tm` (text manipulation) ((21), (22)) and `textstem` ((23)), as well as converting all text to lowercase, and the removal of digits and non-alphabetic characters such as whitespace. To have the fewest number of unique words, we lemmatized (sort words by grouping inflected or variant forms of the same word) words to trace them back to their root words and eliminate any possible issues with word tense. After this, we created and counted our 'tokens', phrases of up to 1-3 consecutive words from the text of the paper using R package `tokenizers` ((**tokenizers?**)). Towards the goal of the fewest meaningful number of words, we used the 'Snowball' ((24)) dictionary of 'stop words' to remove non-meaningful words such as articles 'a', 'an', and 'the'. We removed the 'space' character with an underscore in multi-word tokens for ease of processing, and created a count table for the tokens in each paper.

Once the tokens in each paper were counted, we transformed the data into a sparse matrix format useable by the R package `mikropml` ((25) ref), using R packages `caret` and `dplyr` ((26), (27), (28)). Tokens were filtered to those which appear in greater than one paper. This allows comparison between papers by the model. We removed near zero variants (tokens with frequency very close to zero) as well as collapsing perfectly correlated tokens (tokens that always appear together) using R packages `caret` and `mikropml` to reduce model complexity. The data was then simplified to keep only the following variables; tokens, frequency, journal information, and hand identified NSD and DA variables. This simplified sparse matrix data had the mean and standard deviation calculated and saved for the frequency of each token to later apply a z-scoring method to future data to be predicted by the model.

Training of the DA and NSD Models

We trained two random forest machine learning models using `mikropml`'s "run_ml" function, one to determine if a paper contained new sequence data (NSD), and another to determine if the paper had data available (DA). The `mikropml` "run_ml" function uses methodology described by *Topcuoglu et al.*((**topcuoglu2020?**)) to split data for model training. Random forest models have

one hyperparameter to tune, the mtry value. We began with mtry values of 100, 200, 300, 400, 500, and 600, to find peak hyperparameter performance given N tokens. We trained the models multiple times in accordance with existing methodologies, first to find the optimal Area Under the Receiver-Operator Curve (AUROC) value for each model with $N=100$ seeds. Then to find the best mtry performance for each model, with $N=1$ seed. Finally, with $N=1$ seed to train each final model for use on experimental data.

Preparation of the Experimental Dataset

To fully answer our research questions, we created a larger database with $N = 155779$ papers curated from reference datasets Crossref, NCBI, Scopus, and the Web of Science ((crossref?), (ncbi?), (scopus?), (29)). These papers span all twelve ASM journals of interest from the start of 2000 to the end of 2024. Once database was curated, we applied the same steps to ready papers for application of machine learning models as the model training datasets. See above for descriptions of webscraping html, cleaning html, removing unnecessary text, and creation of token count table for application in each of the machine learning models to determine the NSD and DA statuses for each paper. Once the frequency count tables were prepared for each paper, a z-score was applied using the saved data from each model appropriately, using the formula $XXX((\text{observed_token_frequency} - \text{model_token_frequency_mean})/(\text{model_token_frequency_sd}))$. This z-scoring formula was applied to standardize the frequency of each token. Only tokens included in the machine learning models were retained in experimental datasets. Finally, each model was deployed on each paper to determine its NSD and DA status.

Statistical Methodology

After each random forest model was deployed on our experimental dataset, we used a negative binomial regression model using the R package MASS ((MASSref?)). A negative binomial regression model allows us to investigate data where group means are different than the overall dataset

370 mean. A log transformation of the time variable(age.in.months) was applied prior to estimating the statistical regression model to correct for the nature of time as compared to other variables in the dataset. After applying the negative binomial model, we calculated ratios of the estimated number of citations per paper over time by DA status using R package emmeans ((30)). We also used R package sjPlot to estimate the 95% CI for estimated citations over time for each journal by DA
375 status ((**sjPlotref?**)).

- Supplemental Material file list (where applicable)
- Acknowledgments

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ARC's RRID is: [SCR_027337](#)

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- Figures/Tables/stats to make/get
 - table of conditions to add to the methods of classification?

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