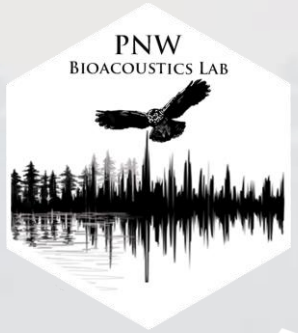
Shiny PNW-Cnet: AI-Powered Audio Processing for Wildlife Research

Zack Ruff[1,2*], Damon Lesmeister[1,2], Julianna Jenkins[2], Chris Sullivan[3]

[1] Dept of Fisheries, Wildlife, and Conservation Sciences, Oregon State University
[2] USDA Forest Service Pacific Northwest Research Station
[3] College of Earth, Ocean, and Atmospheric Sciences, Oregon State University
* zjruff@gmail.com



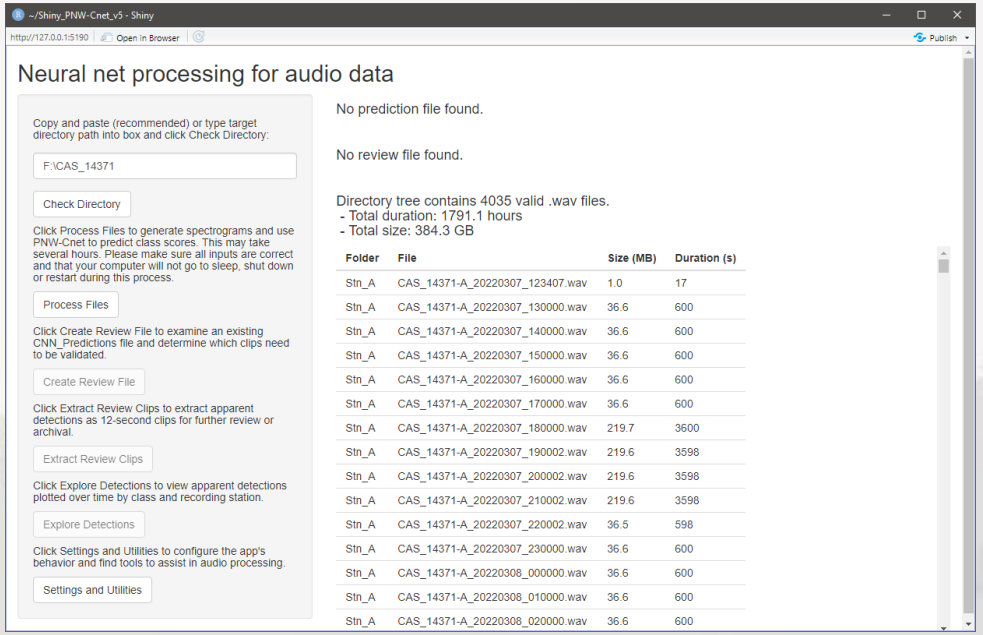
Oregon State University

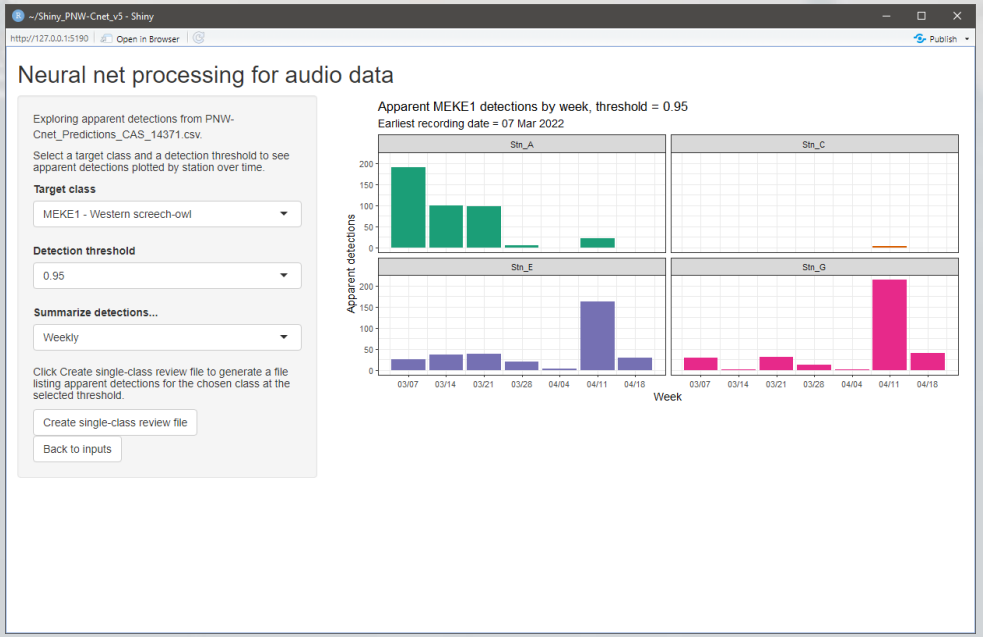
Cascadia R Conf - Seattle, WA, 19 Aug 2023

Why I’m here

Shiny PNW-Cnet

- Desktop app to process audio data for bioacoustic research and wildlife monitoring
- Uses deep learning to automate detection of target species
- Facilitates manual review of apparent detections
- Supports efficient bioacoustics workflows





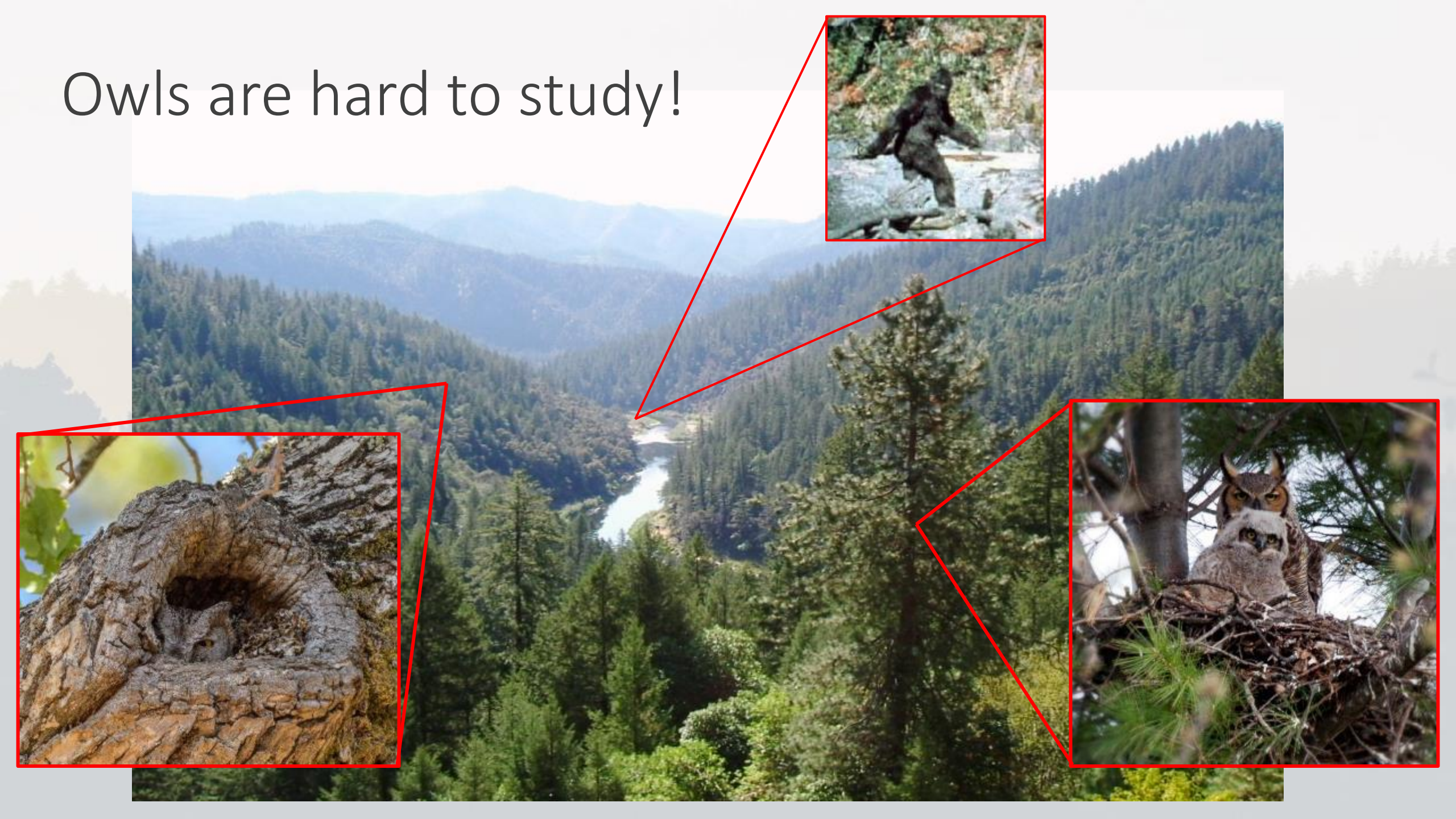
Background: Spotted owls

Northern spotted owl (NSO)

- Endemic to old forests of the PNW
- Major population declines since early 1900s
- Threatened by habitat loss, invasive species

- Northwest Forest Plan (1994)
  - Halted logging, established reserves
  - **Mandates NSO population monitoring**

Owls are hard to study!



Historic methods: Surveys

Issues with historic methods

- Effects on study species
  - Altered behavior
  - Induced stress
  - Exposure to predators
  - Desensitization over time
- Increasing costs
  - Rare species are harder to find
- Field crew safety

Passive acoustic monitoring

- Automated recording units (ARUs) record audio on a programmed schedule
- Non-invasive, captures natural calling activity
- Very high detection probability for spotted owls and other species

THE CONDOR
Ornithological Applications
AmericanOrnithology.org

Volume 122, 2020, pp. 1–22
DOI: 10.1093/condor/duaa017

RESEARCH ARTICLE

Passive acoustic monitoring effectively detects Northern Spotted Owls and Barred Owls over a range of forest conditions

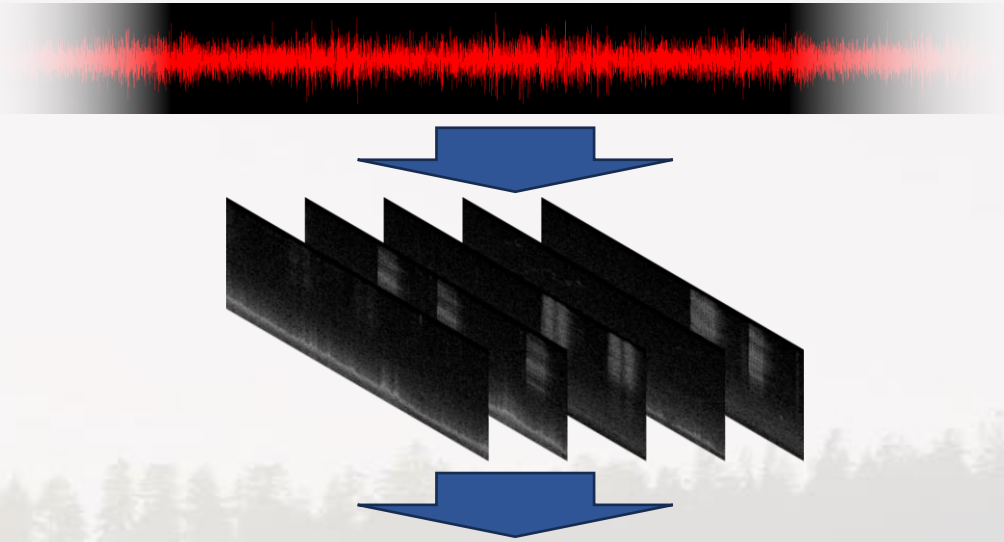
Leila S. Duchac,[1,2,*] Damon B. Lesmeister,[1] Katie M. Dugger,[3] Zachary J. Ruff,[1] and Raymond J. Davis[4]

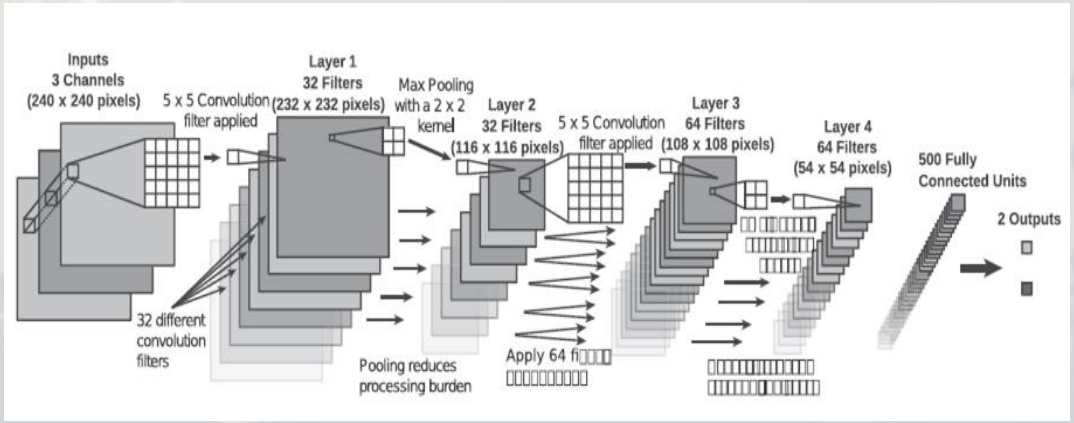
Big data

- Acoustic monitoring generates **lots** of data
- Data curation / management is a full-time job
- Automated detection is crucial
- Errors have ecological and legal consequences

PNW-Cnet

- Deep convolutional neural net developed with the Forest Service
- Detects sounds in spectrograms
- Class scores indicate presence / absence of each target class
- Filter scores to get apparent detections





Filename	AEAC	BRCA	BRMA	BUVI	CAGU	CALU	CAUS	CCOO	CHFA
CAS_14371-A_20220307_123407_part_001.png	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CAS_14371-A_20220307_130000_part_001.png	0.00000	0.00000	0.00000	0.00005	0.00027	0.00000	0.00005	0.00022	0.00006
CAS_14371-A_20220307_130000_part_002.png	0.02357	0.00315	0.00001	0.00114	0.00029	0.00000	0.00011	0.00038	0.00017
CAS_14371-A_20220307_130000_part_003.png	0.00003	0.00000	0.00000	0.00067	0.00003	0.00000	0.00001	0.00001	0.00000
CAS_14371-A_20220307_130000_part_004.png	0.00002	0.00001	0.00000	0.00038	0.00005	0.00000	0.00003	0.00001	0.00001
CAS_14371-A_20220307_130000_part_005.png	0.00003	0.00005	0.00000	0.00048	0.00034	0.00000	0.00034	0.00022	0.00005
CAS_14371-A_20220307_130000_part_006.png	0.00001	0.00000	0.00000	0.00043	0.00002	0.00000	0.00000	0.00000	0.00000
CAS_14371-A_20220307_130000_part_007.png	0.00000	0.00000	0.00000	0.00048	0.00020	0.00000	0.00004	0.00010	0.00002
CAS_14371-A_20220307_130000_part_008.png	0.00001	0.00000	0.00000	0.00051	0.00004	0.00000	0.00001	0.00001	0.00001

The bioacoustic workflow

I. Collect data

1. Deploy recorders

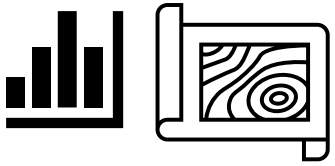
2. Retrieve Data

3. Organize data

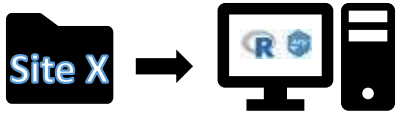
II. Process data

6. Review detections

5. Explore detections



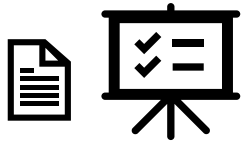
4. Process with neural net



III. Analyze and communicate

7. Analyze detections

8. Report results



9. Repeat process, report trends

Version 1
Oct 2018
6 target species






Version 2
May 2019
14 target species








Version 3
Sept 2020
28 target species














Version 4
June 2021
38 target species





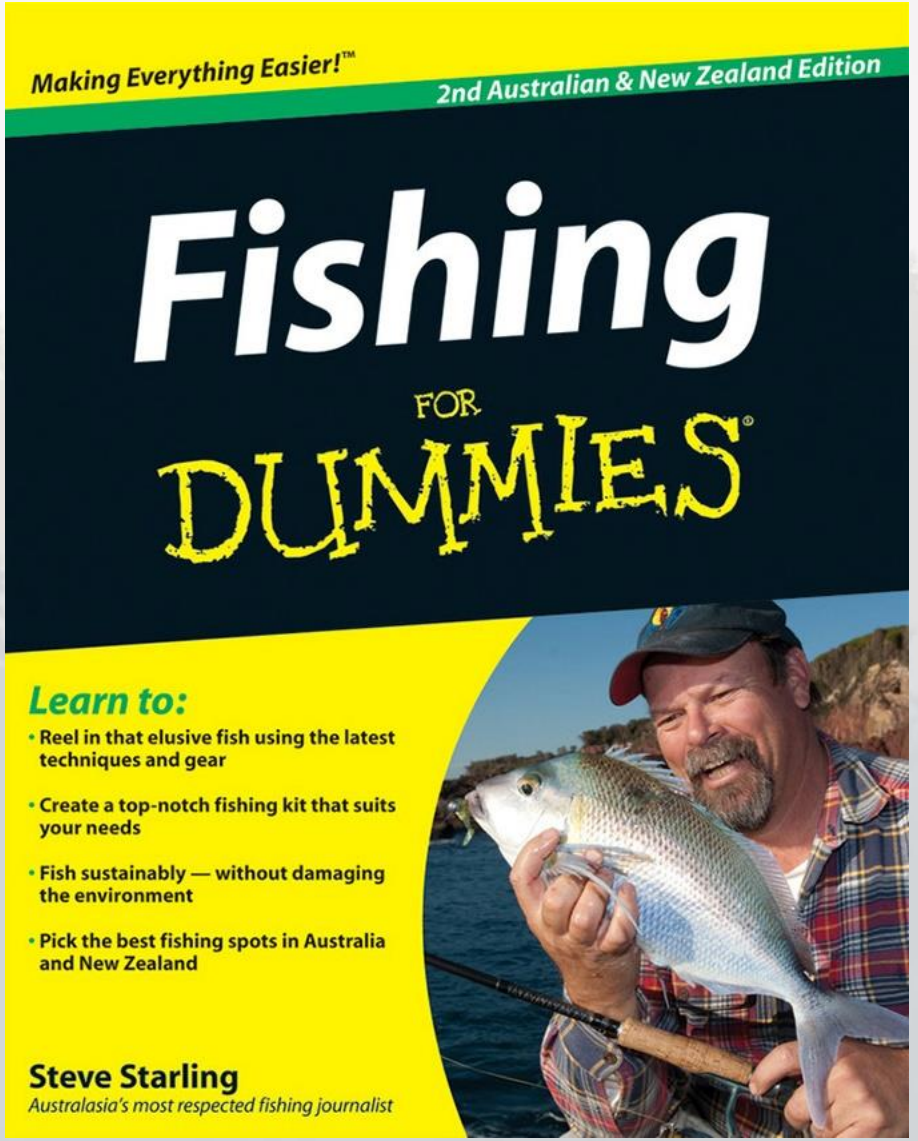





Evolution of PNW-Cnet

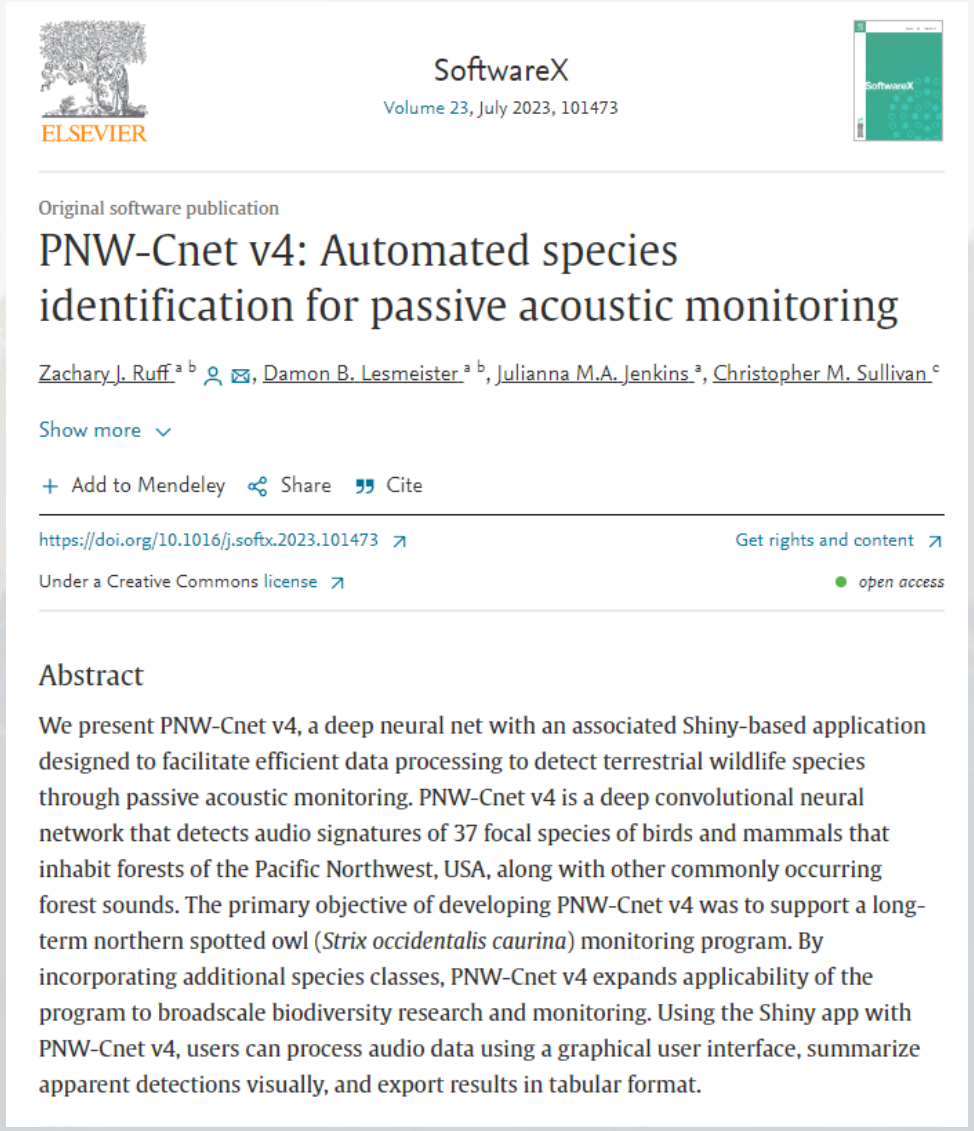
Why build an app?

- Share proven tools and methods
- Distribute the processing workload
- Collaborate with other researchers
- Expand monitoring footprint
- GUI = more approachable for non-power users



Shiny PNW-Cnet

- Available through GitHub
- Requirements:
  - Windows 64-bit
  - R + RStudio
  - Anaconda or Miniconda
  - SoX
  - various R and Python packages
- Neural net and app documented in open-access journals



ELSEVIER

SoftwareX

Volume 23, July 2023, 101473

Original software publication

PNW-Cnet v4: Automated species identification for passive acoustic monitoring

Zachary J. Ruff [a b], Damon B. Lesmeister [a b], Julianna M.A. Jenkins [a], Christopher M. Sullivan [c]

Show more

+ Add to Mendeley Share Cite

https://doi.org/10.1016/j.softx.2023.101473 Get rights and content

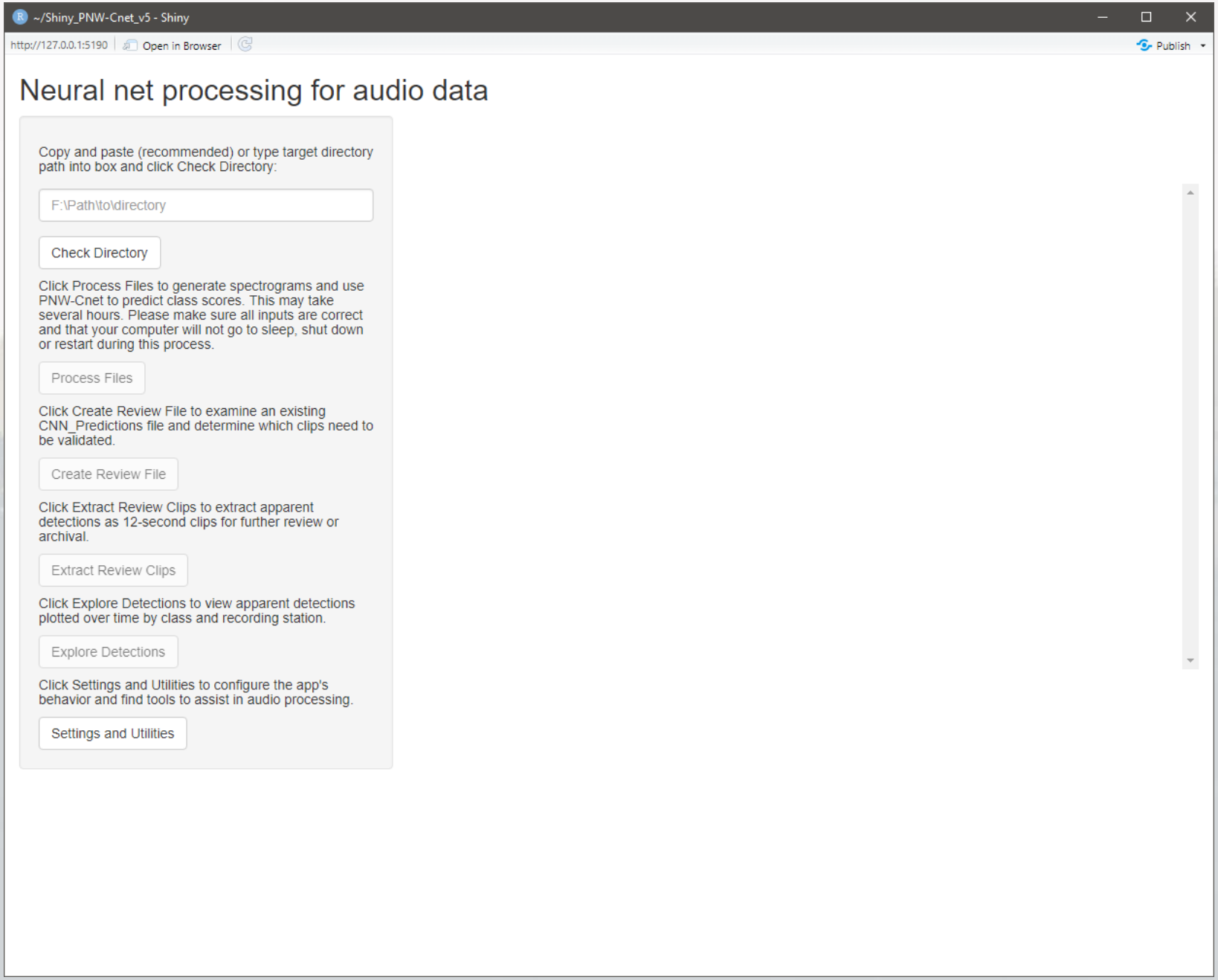
Under a Creative Commons license open access

Abstract

We present PNW-Cnet v4, a deep neural net with an associated Shiny-based application designed to facilitate efficient data processing to detect terrestrial wildlife species through passive acoustic monitoring. PNW-Cnet v4 is a deep convolutional neural network that detects audio signatures of 37 focal species of birds and mammals that inhabit forests of the Pacific Northwest, USA, along with other commonly occurring forest sounds. The primary objective of developing PNW-Cnet v4 was to support a long-term northern spotted owl (*Strix occidentalis caurina*) monitoring program. By incorporating additional species classes, PNW-Cnet v4 expands applicability of the program to broadscale biodiversity research and monitoring. Using the Shiny app with PNW-Cnet v4, users can process audio data using a graphical user interface, summarize apparent detections visually, and export results in tabular format.

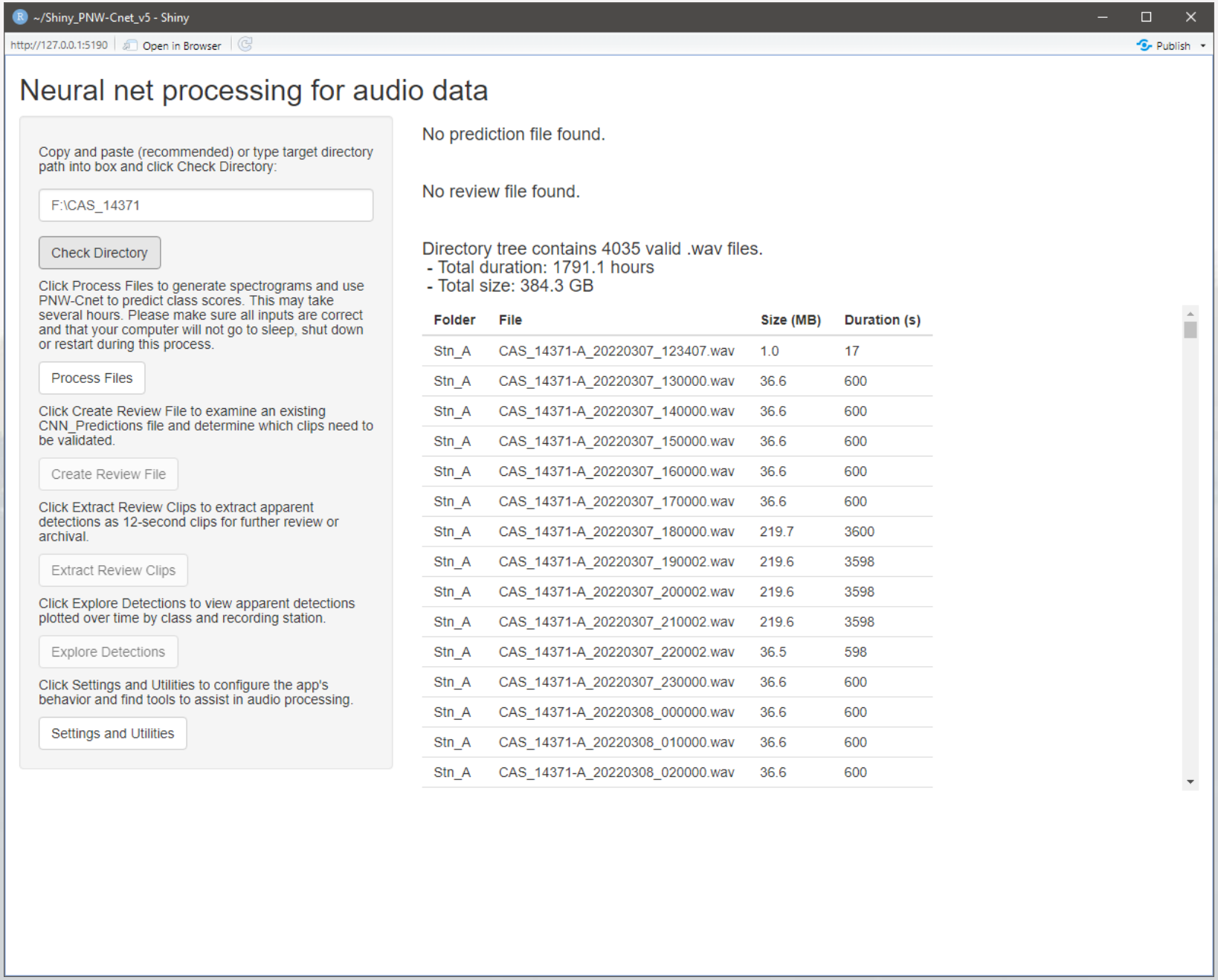
Using the app

- Launched from RStudio
- Main view provides navigation and instructions
- Controls become active as needed



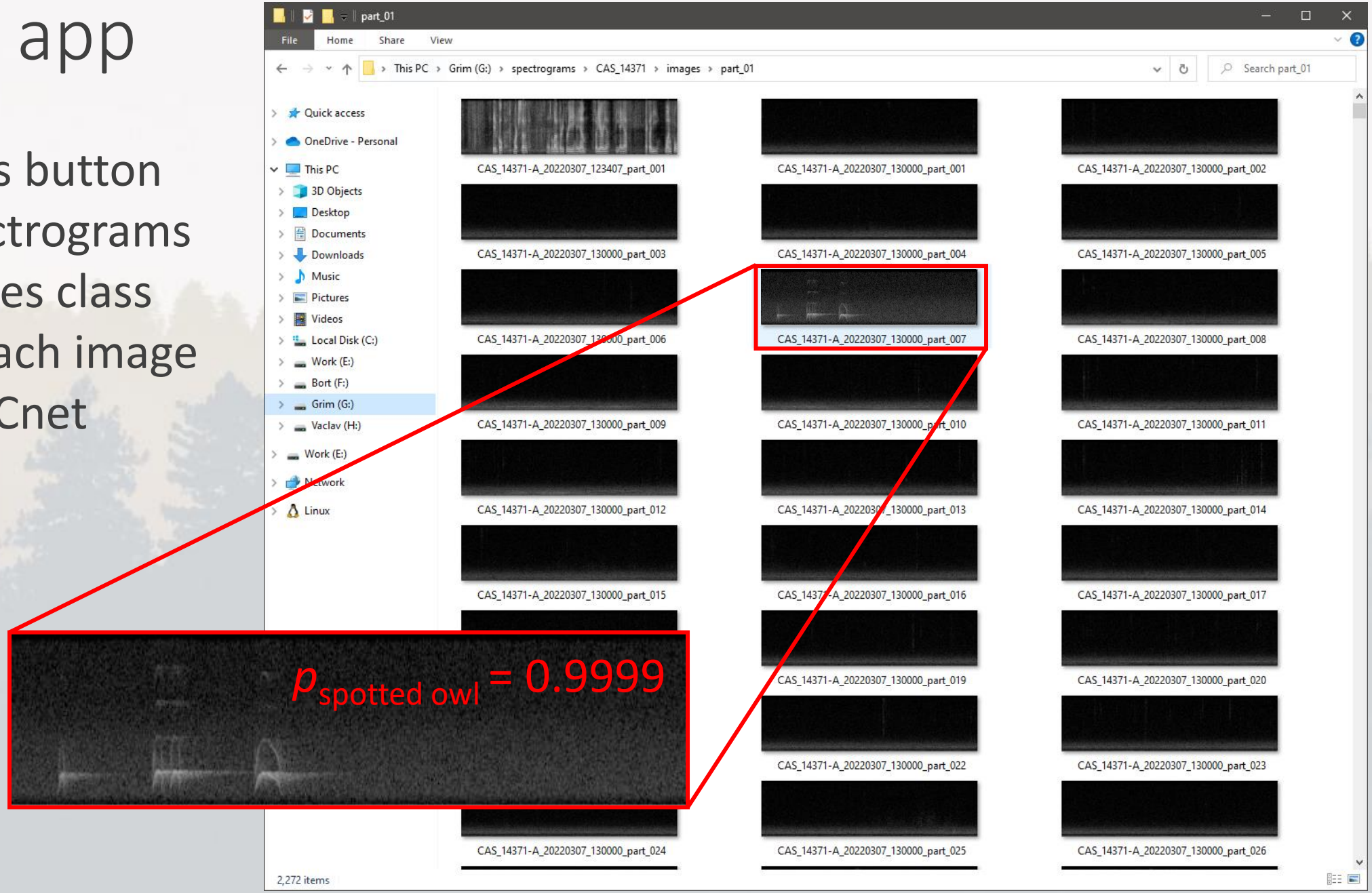
Using the app

- Enter target folder and click Check Directory
- App searches for .wav files within the folder, summarizes data, enables Process Files button



Using the app

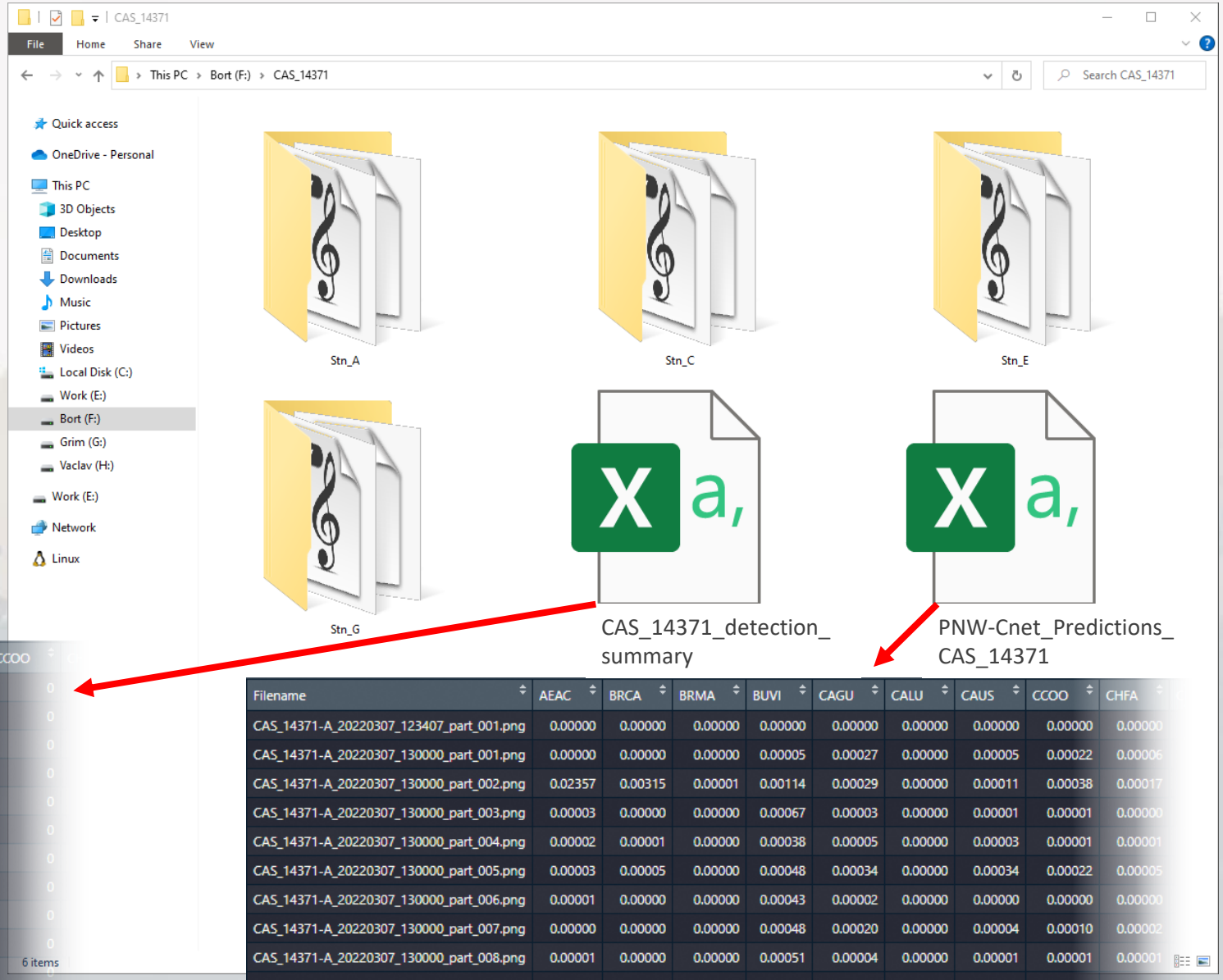
- Process Files button creates spectrograms and generates class scores for each image using PNW-Cnet



Using the app

Processing output:

- Predictions file (class scores by image)
- Detection summary file (apparent detections by class)



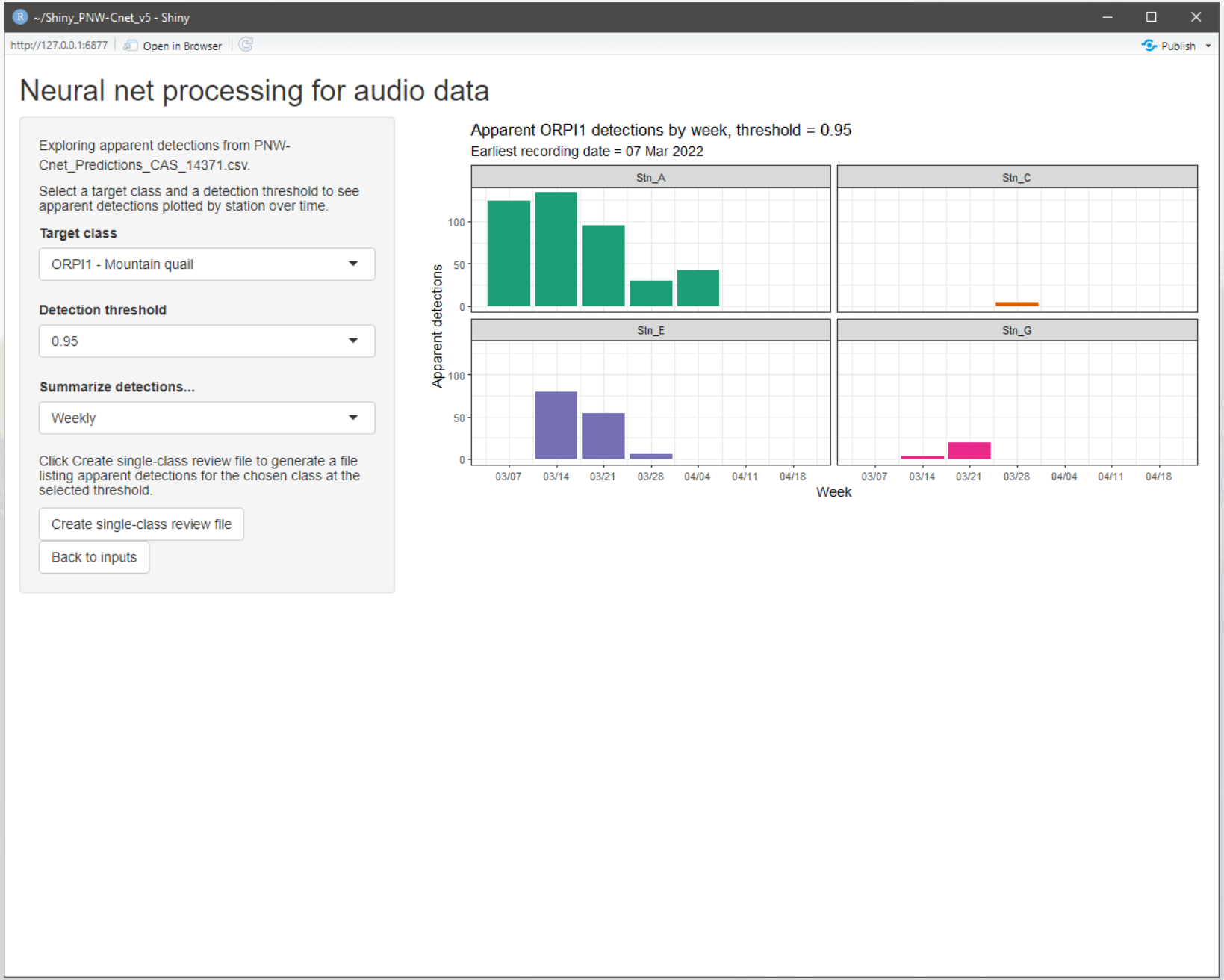
Station	Rec_Date	Week	Threshold	AEAC	BRCA	BRMA	BUVI	CAGU	CALU	CAUS	CCOO
Stn_A	19058	1	0.95	0	0	0	4	0	0	0	0
Stn_A	19059	1	0.95	0	0	0	2	0	0	0	0
Stn_A	19060	1	0.95	0	0	0	0	0	0	0	0
Stn_A	19061	1	0.95	0	0	0	0	0	0	0	0
Stn_A	19062	1	0.95	0	0	0	0	0	0	0	0
Stn_A	19063	1	0.95	0	0	0	0	0	0	0	0
Stn_A	19064	1	0.95	0	0	0	0	0	0	0	0
Stn_A	19065	2	0.95	0	0	0	0	0	0	0	0
Stn_A	19066	2	0.95	0	0	0	0	0	0	0	0
Stn_A	19067	2	0.95	0	0	0	0	0	0	0	0
Stn_A	19068	2	0.95	0	0	0	0	0	0	0	0
Stn_A	19069	2	0.95	0	0	0	0	0	0	0	0
Stn_A	19070	2	0.95	0	0	0	1	0	0	0	0
Stn_A	19071	2	0.95	0	0	0	8	0	0	0	0
Stn_A	19072	3	0.95	0	0	0	0	0	0	0	0

Filename	AEAC	BRCA	BRMA	BUVI	CAGU	CALU	CAUS	CCOO	CHFA
CAS_14371-A_20220307_123407_part_001.png	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
CAS_14371-A_20220307_130000_part_001.png	0.00000	0.00000	0.00000	0.00005	0.00027	0.00000	0.00005	0.00022	0.00006
CAS_14371-A_20220307_130000_part_002.png	0.02357	0.00315	0.00001	0.00114	0.00029	0.00000	0.00011	0.00038	0.00017
CAS_14371-A_20220307_130000_part_003.png	0.00003	0.00000	0.00000	0.00067	0.00003	0.00000	0.00001	0.00001	0.00000
CAS_14371-A_20220307_130000_part_004.png	0.00002	0.00001	0.00000	0.00038	0.00005	0.00000	0.00003	0.00001	0.00001
CAS_14371-A_20220307_130000_part_005.png	0.00003	0.00005	0.00000	0.00048	0.00034	0.00000	0.00034	0.00022	0.00005
CAS_14371-A_20220307_130000_part_006.png	0.00001	0.00000	0.00000	0.00043	0.00002	0.00000	0.00000	0.00000	0.00000
CAS_14371-A_20220307_130000_part_007.png	0.00000	0.00000	0.00000	0.00048	0.00020	0.00000	0.00004	0.00010	0.00002
CAS_14371-A_20220307_130000_part_008.png	0.00001	0.00000	0.00000	0.00051	0.00004	0.00000	0.00001	0.00001	0.00001
CAS_14371-A_20220307_130000_part_009.png	0.00007	0.00003	0.00000	0.00418	0.00002	0.00000	0.00001	0.00001	0.00000
CAS_14371-A_20220307_130000_part_010.png	0.00001	0.00000	0.00000	0.00065	0.00003	0.00000	0.00000	0.00000	0.00000
CAS_14371-A_20220307_130000_part_011.png	0.00001	0.00000	0.00000	0.00039	0.00004	0.00000	0.00001	0.00003	0.00001
CAS_14371-A_20220307_130000_part_012.png	0.00000	0.00000	0.00000	0.00051	0.00001	0.00000	0.00000	0.00000	0.00000

Using the app

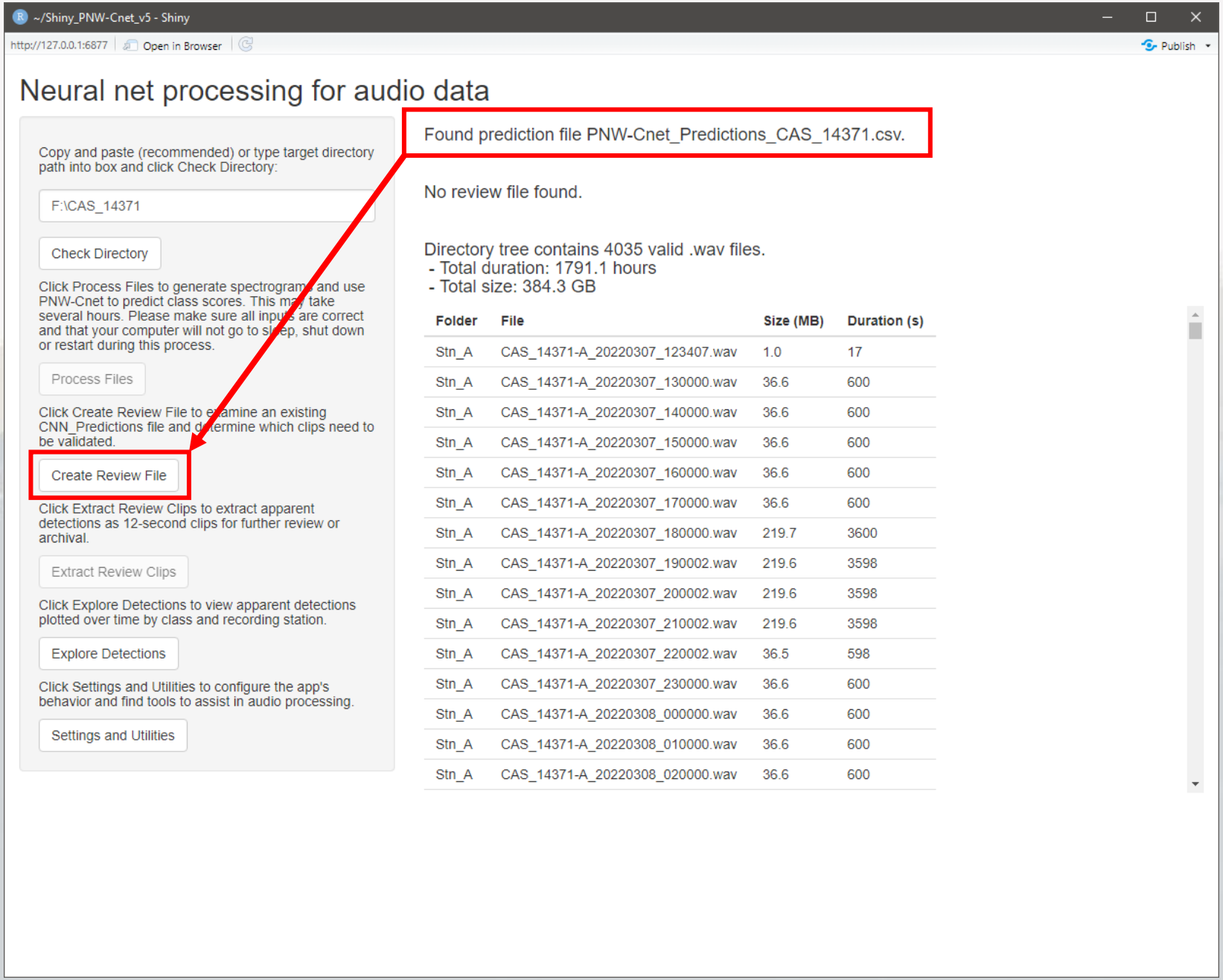
- Explore Detections view plots apparent detections for any class with specified score threshold, grouped by station and time

- Export apparent detections for a single class



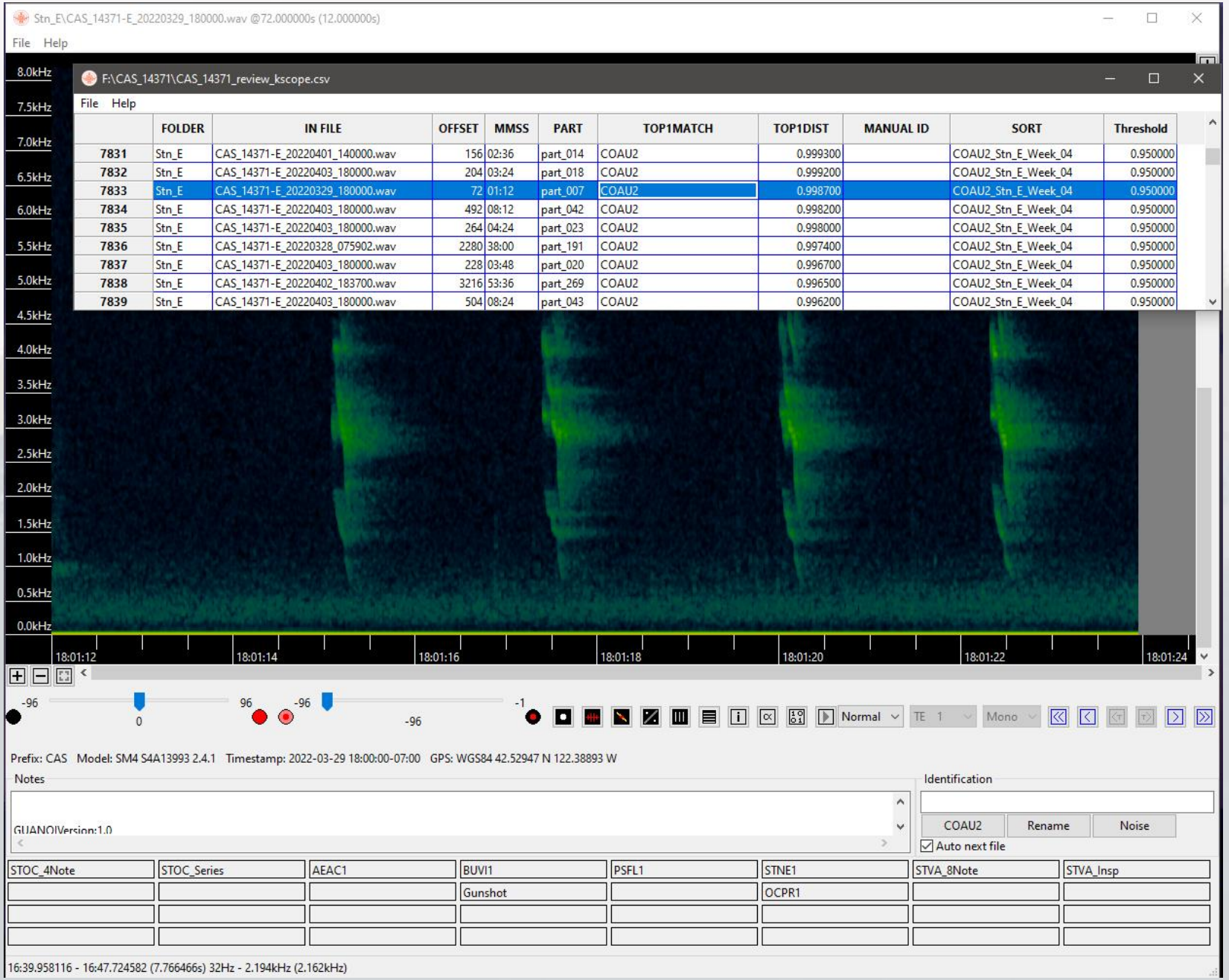
Using the app

- Create Review File button exports apparent detections for many classes
- Use default settings or define custom rules
- Review file is optimized for use with Kaleidoscope (Wildlife Acoustics, Inc)



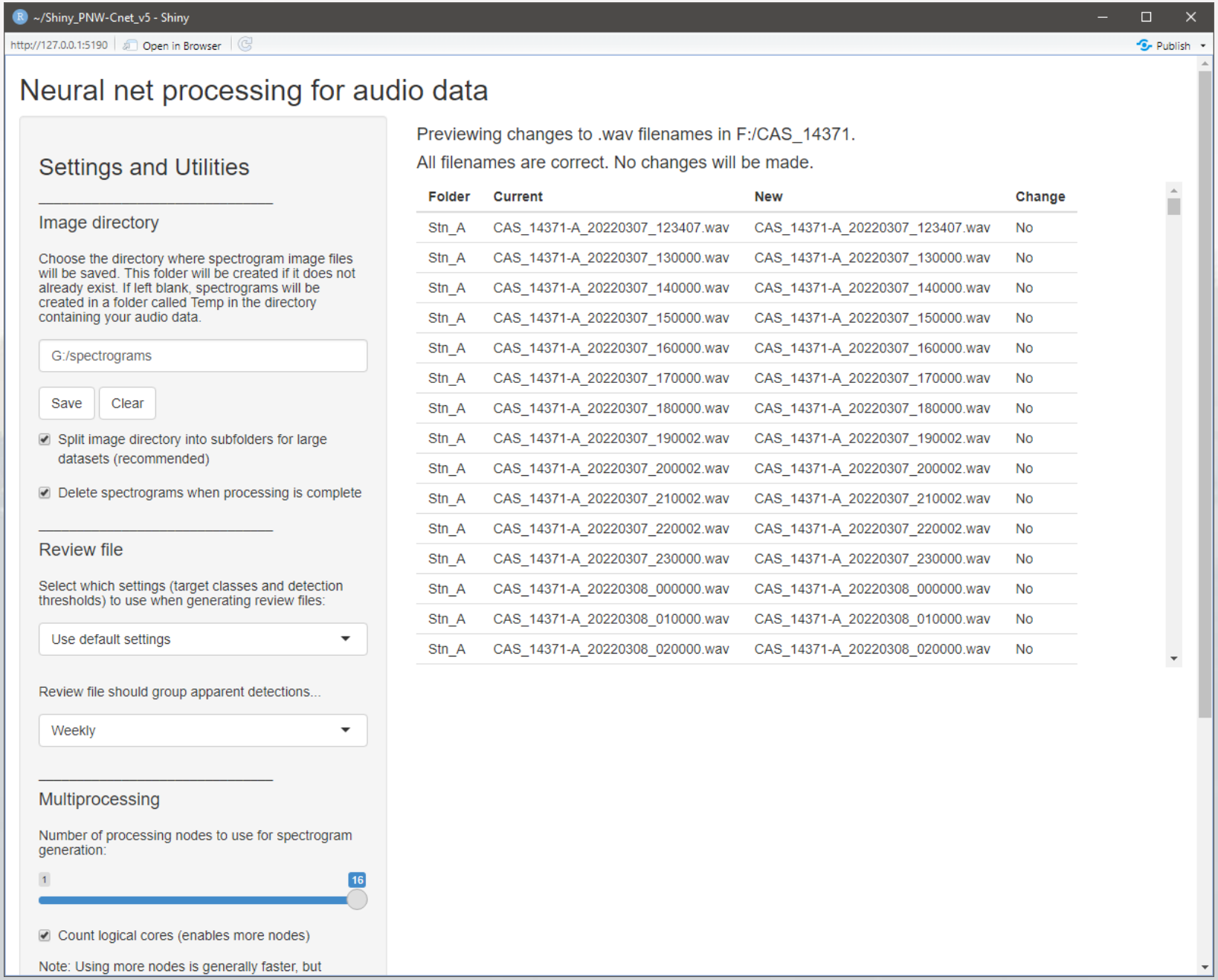
Explore further

- Open review file in Kaleidoscope to review apparent detections, apply ID tags
- Confirmed detections used for further analyses, e.g. occupancy modeling



Using the app

- Settings view adjusts app behavior
- Specify output directory, fine-tune multiprocessing, standardize audio filenames…



Using Shiny*

Pros:

- Does everything R can (lots!)
- Dynamic, responsive GUI
- Fine control over user experience
- Lots of good design baked in

Cons:

- Literally everything is more complicated
- Hard to debug

Adoption

- Shiny PNW-Cnet is currently in use by agency biologists, academics, private companies, and nonprofits
- Used by NSO monitoring program to process our own data faster
- Held first training workshop in Corvallis in October; more to come!

Oregon State University

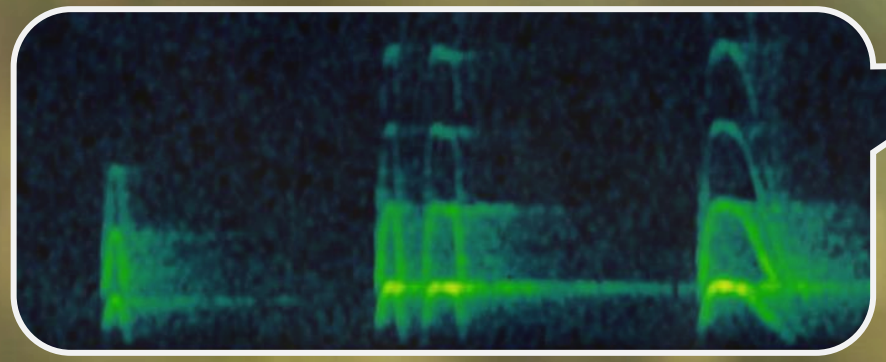
* Not official endorsements

Future additions

- Incorporate the newest version of the neural net (PNW-Cnet v5)
- Streamline the setup and installation process
- Add support for ecological analyses based on confirmed detections
- Video documentation
- Mailing list?

Photo: Alan Dyck

Thanks for listening!



Special thanks: Cara Appel, Ray Davis, Cara Gates, Aleena Habib, Hailey Hester, Natalie Rugg, Jelena Runjaic, Cheyenne Stephens, Alaina Thomas

zjruff@gmail.com
https://github.com/zjruff
https://www.damonlesmeister.com/projects