Test strategy for bird species detection API

Approaches:

Unit test – test each individual function in isolation with mocked dependencies
Integration test: test the interaction between functions
End-to-End Testing: Test the API endpoint with real HTTP requests (test on web, not covered here)

Tools:

- pytest for test framework
- pytest-mock for mocking
- librosa for generating test audio files

Test Cases in Unit Test:

1. Audio Preprocessing

    o   Test padding of short audio
    o   Test of long audio over limit
    o   Test handling of invalid audio

2. BirdNET Analysis

    o   Test successful detection
    o   Test no detection case
    o   Test error handling

3. Custom Model Classification

    o   Test known species detection
    o   Test unknown species case

4. Full Pipeline

    o   Test BirdNET primary path
    o   Test fallback to custom model

Test Cases in Integration Test:

1. Test the full pipeline with real audio
   Verify the entire workflow from audio upload to species prediction
2. API integration test with real request
   Test the FastAPI endpoint with real HTTP call and actual audio processing
3. Test edge cases in integration
   Verify real-world scenarios that unit test might miss
4. Cross-validate BirdNET and Custom model
   Ensure both models agree on simple case as it expected
5. Performance testing
   Check if the system meets real-time requirement

For unit test, only simulated audio inputs are applied. For integration test, both simulated and real audio input can be used during the test, but real audio inputs are commonly used. Below is the comparison between unit and integration tests.

Key Differences from Unit Tests			
Aspect	Unit Tests	Integration Tests	
Scope	Isolated functions	Multi-component workflows	
Mocks	Heavy use of mocking	Minimal/no mocking	
Speed	Fast	Slower (real processing)	
Purpose	Verify logic	Verify system behavior	
Dependencies	Mocked	Real databases/APIs/files	

Instruction to run tests:

(1) Copy the main.py to the folder birdnet_app folder and rename it (eg. bird.py) since the import of main class is not allowed when you import the class and method
(2) Place the unit_test.py and integration_test.py under the same folder as the bird.py (contains all functions for bird species predictions).
(3) Get to the directory of above file in bash
(4) pytest unit_test.py or pytest unit_test.py -v -s (details showed for each test)
(5) pytest integration_test.py or pytest integration_test.py -v -s (details showed for each test)

The test results are shown below:

```
● (base) b9b8ec2f-20ba-423c-b57c-0a63f1671448:birdnet_app zhijun923$ pytest unit_test.py -v -s
============================= test session starts =============================
platform darwin -- Python 3.12.7, pytest-7.4.4, pluggy-1.0.0 -- /opt/anaconda3/bin/python
cachedir: .pytest_cache
rootdir: /Users/zhijun923/Documents/E115/Project/E115_BirdWatchingApp_M5/src/birdnet_app
configfile: pytest.ini
plugins: anyio-4.2.0
collected 10 items

unit_test.py::test_preprocess_short_audio Audio duration: 35.446281179138325 seconds
PASSED
unit_test.py::test_preprocess_long_audio Audio duration: 35.446281179138325 seconds
PASSED
unit_test.py::test_analyze_birdnet_success Test result: {'scientific_name': 'Testus birdius', 'average_confidence': 0.85}
PASSED
unit_test.py::test_analyze_birdnet_no_detection PASSED
unit_test.py::test_classify_known_species PASSED
unit_test.py::test_classify_unknown_species PASSED
unit_test.py::test_detect_species_birdnet_success Test result: {'scientific_name': 'Birdnet result', 'average_confidence': 0.9, 's
ource': 'birdnet'}
PASSED
unit_test.py::test_detect_species_fallback PASSED
unit_test.py::test_api_endpoint_success PASSED
unit_test.py::test_api_endpoint_invalid_audio PASSED

============================== warnings summary ===============================
../../../../../../../../opt/anaconda3/lib/python3.12/site-packages/pydub/utils.py:14
  /opt/anaconda3/lib/python3.12/site-packages/pydub/utils.py:14: DeprecationWarning: 'audioop' is deprecated and slated for remova
l in Python 3.13
    import audioop

<frozen importlib._bootstrap>:488
  <frozen importlib._bootstrap>:488: DeprecationWarning: Type google._upb._message.MessageMapContainer uses PyType_Spec with a met
aclass that has custom tp_new. This is deprecated and will no longer be allowed in Python 3.14.

<frozen importlib._bootstrap>:488
  <frozen importlib._bootstrap>:488: DeprecationWarning: Type google._upb._message.ScalarMapContainer uses PyType_Spec with a meta
class that has custom tp_new. This is deprecated and will no longer be allowed in Python 3.14.

-- Docs: https://docs.pytest.org/en/stable/how-to/capture-warnings.html
======================= 10 passed, 3 warnings in 3.20s ========================
(base) b9b8ec2f-20ba-423c-b57c-0a63f1671448:birdnet_app zhijun923$
```

Fig.1 Unit test run screen shot

```
(base) b9b8ec2f-20ba-423c-b57c-0a63f1671448:birdnet_app zhijun923$ pytest integration_test.py -v
======================================================= test session starts =======================================================
platform darwin -- Python 3.12.7, pytest-7.4.4, pluggy-1.0.0 -- /opt/anaconda3/bin/python
cachedir: .pytest_cache
rootdir: /Users/zhijun923/Documents/E115/Project/E115_BirdWatchingApp_M5/src/birdnet_app
configfile: pytest.ini
plugins: anyio-4.2.0
collected 5 items

integration_test.py::test_full_integration_with_real_audio PASSED                                                         [ 20%]
integration_test.py::test_api_integration_with_real_audio PASSED                                                          [ 40%]
integration_test.py::test_integration_edge_cases PASSED                                                                   [ 60%]
integration_test.py::test_model_agreement_on_known_samples PASSED                                                         [ 80%]
integration_test.py::test_processing_performance PASSED                                                                   [100%]

======================================================== warnings summary =========================================================
../../../../../../../../opt/anaconda3/lib/python3.12/site-packages/pydub/utils.py:14
  /opt/anaconda3/lib/python3.12/site-packages/pydub/utils.py:14: DeprecationWarning: 'audioop' is deprecated and slated for removal in Python 3.13
    import audioop

<frozen importlib._bootstrap>:488
  <frozen importlib._bootstrap>:488: DeprecationWarning: Type google._upb._message.MessageMapContainer uses PyType_Spec with a metaclass that has custom tp_n
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<frozen importlib._bootstrap>:488
  <frozen importlib._bootstrap>:488: DeprecationWarning: Type google._upb._message.ScalarMapContainer uses PyType_Spec with a metaclass that has custom tp_ne
w. This is deprecated and will no longer be allowed in Python 3.14.

integration_test.py::test_full_integration_with_real_audio
  /opt/anaconda3/lib/python3.12/site-packages/audioread/rawread.py:16: DeprecationWarning: 'aifc' is deprecated and slated for removal in Python 3.13
    import aifc

integration_test.py::test_full_integration_with_real_audio
  /opt/anaconda3/lib/python3.12/site-packages/audioread/rawread.py:19: DeprecationWarning: 'sunau' is deprecated and slated for removal in Python 3.13
    import sunau

-- Docs: https://docs.pytest.org/en/stable/how-to/capture-warnings.html
================================================= 5 passed, 5 warnings in 5.45s ===================================================
(base) b9b8ec2f-20ba-423c-b57c-0a63f1671448:birdnet_app zhijun923$
```

Fig.2 Integration test run screen shot