Jun 27th, 11:05 AM - 11:25 AM

Concurrent Sessions B: Case Studies - A Fisheries Information Management System (FIMS) for Petabyte Acoustic Telemetry

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LaMarche, Brian; Woodley, Christa; Auberry, Kenneth; Parrs, David; Thronas, Aaron; Choi, Eric; Eppard, Brad; and Weiland, Mark, "Concurrent Sessions B: Case Studies - A Fisheries Information Management System (FIMS) for Petabyte Acoustic Telemetry" (2013). *International Conference on Engineering and Ecohydrology for Fish Passage*. 27.  
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A Fisheries Information Management System for Petabyte Scale Telemetry

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Since 2004, the Juvenile Salmonid Acoustic Telemetry System (JSATS) has been used to study fish survival and passage on the Lower Columbia River.

25,850 fish were tagged and released during 448 events between April-July (72 Days) in 2012.
- Compared to 12,214 fish released in 2010 during 190 release events
- Compared to 15,458 fish released in spring 2011 during 224 release events

If the 2012 data was stored in its raw form, it would surmount a petabyte.

Large scale acoustic telemetry studies pose challenges for data
- Management
- Collection
- Processing

This work presents an information management approach for spatiotemporal analysis to support management of hydropower systems.
Survival Studies on the Lower Columbia

Why? 

Salmon are protected under the Endangered Species Act; Federal law requires the United States Army Corps of Engineers (USACE) to evaluate survival of juvenile salmonids through the dams on the Columbia River.*

- Spring
  - 96% survival yearling Chinook salmon and steelhead
- Summer
  - 93% survival sub yearling Chinook salmon

Criteria need to be met in 2 consecutive years with no slippage in metrics (forebay residence time, tailrace egress time, spill passage efficiency)

Survival estimates and route of passage are estimated based on data collected using JSATS.

Route of passage helps the USACE:

- understand how structural or hydraulic changes to dams can affect survival
- determine the best routes to target for passage to increase survival

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*Biological Opinion (NOAA BiOp 2008) and Columbia River Fish Accords
Scale and Challenges

Study Area
- 4 Dams (McNary, John Day, The Dalles, Bonneville Dams)
- Study area extends over 417 rkm

Telemetry Equipment
- 84 autonomous nodes (14 arrays)
- 4 dam mounted cabled arrays
  - 355 dam mounted hydrophones
  - 27 Miles of JSATS cable deployed

Data Processing and Collection Resources
- 92 acquisition computers at dams
- 49+ computers for data analysis, status monitoring, and QA/QC
- 33 Sierra Wireless Raven XE Airlink wireless modems and antenna for remote monitoring

- Over 30,000 fish handled, including 25,850 tagged and released
- Over 60 personnel working on 23 discrete activities
- QA/QC all data and procedures
What is a petabyte?

- Kilobyte (KB)
- Megabyte (MB)
- Gigabyte (GB)
- Terabyte (TB)
- Petabyte (PB)

- iPod 4G — 32 GB
- X 32
- iPod 4G — 32 GB
- X 32,000

- 1.44 MB
- Text message
- ‘h’
- 1e3
- 1e6
- 1e9
- 1e12
- 1e15
JSATS Acoustic Microtransmitter (AMT)

- **Signal**
  - Acoustic
  - Binary Phase Shift Key (BPSK) encoded
  - 65,536 unique codes
  - Programmable ping rate (3s pri)
  - 167 kb file size per detection

= 0111 0010 0010 0100...

Acoustic Signal Emitted from tag
Fish collected and tagged at the John Day Dam Smolt Monitoring Facility

Fish quickly undergo several steps during tagging for documentation purposes prior to their release.
- Photograph, fish condition, inventory

Data acquired using suite of software tools called FishSuite!

Tagging Process

Tag
Photograph
Fish Condition
Inventory, recovery, and release
FishBooth! – Photography

- At least 2 images are saved for EVERY Fish
  - 12 Megapixel resolution ~ 12 Mb (24 Mb per fish) ~
  - 810 GB – tagging only
- Interfaces with digital SLR
- Saves information as EXIF meta-data in image file
  - PIT tag, Dam Location, Surgeon Name
- Integrates with PIT tag reader

Tagging Process

P-125 Fishsuite – Software for Annotating, Photographing, Tracking, and Reporting on Physiological Condition for Telemetry Related Studies
Nathan G. Trimble
FishEye! – Assess fish condition rapidly

- Quickly assesses fish condition (50+ metrics)
- Build customizable templates for anatomy / condition
- Saves data to local database
- Exports data for use with other tools / databases
- Integrates with scale and PIT tag reader

Tagging Process

Tag | Photograph | Fish Condition | Inventory, recovery, and release
FishBucket! and FreeWilly!

Two applications that help track where fish are released and when

Inventory Fish Buckets using FishBucket (PIT Tag Reader)

Allow for recovery

Release, each bucket scanned with FreeWilly!, GPS locations stored

Tagging Process

Tag
Photograph
Fish Condition
Inventory, recovery, and release

Tagging Process

Inventory, recovery, and release

Tag
Photograph
Fish Condition

Tagging Process

Inventory, recovery, and release

Tag
Photograph
Fish Condition

Tagging Process

Inventory, recovery, and release

Tag
Photograph
Fish Condition

Tagging Process

Inventory, recovery, and release

Tag
Photograph
Fish Condition

Tagging Process

Inventory, recovery, and release

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Nathan G. Trimble
Fish Detection and Acoustic Waveform Collection

- **JSATS Receivers – Cabled***
  - Hydrophones mounted on dam face (upstream)
  - Used to estimate 3D positions and tracks for route of passage

- **Autonomous Nodes**
  - On-board power and data storage
  - Measures and stores environmental data (temp, depth, tilt)
  - Presences/Absence Detection

*Weiland, et. al., Sensors 2011, 11, 5645-5660;*
JSATS Receivers - Cabled

- Sub-micro second clock accuracy
  - For 2D and 3D tracking
  - Detection range ~100 m
- Real-time decoding reduces data amount
- Each computer has multiple 2 TB hot-swappable hard drives.

System Hydrophones

Analog AMT Signal

Pre-Amplifier

DSP + FGPA

GPS

Detector

Acquisition PC

RAM

Acquisition and Timing

Processing

Disk

Decoder

GPS Antenna

JSATS Cabled Receiver PC

TOA Results (Terabytes)

JSATS Cabled Receiver PC’s and pre-amplifiers rack mounted in trailer on dam
Remote System Monitoring Mitigates Risk of System Downtime

- System health is transmitted to a centralized server using wireless modems*+
- Health is displayed using BigBrother (Qwest Software)
- 375 Mb data usage per month / per system
- 33 deployed modems monitoring 92 systems

*Sierra Wireless Airlink Raven XE modem, *Satellite was used in remote locations.
Data Transfer and Unique Identification for Tracking

► **It is essential that data:**
  - Is given a unique identifier
  - formats are portable to allow data to be transferred to a centralized repository

► **All tools were designed to write local databases or files**
  - SQLite
  - CompactSQL
  - Comma separated value (CSV)

► **A few Unique ID options**
  - Globally unique identifier — GUID
    - 128-bit value, with $2^{122}$ possibilities
    - Images, surgery notes, observations
  - Time / Date / Location
    - Detections
    - Releases
Fisheries Information Management System Architecture

Based on management information system from proteomics*

JSATS Yearly Databases

- 2012
- 2011
- ...
- 2007
- 2006

Data Ingest

Meta-data Database

Raw Data Archives*

MyDAM

- Data Packages / Results*
- Schedule Processing Job
- Process
- Distribute Data
- Store Results

Legend

- Raw/Processed Data Store
- Relational database
- Custom Software

* Raided for data protection

Data Processing Pipeline

- Automates data processing and tracks how a tool is run
- **MyDAM**
  - Route of passage
  - Gap check analysis
  - JSATS Detection
- Investigating Hadoop as processing pipeline manager
  - Distributed / Parallel processing using MapReduce
  - Used by Twitter, Facebook, Yahoo!, NASA
  - Manages job tracking / restarts
- **Move away from saving raw waveforms!!**

![Data Processing Pipeline Diagram]

Schedule
Processing
Job

Process

Distribute
Data

Store Results
Future and Conclusion

- Telemetry at the petabyte scale introduces data management, collection, and processing challenges
  - Remote system monitoring is useful for maintaining full operation

- Building data processing pipelines in addition to database management systems is useful for reproducibility and automated analysis

- Introduce new processing pipelines and external data sources

- Add a web interface to facilitate data analysis and interaction with FIMS

- Perform meta-data analysis relating dam operations to route of passage and survival
  - Answer questions posed by hydropower management
Acknowledgements

► USACE Portland District
► PNNL Staff
  - Tom Carlson
  - Jina Kim
  - Daniel Deng
  - Gene Ploskey
  - James Hughes
  - Eric Fischer
  - Shon Zimmerman
  - Katie Wagner
  - Charles Pratt
  - Jeni Smith (Sequim)
  - Valorie Hiner
  - Tylor Abel
  - Yuan Yong
► Pacific States
  - Scott Carpenter
  - George Batten
  - Aaron Cushing