The Recent History of Stream Bioassessments in Hawaii

Reuben H. Wolff
U.S. Geological Survey
Overview

- Definitions
- Earlier Bioassessments
  - Timbol and Maciolek
  - HSA
- Who’s who in Hawaiian Stream Ecology
- Overview of Bioassessment Protocols Applied in Hawaii
  - State
  - Federal
    - NAWQA
    - EMAP
- Development of a multi-metric index of biotic integrity using benthic invertebrates
Survey:
The collecting, processing, and analyzing of representative parameters of an aquatic community to determine the community structure and function (USEPA Region 5)

Biomonitoring:
The measurement of biological parameters in repetition to assess the current status and changes in time of the parameters measured (USFWS)

Bioassessment:
An evaluation of the condition of a water body using biological surveys and other direct measurements of the resident biota in surface waters (Gibson et al. 1996)

Biocriteria:
Numerical values or verbal standards that define a desired biological condition (reference biological condition) for a water body. (Karr 1999)
Biological Integrity

A balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural, unimpaired habitat of the region (Karr and Dudley, 1981)

Biological integrity is equated with pristine conditions or those conditions with minimal disturbance, and it is used as the baseline for the IBI;


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![Diagram](image-url)
Federal

**Wild and Scenic Rivers Act** (16 USC 1271-1287) - Public Law 90-542, approved October 2, 1968, (82 Stat. 906) establishes a National Wild and Scenic Rivers System and prescribes the methods and standards through which additional rivers may be identified and added to the system.

**National Environmental Policy Act** of 1969 (NEPA), (Pub. L. 91-190, 42 U.S.C. 4321-4347) the foundation of modern American environmental protection within a comprehensive national policy. Intended to help public officials make decisions that are based on understanding of environmental consequences, and take actions that protect, restore, and enhance the environment.

**Federal Clean Water Act**, 1972, is to achieve “fishable and swimmable” waters by restoring and maintaining the chemical, physical, and biological integrity of the Nation’s surface waters (33 U.S.C. §1251).
The **Hawaii State Water Code** (Hawaii Revised Statutes (HRS), Chapter 342D) states that the waters of the state are held for the benefit of citizens who have a right to have the waters protected for their use.

**Hawaii Administrative Rules** (HAR) Chapter 11-54, Water Quality Standards designate uses, set water quality criteria and establish an antidegradation requirement for all state waters.

**Section 303(d)** of the federal **Clean Water Act** to generate a list of surface waters that are exceeding or will likely exceed state Water Quality Standards. (aka the List of Impaired Waters)
Stream Bioassessments in Hawaii

Built upon the accumulation of years of knowledge

- Observations by Hawaiians
- Naturalists / Linnean Taxonomists
  - Surveys / Collections
- Biologists / Ecologists

Native Stream Animals of Hawaii
1978: Amadeo Timbol and John Maciolek
Stream Channel Modification in Hawaii.
Part A: Statewide Inventory of Streams:
Habitat Factors and Associated Biota

**Ecological Quality:**

I **Pristine-Preservation:** High environmental and biological quality.

II **Limited Consumptive:** Moderate to high quality water or natural values.

III **Exploitive-consumptive:** Moderate to low natural and/or water quality (well exploited, modified or degraded).

IV **Construct-Alter:** Low environmental and biological quality.

**Indicator Species:**
- Alamoo - Lentipes concolor
- Nopili - Sicydium stimpsoni (*Sicyopterus stimpsoni*)
- Nakea - Awaous stamineus (*Awaous guamensis*)
Bob Kinzie
Mike Kido
Dan Polhemus
Bob Nishimoto
Michael Fitzsimons
1990: Hawaii Stream Assessment

The primary task of the HSA was to identify streams appropriate for protection.

- In response to the National Wild and Scenic Rivers Act
- Initiated by the State Commission on Water Resource Management
- National Park Service's State and Local Rivers and Trails Conservation Assistance Program.
- Consolidated a vast amount of published information from diverse sources.

Established assessment criteria to identify streams containing ecosystems with potentially high quality aquatic resources.
Hawaii Stream Assessment
Aquatic Resources

Native Species Group 1 (NG1): Sensitive native species.
- Alamoo - Lentipes concolor
- Nakea - Awaous stamineus (guamensis)
- Nopili - Sicyopterus stimpsoni
- Hihiwai - Neritina granosa

Native Species Group 2 (NG2): The other seven native species considered more common.

Introduced Species Group One (IG1): Included harmful, non-native stream animals.
- Convict cichlid
- Chinese catfish
- Corbicula
- Mosquito fish
- Malaysian prawn
- Smallmouth bass
- Guppy (Topminnow)
- Tilapia
- Swordtails

Introduced Species Group Two (IG2): Relatively harmless non-native stream animals.

*Aquatic insects were not considered only because their taxonomy and distribution are poorly understood.
Hawaii Stream Assessment

Aquatic Resources Ranking Biocriteria

Outstanding
Either A or B
A. Any of these criteria
   * Lentipes concolor* is common in any reach of the stream; Evidence of spawning by any of the NG1 gobies; An abundance of any of the four rare NG1 species anywhere in the stream; Presence of all of the four NG1 species in the stream.
B. All of these criteria
   * Two or more representatives of NG1 and NG2 each, representing high native species diversity.
   * One or fewer IGI introduced species
   * No dams, diversions, or channelization.

Substantial
Both A and B
A. At least three total representatives from NG1 and NG2.
B. One or fewer introduced species IG1.

Moderate
   * Presence of at least one native species from NG1.
   * Presence of at least one NG2.

Without: No native species present.
Unknown: Insufficient biological information available for the stream.
Gathers various types of data for use in monitoring, assessing, managing, and protecting the freshwater aquatic resources of the State.

Hawaii Division of Aquatic Resources

The mission of the Division of Aquatic Resources is to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations.

USGS

Estimating Density and Abundance of Endemic Fishes in Hawaiian Streams

May 1992
DAR Freshwater Database

Survey data from the States' perennial and intermittent streams, reservoirs, lakes, ponds, ditches, and diversions.

The data dates back to the early 1960s and includes data from the Hawaii Stream Assessment (HSA).

Atlas of Hawaiian Watersheds & Their Aquatic Resources

Dr. James E. Parham
Glenn R. Higashi
Darrell G.K. Kuamoʻo

Yamamoto and Tagawa
Waipio Stream Team
A collaboration of scientists and students

Bishop Museum

Hawaii Biological Survey Databases
- Northwestern Hawaiian Islands
- Entomology
- Botany
- Mollusk
- Vertebrate
- Fish
- Marine Invertebrates

Numerous Surveys and Publications

USGS
University of Hawaii

1979, Biology of a Hawaiian fluvial gastropod Neritina granosa Sowerby

1982, Life crawls upstream

1982, Population biology in small Hawaiian streams

1993, Reproductive biology of an endemic, amphidromous goby Lentipes concolor in Hawaiian streams

1996, Reproductive biology of Awaous guamensis, an amphidromous Hawaiian goby

2000, Goby recruitment to two streams on the north shore of Kauai

2006, Effects of water removal on a Hawaiian stream ecosystem
Other Research


And Many Others…
Hawaii Department of Health
Environmental Planning Office (EPO)

The mission of the Department of Health is:
• To protect and improve the health and environment for all people in Hawaii
• To prevent pollution and promote and preserve a clean, healthy and natural environment
• **Ensure that federal mandates are satisfied**

**List of Impaired Waters**: Section 303(d) of the Federal Clean Water Act

Hawaii Administrative Rules
Water Quality Standards
§11-54-4 Basic water quality criteria applicable to all waters.
§11-54-5 Uses and specific criteria applicable to inland waters.
Assessment Protocols Used by the Hawaii Department of Health EPO

Hawaii Stream Visual Assessment Protocol

USDA
Natural Resources Conservation Service
January 31, 2001

VERSION 1.0

The Hawaii Stream Bioassessment Protocol
Version 3.01
Michael H. Kide

January 2002
The Hawaii Stream Research Center
Center for Conservation Research and Training
University of Hawaii

HSVAP

USGS

HSBP
Hawaii Stream Visual Assessment Protocol

- Formed the “Hawaii Stream Bioassessment Working Group”,
- Modified the protocol to better reflect stream conditions in Hawaii.

**Ten Scored Elements (Metrics)**

1. Turbidity
2. Plant growth
3. Channel Condition
4. Channel Flow Alteration
5. Percent Embeddedness
6. Bank Stability
7. Canopy/Shade
8. Riparian Condition
9. Habitat Available for Native Species
10. Litter/trash

**Scoring**

<table>
<thead>
<tr>
<th>Score Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8 - 2.0</td>
<td>Very High</td>
</tr>
<tr>
<td>1.5 - 1.7</td>
<td>High</td>
</tr>
<tr>
<td>1.1 - 1.4</td>
<td>Medium</td>
</tr>
<tr>
<td>0 - 1.0</td>
<td>Low</td>
</tr>
</tbody>
</table>
Hawaii Stream Bioassessment Protocol

- A “first generation” methodology for assessment and monitoring of Hawaiian streams utilizing a standardized “multimetric” approach
- Conduct meaningful water quality assessments aimed at restoring and/or maintaining the “biological integrity” of Hawaii’s streams

### Hawaii Stream Index of Biotic Integrity (HS-IBI)

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Number of <strong>Native</strong> amphidromous macrofauna</td>
</tr>
<tr>
<td>2.</td>
<td>Percent Contribution <strong>Native</strong> Taxa</td>
</tr>
<tr>
<td>3.</td>
<td>Percent Sensitive <strong>Native</strong> Fish</td>
</tr>
<tr>
<td>4.</td>
<td>Sensitive <strong>Native</strong> Fish Density</td>
</tr>
<tr>
<td>5.</td>
<td>Sensitive <strong>Native</strong> Fish Size</td>
</tr>
<tr>
<td>6.</td>
<td><strong>Awaous guamensis</strong> Size</td>
</tr>
<tr>
<td>7.</td>
<td>Total <strong>Native</strong> Fish Density</td>
</tr>
<tr>
<td>8.</td>
<td>Community Weighted Average</td>
</tr>
<tr>
<td>9.</td>
<td>Number of Alien Taxa</td>
</tr>
<tr>
<td>10.</td>
<td>Percent Tolerant Alien Fish</td>
</tr>
<tr>
<td>11.</td>
<td>Percent Diseased / Parasitized Fish</td>
</tr>
</tbody>
</table>

### Stream Habitat Assessment

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Habitat Availability</td>
</tr>
<tr>
<td>2.</td>
<td>Substrate Embeddedness</td>
</tr>
<tr>
<td>3.</td>
<td>FPOM / CPOM Characterization</td>
</tr>
<tr>
<td>4.</td>
<td>Velocity-Depth Combinations</td>
</tr>
<tr>
<td>5.</td>
<td>Channel Status</td>
</tr>
<tr>
<td>6.</td>
<td>Channel Alteration</td>
</tr>
<tr>
<td>7.</td>
<td>Bank Stability</td>
</tr>
<tr>
<td>8.</td>
<td>Riparian Vegetation Zone Width</td>
</tr>
<tr>
<td>9.</td>
<td>Percent Riparian Understory Coverage</td>
</tr>
<tr>
<td>10.</td>
<td>Boulder / Cobble vs. Soil Presence</td>
</tr>
</tbody>
</table>
Hawaii Stream Bioassessment Protocol

Index Scoring

<table>
<thead>
<tr>
<th>HS-Ibi Score</th>
<th>Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Good</td>
<td>90 - 100 %</td>
</tr>
<tr>
<td>Good</td>
<td>79 - 89 %</td>
</tr>
<tr>
<td>Fair</td>
<td>69 - 78 %</td>
</tr>
<tr>
<td>Poor</td>
<td>69 - 78 %</td>
</tr>
<tr>
<td>Very Poor</td>
<td>59 - 68 %</td>
</tr>
<tr>
<td>Impaired</td>
<td>40 - 58 %</td>
</tr>
<tr>
<td>Non-Supporting</td>
<td>&lt; 39 %</td>
</tr>
<tr>
<td>Supporting</td>
<td></td>
</tr>
</tbody>
</table>

Percent of Reference Biological Index vs. Percent of Reference Habitat Quality
National Water-Quality Assessment Program (NAWQA)
U.S. Geological Survey
1999-2001

Assess the condition of our Nation's streams, rivers, and ground water.

How water-quality conditions may vary locally, regionally, and nationally.
National Water-Quality Assessment Program

Comprehensive Protocols for Sampling and Analyses

- Water Chemistry
- Macroinvertebrates
- Fish
- Algae
- Physical Habitat Characterization
- Fish Tissue and Bed Sediment Contaminants
A probability-based sampling design, the EMAP approach provides a statistically-valid basis for determining aquatic ecological condition.

Sites can be selected from anywhere along perennial streams.

Results can be extrapolated to assess water quality across the watershed or the region.

Oahu EMAP – Cooperative effort of the USGS, HDOH, and USEPA.
Comprehensive and Standardized Protocols for Sampling and Analyses

EMAP Oahu 2006-2007

- 40 Sites
- Water Chemistry
- Stream Discharge
- Physical Habitat Characterization
- Benthic Macroinvertebrates
- Rapid Habitat and Visual Stream Assessments

USGS
EMAP on Oahu
USGS & HDOH

EXPLANATION
Land Use
- Agriculture
- Barren
- Developed
- Other (Forested)
- Stream
- 2006 EMAP Site
- 2007 EMAP Site
Benthic Invertebrates as Indicators of Stream Quality in Hawaii

A goal of the HDOH is to use assessment protocols that include fish, invertebrates, and algae. The use of diverse groups of organisms in biological monitoring can provide a more robust assessment of stream quality.

- Feasibility Study by USGS in cooperation with the Hawaii Department of Health
- Develop a multi-metric index of biotic integrity using benthic invertebrates (BIBI) in Hawaiian streams
- Identify those components of the invertebrate assemblages that showed the most potential for further investigation
<table>
<thead>
<tr>
<th>Candidate metrics</th>
<th>Core metrics</th>
<th>Final P-HBIBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invertebrate abundance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Insect abundance</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Trichopteran abundance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alien mollusc abundance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Dominant taxa abundance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amphipod abundance</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chironomidae abundance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trichopteran-dipteran ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of trichoptera</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Percentage of chironomidae</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Percentage of insecta</strong></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Percentage of oligochaeta</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Percentage of alien mollusca</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Percentage of amphipoda</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number of taxa</strong></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Native mountain shrimp P/A</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Crayfish P/A</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Alien prawn richness</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Modified family biotic index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Margelel's diversity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results

SITE IMPAIRMENT CATEGORIES
Mild  Moderate  Severe

INDEX SCORE

PUNB  MKPA  KALU  HULA  ULWI  LLWI  KALA

CUMULATIVE DISTRIBUTION FUNCTION

PUAL

SITE IMPAIRMENT CATEGORIES
Mild  Moderate  Severe

ENVIRONMENTAL ASSESSMENT SCORES

PUNB  MKPA  KALU  HULA  ULWI  LLWI

EXPLANATION
- Trend line
- Cut-off values
- Degree of impairment:
  - Mild
  - Moderate
  - Severe
- UKPA: Abbreviation of sampling site name
Thank You