National Fish Habitat Action Plan
Science and Monitoring Needs Workshop
Summary

The National Fish Habitat Action Plan (NFHAP) Science and Monitoring Needs Workshop occurred March 4-6, 2008, at the Bureau of Land Management Training Center in Phoenix, Arizona. This workshop was well attended, with a diverse audience—approximately 50 people from Federal and State agencies, Fish Habitat Partnerships, and non-governmental organizations (Attachment A). The workshop was sponsored by the U.S. Geological Survey (USGS).

The workshop had the goal of developing a short term (3-5 years) science and monitoring agenda for the National Fish Habitat Board. Specifically, the workshop participants were to develop priorities that:

- define the characteristics of healthy aquatic habitats;
- identify major issues that are impacting fisheries across the United States;
- develop methods to periodically assess aquatic habitat condition;
- develop methods to evaluate the effectiveness of conservation action to change in habitat condition (overall success of the NFHAP);
- develop structured approaches to link habitat condition to fish communities/populations; and,
- identify indicators to monitor in evaluating habitat condition in an adaptive management context.

The workshop results include a science plan covering the next 3-5 years for the NFHAP with a prioritized list of research and monitoring needs. The USGS, and hopefully other agencies, will use this document to develop projects within their agencies to support the research and monitoring needs of the NFHAP.

On Day 1, the workshop started with introductions and background presentations to ensure everyone had a broad understanding about the NFHAP, the activities of the National Fish Habitat Science and Data Committee, National Fish Habitat Assessment, and the role of USGS in this workshop. Following the presentations, the participants broke out into four working groups that were aligned with the major aquatic sectors:

- Rivers
- Lakes/Reservoirs
- Estuaries
- Marine

To facilitate defining priority research and monitoring needs, the Group Leaders used the following discussion questions and tasks:

- How do we define “healthy” habitat, and when do we consider habitat to be “impaired?”
- Define the current state of knowledge and linkages between target and the healthy aquatic habitat.

- Develop or refine conceptual models with the identification of drivers, stressors, and likely indicators of aquatic habitat condition that should be monitored.

On Day 2, the four breakout groups built on their discussion from Day 1 to determine gaps in knowledge about the drivers and stressors for their systems, as well as the key variables to measure change. At the end of the day, the breakout groups returned to report on the research and monitoring needs for their sector areas (see Attachment B for the individual groups' research and monitoring needs).

On Day 3, the workshop participants were assigned into four new groups, so there would be a mix of sector expertise in each group. All the groups were instructed to examine all the research and monitoring priorities developed by the sector groups from the previous day, and to determine: 1) if there were common priorities to be found across all four systems and if there were some priorities that were unique, and 2) to prioritize those research and monitoring needs.

At the end of the workshop the participants returned together to report on the common science priorities. The participants identified five common research and monitoring themes (see Attachment C for sub-categories):

1. Fish-habitat relationships, including human impacts and their variation at different scales
2. Identifying baselines and their current range, trajectories and gaps in knowledge
3. Appropriate standardization of sample design, methodology and monitoring for data analysis
4. Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover
5. Evaluate socioeconomic value of habitat

Attachment D shows the specific questions for each group within the framework of common research and monitoring themes. The workshop ended with Paul Dresler and Doug Beard describing the process that will occur following the workshop in regard to writing the workshop summary report, USGS Request for Proposals, and review by the Science and Data Committee and NFH Board.

Attachment A –
National Fish Habitat Science & Monitoring Workshop Attendees

Steering Committee

Paul Dresler (USGS, Co-chair)
Douglas Beard (USGS, Co-chair) – Science & Data Committee
Janet Cushing (USGS, Co-chair) – NFH Board Staff
*Matthew Andersen (USGS)
*Zachary Bowen (USGS) – Science & Data Committee
Melissa Drake (MN DNR)
Christopher Estes (AK Fish & Game) – Science & Data Committee, NFH Board Staff
Mary Freeman (USGS)
Bob Gresswell (USGS)
*Roger Helm (FWS)
*Kelly Hepler (AK, NFH Board)
Jo Hinck (USGS)
*Bob Hoffman (NOAA)
Adam Kaeser (Georgia DNR, SARP)
*Bill Taylor (MSU, NFH Board)
James Thomas (NOAA)
Gary Whelan (Michigan DNR) – Science & Data Committee

*Unable to attend workshop.

Rivers

Mark Hudy (USDA Forest Service) – Science & Data Committee **– Group Leader**
Lizhu Wang (Inst. Fisheries Res., MI DNR)
Lynn Schrader (MO DNR)
Jonathan Higgins (TNC) – Science & Data Committee
Sam Lohr (FWS)
Ken Lubinski (USGS) – Fish & Farmers Partnership
Holly Kent (AK Watershed) – Salmon in City
Robert Ruffner (Kenai Watershed Forum) – Kenai Peninsula FHP
Krissy Wilson (UT DWR) – Desert FHP
Sue Thompson (PA Fish & Boat Comm) – OH River Basin Partnership
Kerry Reeves (TX Parks & Wildlife)
Elise Irwin (USGS /AL CRU)
George Noguchi (FWS)
Dan James (USGS)

Lakes/Reservoirs

Jim McKenna (USGS)- Science & Data Committee **—Group Leader**
Morgan Elmer (FWS)
Paul Pajak (FWS)

Pat Rivers (MN DNR) – Midwest Glacial Lakes Partnership
Mark Brouder (FWS) – Great Lakes FHP, Science & Data Committee
Sandy Morrison (USGS) – Great Lakes FHP
Dave Devault (FWS)
Mary Bremigan (MSU)
Dave Beauchamp (USGS/ WA CRU)

Estuaries
Correigh Greene (NOAA)-Group Leader
Tracy Collier (NOAA)
Bill Lellis (USGS)-Atlantic Coastal FHP
Joel Fleming (GA DNR) – SARP
Jay Davis (FWS)
Lyman Thorsteinson (USGS)
Tim Gleason (EPA)
Jay Odell (TNC)
Cecil Rich (AK) – Matanuska-Susitna Basin Salmon Conservation
Derk Bergquist (Marine Resources Institute)

Marine
Tom Noji (NOAA) – Group Leader
Heath Rauschenberger (FWS)
Donna Schroeder (MMS Pacific OCS Region)
Karen Chytalo (NY DEC) – Atlantic Coastal FHP
Glenn Sibbald (CA Dept. of Fish and Game)
Becky Allee (NOAA)
Vin Malkoski (MA Division of Marine Fisheries)
Kathy Goodin (NatureServe)
Erika Ammann (NOAA) – Salmon in City

Attachment B –
System Groups Research and Monitoring Priorities

Rivers Group Priorities

1. Understand relationships among fish, fish habitat and landscape metrics (including stressors) across various scales and regions. (limiting factors, thresholds, sensitivity analysis).

2. Range of conditions (historical, natural, etc, variability).

3. Cumulative effects methodologies (assessment, forecasting, ROI).

4. Framework for probabilistic approach to sampling (for physical, chemical, biological parameters) across regions scales.

5. Evaluate appropriateness of existing technologies (methods) for measuring physical, chemical, biological parameters and emerging technologies at various scales.

Lakes/Reservoirs Group Priorities

1. Develop a model that classifies lake types with characteristics that indicate potential fish resource.

2. Identify gaps in key lake indicator data.

3. Develop standard spatial units for use in a lake classification system -- appropriate scale for data available (.e.g. 1:100K lower-48, AK 1:63,360).

4. Investigate the role of lake position within watershed drainage network and landscape mosaic.

5. Develop biological indicators of fish biomass, abundance, and other in lake habitats and use those measures to assess status of lake fish communities.

6. Develop biological indicators of fish composition and distribution, and other in lake habitats and use those measures to assess status of lake fish communities.

7. Methods to evaluate effects of habitat management actions on living resources, particularly fish.

8. Methods to evaluate effects of biotic management actions on living resources, particularly fish.

9. Develop habitat indicators of lake conditions that support desirable fish assemblages.
10. Investigate the thresholds of change in key habitat indicators of healthy fish habitat in lakes.

Estuaries Group Priorities

1. Biological responses

- What biological levels (multispecies, population measures, individual metrics) best signal anthropogenic impacts?

2. Habitat impacts

What's the baseline?

- How do we define baseline conditions? Can the National Estuarine Reserve Network, National Parks, and Wildlife Refuges provide reference conditions by which other estuarine units can be effectively evaluated?
- Where would conservation activities be most needed or feasible, and where are reference areas located? What mapping methods could be used to identify reference areas?

Climate change

- Which estuarine habitats are most vulnerable to sea level rise and most important as nurseries?
- How will estuarine-dependent species respond to climate change, in terms of demographic changes as well as range changes?

Invasive species

- How is colonization of nonnative species in estuaries related to marine (and freshwater) processes?

Connectivity impairments

- To what extent do reductions in habitat quality (e.g., temperature, contaminants) act as barriers to juvenile fish rearing in estuaries?

Habitat quality reductions

- How do changes in riverine habitat processes alter estuarine habitat and fish?
- How do upstream dams alter habitat forming processes in estuaries?
- What ecological processes have the largest effects on habitat formation and fish populations?

Habitat amount

- What are the specific contributions of different habitat types to marine fish population changes?
- What is the most beneficial distribution of different estuarine habitats for fish?

Water quality

- What are the impacts of stormwater on hydrology, contaminants, and nutrients?
- What are the effects of mixtures of contaminants on fish species?

3. Socioeconomics

- What habitat restoration strategies have the biggest bang (effects on fish populations) for the buck?

4. Data synthesis

- How important is long-term monitoring in assessing strategy effectiveness compared to less frequent assessments?

Marine Habitats Priorities

1. How does habitat type and condition relate to the life-history stages of fish species and communities (including indicator species, keystone species, endangered and threatened species, harvested species, etc.)?

- To answer this question, information on population life history and life cycle need be integrated and coupled with the environmental and ecosystem conditions. More precisely, life cycle spatial organization of fish populations needs to be documented and modelled using cross mapping and coupling with environmental conditions. Habitat variables of concern may include not only well researched parameters such as temperature but also less well studied factors such as trace nutrients in sediments, the role of the benthic nephaloid layer, pH, pathogens and suspended organic compounds.

***2.* What are the most important attributes of habitat condition that maintain fish productivity?**

3. Which anthropogenic stressors most impair habitat functionality?

Could include acute effects, sub-lethal effects, cumulative effects or multiple stressors; high priority stressors to consider:

- Ocean energy development
- Coastal development
- Mariculture
- Contaminants
- Eutrophication
- Fishing gear impacts
- Marine debris

4. **Which invasive species are most detrimental to habitat function?**

- Impacts to habitat services
- Are there ecological types of invasive species inflicting greater damage than others?

5. **What attributes make habitats most vulnerable to invasion?**

- Study how the shift in species range and distribution can be related to climate change
- Determine the niche, role and impact of a species when introduced in an ecosystem, and their significance to management actions
- Assess the significance to changes in biodiversity

6. **Develop an efficient methodology and tools for integrating and mapping the biotic and geologic attributes of habitats over large areas.**

- Emphasize the development of best utilization of current technologies.
- My involve combination of technologies and methods addressing broad range of spatial scales (e.g. multibeam technology vs. video transects of benthic epifauna vs. sediment sampling of infauna).

7. **What are the responses of marine habitats to global climate change?**

    - Predicted functional responses
    - Loss of habitats
    - Degradation
    - Restoration considerations
    - Proactive adaptations/protection

8. **What are the indicators / metrics and their thresholds of habitat condition and how do you identify reference conditions for marine habitats?**
   The diverse set of indicators and metrics may include not only well documented indicators but also those requiring additional research, such as:

    - Disease manifestation (pathological signs)
    - Disease presence (positive titer)
    - Frequency, extent, intensity and duration of disturbances
    - Diversity, composition, structure of seascapes

9. **How do we appraise habitats based on socio-economic value and ecological services?**

    - Project site selection
    - Restoration vs. mitigation

10. A plan to monitor habitat condition must be developed for decadal scales (50+ years).

- Ocean Observing Systems

11. What are the conservation needs and knowledge gaps for various habitats or ecosystems and how do we prioritize them?

- Sensitive habitats
- Deep water habitats
- Rare habitats
- Broad scale habitats
- Habitat resiliency
- Genetic diversity
- Habitat vulnerability

Attachment C -
Identifying Common Research Themes Across Groups

Below is an outline, in priority order, of the common research themes.

1. **Fish-habitat relationships, including human impacts and their variation at different scales**
    a. Climate change
    b. Invasive species
    c. Habitat connectivity and physical barriers
    d. Water quality
    e. Life history habitat use and connectivity effects
        i. Biological levels of organization for examining stressor effects
    f. Underlying processes and functional understanding
        i. Habitat processes
        ii. Habitat-fish relationships/Processes
    g. Predictive models

2. **Identifying baselines and their current range, trajectories and gaps in knowledge**
    h. Identify appropriate indicators of condition
    i. Benchmarks for success
        i. Scorecard
        ii. Standards for protection, rehabilitation/restoration, and enhancement
            1. Reference conditions
            2. Retrospective analyses for theoretical potential

3. **Appropriate standardization of sample design, methodology and monitoring for data analysis**
    j. Probabilistic sampling framework
    k. Long-term monitoring in appropriate context
    l. Standardization and optimization of methodology
        i. Mapping – spatial georeferencing
        ii. Fish and habitat data acquisition
    m. Effective data management, access and visualization
        i. Portal integration
        ii. Informatics
        iii. Data visualization tools

4. **Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover**
    n. Linking human effects together system-wide
    o. Effects of multiple projects
    p. System responses and interactions

5. **Evaluate socioeconomic value of habitat**
    q. Goods and services
    r. Stakeholder interest/values/expectations/acceptance
    s. Societal constraints and legal impediments
    t. Appraisal/valuation of habitat and project results
        i. Socioeconomic
        ii. Ecosystems goods and services

Attachment D –
Specific Priorities Under Common Themes

Below are the specific research and monitoring questions under each group, and organized under the priority headings given in Attachment C.

Research Priorities- Rivers

1. **Fish-habitat relationships, including human impacts and their variation at different scales**
    a. Climate change
    b. Invasive species
    c. Habitat connectivity and physical barriers
    d. Water quality
        iii. Define water quality targets, develop tools to support defined level of aquatic health
    u. Life history habitat use and connectivity effects
        i. Biological levels of organization for examining stressor effects
    v. Underlying processes and functional understanding
        i. Habitat processes
            1. Develop dependant biotic variables to test against watershed metrics
            2. Identify key limiting factors (various scales)
            3. Understand the interaction of scale and functional response
        ii. Habitat-fish relationships/Processes
            1. Develop relationships among spatial data and aquatic habitat condition
    w. Predictive models
        i. Predictive relationships between fish communities and landscape features
        ii. Analyze the robustness of model approaches to different scales
        iii. Develop uncertainty associated with the models at various scales
    x. Develop empirical transfer function between surrogates and more direct variables

2. **Identifying baselines and their current range, trajectories and gaps in knowledge**
    a. Identify appropriate indicators of condition
        i. Develop Bio-health indicators at catchment and region scale
        ii. Determine reference conditions for various geographic settings and catchment scales
    b. Benchmarks for success

3. **Appropriate standardization of sample design, methodology and monitoring for data analysis**
    a. Probabilistic sampling framework

b. Long-term monitoring in appropriate context
c. Standardization and optimization of methodology
    i. Biological and Hydrologic tools for before/after monitoring (which ones, how, when)
    ii. Evaluate the appropriateness of existing technologies (methods) for measuring physical, chemical, biological parameters and emerging technologies at various scales
    iii. Develop framework for monitoring priorities based on uncertainty
    iv. Develop cost effective water quality assessments
    v. Develop effective and rapid tools to estimate hydrographs for non-gauged catchments
d. Effective data management, access and visualization
    i. Develop methods for adding detailed partnership data into the National Assessment

4. Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover

a. Linking human effects together system-wide
b. Effects of multiple projects
c. System responses and interactions
    i. Evaluate differences in effects from landscape disturbance among regions
    ii. Determine the cumulative effects of the aggregation of stressors
d. Develop adaptive management framework

5. Evaluate socioeconomic value of habitat

a. Goods and services
b. Stakeholder interest/values/expectations/acceptance
c. Societal constraints and legal impediments
d. Develop tools for the appraisal/valuation of habitat and project results
    i. Socioeconomic
    ii. Ecosystems goods and services

Research Priorities- Lakes/Reservoirs

1. Fish-habitat relationships, including human impacts and their variation at different scales

a. Climate change
b. Invasive species
c. Habitat connectivity and physical barriers
d. Water quality
e. Life history habitat use and connectivity effects
    i. Biological levels of organization for examining stressor effects
f. Underlying processes and functional understanding

i. Habitat processes
    1. Investigate the role of lake position within watershed drainage network and landscape mosaic
ii. Habitat-fish relationships/Processes
    1. Develop mechanistic models of how living fisheries resources are affected by key habitat characteristics and dynamics

g. Predictive models
    i. Develop a model that classifies lake types with characteristics that indicate potential fish resource.
    ii. Evaluate predictive models as planning tools and assess compatibility across aquatic habitat types for the needs of National Fish Habitat Action Plan goals

2. Identifying baselines and their current range, trajectories and gaps in knowledge

a. Identify appropriate indicators of condition
    i. Develop biological indicators of fish biomass, abundance, and other in lake habitats and use those measures to assess status of lake fish communities.
    ii. Develop biological indicators of fish composition and distribution, and other in lake habitats and use those measures to assess status of lake fish communities.
    iii. Develop habitat indicators of lake conditions that supports desirable fish
b. Benchmarks for success
    i. Scorecard
    ii. Standards for protection, rehabilitation/restoration, and enhancement
        1. Reference conditions
        2. Retrospective analyses for theoretical potential
c. Identify key gaps in lake indicator data
d. Determine adequacy of data and information needed to apply classification models to identify lake habitats in need of protection, restoration, enhancement (regional and national)
    i. Complete development of the georeferenced layers of information that quantify the state of habitat influencing factors listed below, at the best available resolution and appropriate spatial and temporal scales (including metadata and existing gaps)
    ii. Expansion of existing databases to include broader species representation -- better representation of complete fish assemblages in data collection and organization

3. Appropriate standardization of sample design, methodology and monitoring for data analysis

a. Probabilistic sampling framework
b. Long-term monitoring in appropriate context
c. Standardization and optimization of methodology
    i. Mapping – spatial georeferencing
        1. Develop standard spatial units for use in a lake classification system -- appropriate scale for data available (.e.g. 1:100K lower-48, AK 1:63,360)
    ii. Fish and habitat data acquisition
        1. Develop and/or adopt standardized methods to sample and monitor complete fish species assemblages
d. Effective data management, access and visualization
    i. Portal integration
    ii. Informatics
    iii. Data visualization tools

4. Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover

a. Linking human effects together system-wide
    i. Methods to evaluate effects of habitat management actions on living resources, particularly fish
    ii. Methods to evaluate effects of biotic management actions on living resources, particularly fish
b. Effects of multiple projects
    i. Investigate the thresholds of change in key habitat indicators of healthy fish habitat in lakes
c. System responses and interactions
    i. Develop mechanistic models that address synergistic/antagonistic and cumulative habitat influences (acute and chronic) on fish and fisheries resources

5. Evaluate socioeconomic value of habitat

a. Goods and services
b. Stakeholder interest/values/expectations/acceptance
c. Societal constraints and legal impediments
d. Appraisal/valuation of habitat and project results
    i. Socioeconomic
    ii. Ecosystems goods and services
e. Develop or modify models of socioeconomic valuation, limits/impediments to improving human behavior, and trade-offs of management decisions for protection, restoration, or enhancement of fish habitats and communities

Research Priorities- Estuaries

1. **Fish-habitat relationships, including human impacts and their variation at different scales**
    a. Climate change
        i. Which estuarine habitats are most vulnerable to sea level rise and most important as nurseries?
        ii. How will estuarine-dependent species respond to climate change, in terms of demographic changes as well as range changes?
    b. Invasive species
        i. How is colonization of nonnative species in estuaries related to marine (and freshwater) processes?
    c. Habitat connectivity and physical barriers
        i. To what extent to reductions in habitat quality (e.g., temperature, contaminants) act as barriers to juvenile fish rearing in estuaries?
        ii. How do changes in riverine habitat processes alter estuarine habitat and fish?
        iii. How do upstream dams alter habitat forming processes in estuaries?
    d. Water quality
        i. What are the impacts of stormwater on hydrology, contaminants, and nutrients?
        ii. What are the effects of mixtures of contaminants on fish species?
    e. Life history habitat use and connectivity effects
        i. Biological levels of organization for examining stressor effects
    f. Underlying processes and functional understanding
        i. Habitat processes
            1. What ecological processes have the largest effects on habitat formation and fish populations?
        ii. Habitat-fish relationships/Processes
            1. What are the specific contributions of different habitat types to marine fish population changes?
            2. What is the most beneficial distribution of different estuarine habitats for fish?
    g. Predictive models

2. **Identifying baselines and their current range, trajectories and gaps in knowledge**
    a. Identify appropriate indicators of condition
        i. What biological level (multispecies, population measures, individual metrics) best signal anthropogenic impacts?
    b. Benchmarks for success
        i. Scorecard
        ii. Standards for protection, rehabilitation/restoration, and enhancement
            1. Reference conditions

a. How do we define baseline conditions? Can the National Estuarine Reserve Network, National Parks, and Wildlife Refuges provide reference conditions by which other estuarine units can be effectively evaluated?
b. Where would conservation activities be most needed or feasible, and where are reference areas located? What mapping methods could be used to identify reference areas?

2. Retrospective analyses for theoretical potential

3. Appropriate standardization of sample design, methodology and monitoring for data analysis

a. Probabilistic sampling framework
    i. How important is long-term monitoring in assessing strategy effectiveness compared to less frequent assessments?
b. Long-term monitoring in appropriate context
c. Standardization and optimization of methodology
    i. Mapping – spatial georeferencing
    ii. Fish and habitat data acquisition
d. Effective data management, access and visualization
    i. Portal integration
    ii. Informatics
    iii. Data visualization tools

4. Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover

a. Linking human effects together system-wide
b. Effects of multiple projects
c. System responses and interactions

5. Evaluate socioeconomic value of habitat

a. Goods and services
b. Stakeholder interest/values/expectations/acceptance
c. Societal constraints and legal impediments
d. Appraisal/valuation of habitat and project results
    i. Socioeconomic
        1. What habitat restoration strategies have the biggest bang (effects on fish populations) for the buck?
    ii. Ecosystems goods and services

Research Priorities- Marine

1. **Fish-habitat relationships, including human impacts and their variation at different scales**
    a. Climate change
        i. Study how the shift in species range and distribution can be related to climate change
        ii. What are the responses of marine habitats to global climate change, such as predicted functional responses, loss of habitats, degradation, restoration considerations and proactive adaptations/protection
    b. Invasive species
        i. Which invasive species are most detrimental to habitat function and have impacts to habitat services
        ii. Are there ecological types of invasive species inflicting greater damage than others?
        iii. What attributes make habitats most vulnerable to invasion?
        iv. Determine the niche, role and impact of a species when introduced in an ecosystem, and their significance to management actions
        v. Assess the significance to changes in biodiversity
    c. Habitat connectivity and physical barriers
    d. Water quality
    e. Life history habitat use and connectivity effects
        i. How does habitat type and condition relate to the life-history stages of fish species and communities (including indicator species, keystone species, endangered and threatened species, harvested species, etc.)?
        ii. Biological levels of organization for examining stressor effects
    f. Underlying processes and functional understanding
        i. Habitat processes
        ii. Habitat-fish relationships/Processes
            1. What are the most important attributes of habitat condition which maintain fish productivity.
    g. Predictive models

2. **Identifying baselines and their current range, trajectories and gaps in knowledge**
    a. Identify appropriate indicators of condition
        i. What are the indicators / metrics and their thresholds of habitat condition and how do you identify reference conditions for marine habitats, such as: disease manifestation (pathological signs), disease presence (positive titer), frequency, extent, intensity and duration of disturbances and diversity, composition, structure of seascapes
        ii. Characterize and map habitats
    b. Benchmarks for success

i. Scorecard
ii. Standards for protection, rehabilitation/restoration, and enhancement
    1. Reference conditions
    2. Retrospective analyses for theoretical potential

3. Appropriate standardization of sample design, methodology and monitoring for data analysis

a. Probabilistic sampling framework
b. Long-term monitoring in appropriate context
    i. A plan to monitor habitat condition must be developed for decadal scales (50+ years)
c. Standardization and optimization of methodology
    i. Mapping – spatial georeferencing
        1. Develop an efficient methodology and tools for integrating and mapping the biotic and geologic attributes of habitats over large areas
        2. Emphasize the development of best utilization of current technologies.
        3. My involve combination of technologies and methods addressing broad range of spatial scales (e.g. multibeam technology vs. video transects of benthic epifauna vs. sediment sampling of infauna).
    ii. Fish and habitat data acquisition
d. Effective data management, access and visualization
    i. Portal integration
    ii. Informatics
    iii. Data visualization tools

4. Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover

a. Linking human effects together system-wide
    i. Which anthropogenic stressors most impair habitat functionality including acute effects, sub-lethal effects, cumulative effects or multiple stressors; high priority stressors to consider: such as ocean energy development, coastal development, mariculture, contaminants, eutrophication, fishing gear impacts and marine debris
b. Effects of multiple projects
c. System responses and interactions
d. Methods to restore habitats to levels of natural variability

5. Evaluate socioeconomic value of habitat

a. Goods and services

i. How do we appraise habitats based on socio-economic value and ecological services such as project site selection and restoration and mitigation.

b. Stakeholder interest/values/expectations/acceptance
c. Societal constraints and legal impediments
d. Appraisal/valuation of habitat and project results
    i. Socioeconomic
    ii. Ecosystems goods and services
        1. What are the conservation needs and knowledge gaps for various habitats or ecosystems and how do we prioritize them, such as sensitive habitats, deep water habitats, rare habitats, broad scale habitats, habitat resiliency, genetic diversity and habitat vulnerability.

Cross-cutting research and monitoring priorities

The following research and monitoring priorities should be conducted across different system types to fully address the science question.

<u>Among all four groups</u>

Fish-habitat relationships, including human impacts and their variation at different scales

a. Climate change
    i. How will estuarine-dependent species respond to climate change, in terms of demographic changes as well as range changes?
b. Invasive species
c. Habitat connectivity and physical barriers
d. Water quality
e. Life history habitat use and connectivity effects (particularly true for Rivers-Estuaries-Marine systems)

Evaluate predictive models as planning tools and assess compatibility across aquatic habitat types (i.e, marine, estuarine, freshwater lotic, freshwater lentic) for the needs of National Fish Habitat Action Plan goals

Identifying and predicting impacts and their cumulative effects, and determining thresholds above which fish populations recover

a. Linking human effects together system-wide
b. Effects of multiple projects
c. System responses and interactions

<u>Among Rivers and Lakes groups</u>

Apply models to determine the role of lake position within watershed drainage network and landscape mosaic

<u>Among Rivers and Estuaries</u>

How do changes in riverine habitat processes alter estuarine habitat and fish?
How do upstream dams alter habitat forming processes in estuaries?