

**Science Agenda for Addressing Invasive Species
in Sustainable Forestry**

A Working Group Sponsored by

**The National Commission on Science for Sustainable Forestry and
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Meeting Summary

A workshop was convened April 8-11, 2003 to identify the major science and research questions underlying the threat of non-native invasive species to biodiversity in native forest ecosystems and adaptive management approaches for minimizing this threat at large spatial scales. The 16 participants in the working group were diverse and included members having scientific expertise encompassing various invasive taxa (e.g., pathogens, insects, weeds, etc.) and conceptual areas (e.g., spatial scaling, climate change, economics, social systems) and having experience with various groups of forest managers (e.g., federal, state, and industry) (pp. 4-5).

The meeting was structured to accomplish 4 main tasks (see Appendix 1 for daily agendas):

- Build background information and knowledge across the group (pp. 6-15);
- Identify key thematic areas (p. 16; Appendix 2);
- Develop draft outlines for a co-authored manuscript (pp. 17-26); and
- Identify high priority science needs to inform the next Request for Proposals issued by the National Commission on Science for Sustainable forestry (pp. 27-30; Appendix 3).

Eight key themes emerged during the meeting. Three of these are general concepts that frame the issue of invasive species in sustainable forestry:

- This is an ecological problem that has social origins and solutions;
- It crosses multiple spatial scales, levels of social and institutional dynamics, and ownerships; and
- Consequently, it clearly affects the social, economic, and ecological aspects of sustainable forestry and will require multi- and inter-disciplinary approaches that cross the natural and social sciences.

The group identified five substantive areas of pending science needs:

- The science of invasion;
- Informatics;
- Policy analysis and decision support;
- Social and organizational change; and
- Global change and invasion.

By applying a set of prioritization criteria (p. 27) to these broad areas, the working group identified and voted upon a set of more specific near-term priority science needs. These will inform subsequent development of draft language for the NCSSF RFP. The group identified the following top three priorities:

- Assess the policy framework and identify promising policy approaches;
- Improve early detection technologies and approaches;
- Understand how forest management practices affect species invasions and impacts.

An important conceptual issue that emerged during the group's discussions is the need to better integrate conventional approaches to invasive species (e.g., that generally focus on the trajectory and effect of individual species) with ecosystem-based approaches (e.g., that focus on multi-species assemblages and ecosystem patterns and processes at large spatial scales). Approaches for achieving this integration will be an important part of the multi-author paper resulting from the workshop.

The proceedings that follow provide a solid foundation for NCSSF's next efforts related to invasive species and for one or more publications that will amplify the issues and needs highlighted by the working group.

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2. BACKGROUND INFORMATION

The working group was divided into 8 teams, each covering a different substantive topic. Each team put together a presentation that addressed:

1. What is the nature of the problem?
(5-10 main issues, concepts, pieces of background information)
2. What are the key science gaps? Which problems could be solved by science?
3. Explore where possible the social, economic, and ecological dimensions for each gap identifies in #2.
4. What are the specific science needs?
(includes synthesis; tools; concepts; frameworks; research; etc.)

Pathogens (Cummings-Carlson & Britton)

Nature of the Problem

- Early detection is challenging given the microscopic size of disease-causing organisms.
- Host range plasticity circumvents regulatory requirements (Chestnut blight).
- One forest pathogen can affect multiple hosts and cause a variety of symptoms (SOD).
- Several disease-causing organisms can cause similar symptoms (SOD).
- Morphology or symptomatology alone does not provide diagnosis.
- Genetic changes occur relatively quickly and may go undetected for decades (DED, Chestnut blight VC types/sexual reproduction).
- Taxonomic information is incomplete for many species groups (Botryosphaeria).
- Prevention/detection and management requires multiple agency coordination.
- Roles and responsibilities of various agencies are not well defined, sometimes because the statutes/laws that define responsibilities are not clear (EAB).
- Some agencies have responsibilities to both facilitate trade and minimize entrance of exotics. This can limit effectiveness (SOD).
- Host range maps that provide greater detail are needed to conduct surveys.

Key Science Gaps

- New and rapid detection and identification techniques must be developed for numerous forest pathogens
- There is very little information on the influence of genetic plasticity on host range and risk of invasiveness.
- There is very little information on the influence of anthropogenic factors affecting the level of risk.
- Methods for developing accurate host maps must be refined.
- Information on the epidemiology of new systems is often lacking (permits to study these organisms are limited).
- Existing location or range data are available but have not been summarized or analyzed (FIA). Flexibility is needed in the FIA system to respond to data needs.

What are the specific science needs?

- Synthesis: develop a system to access FIA data in a timely manner and accurately.
- Research/tools – detection methodology using RT PCR. Primers must be developed for all potential invasives.
- Research/tools – remote sensing/modeling and signature development need to be conducted for forest species at risk.
- Research – rigorous study on epidemiology is needed for new systems.
- Research – site factors and host status (age, density) that influence risk.
- Research – determine how biodiversity in a pathogen affects plasticity in the host selection and environmental adaptation.
- Frameworks – coordination of agencies and clarity in responsibilities.

Insect Pests (Haack & Bartuska)

Nature of Problem

- Prevention – of entry or of spread. It's all about economics!
- Biodiversity link – early detection increases speed of action therefore protecting biodiversity.
- Procedural limitations – federal quarantines only exist for 4 of over 400 non-native forest insects species.
- Most are not addressed; APHIS inspects only 2% of what comes into country.

- FAO – new standards proposed for certification of wood packing material (heating or methyl bromide fumigant).

Science Gaps

- What exotics do we have? Where? Spread rate? Population size? Need baseline information
- Some sense of how important an organism is. Impacts.
- Risk management – methods to ID high-risk pathways and ID intercepted pests to lowest taxonomic level possible (genus and species).
- Increase capacity at points of entry to identify intercepted pests.
- Ability to alert and share information about new detections.
- New pathways are being identified (e.g. bonsai, fishing lures from Asia).
- Improve rigor of trapping or monitoring techniques – should be uniform across US and used by State and Federal entities.
- Sampling protocols that recognize biological differences – Does it have to be species specific? What type of trap and lure to use? Are pheromones available?

Science Needs

- Risk Assessment process that allows us to predict likely pathways and taxa and focus action, applied to forested ecosystems and biodiversity goals.
- Analysis of trading practices in past vs. present vs. future – compared with initial occurrence of known non-native forest pests Economic considerations.
- Economic analysis tools associated with the impacts of invasive species on ecosystem services (biodiversity, water quality and quantity).
- Improving taxonomic capacity – re-value these specialists; losing few we have left (e.g., no world –authority on bark beetles currently employed).
- Data mining of interception reports and import/export records.
- Trapping – scientifically designed approach that recognizes taxa and life cycle differences.
- Tools Needed - DNA probe for identification of larval stages/ eggs within shipments (5 – 10 years in development).
- National monitoring and data management system that provides information to decision makers in a relevant time step - will help address the INTRASTATE movement of organisms.
- Creating an early detection cadre, building upon professionals (e.g. tree care companies), volunteers.
- Alternative to methyl bromide for fumigation and treatment.
- People’s responses to treatment options (specifically, chemicals used for eradication) – public awareness may increase comfort level.

Institutional Issues

- APHIS policies and procedures about inspections and reporting – limited information gathered
- APHIS risk assessment procedures may be applicable to sustainable forestry goals but need to be evaluated
- Quarantines are rarely applied against pests of forest ecosystems; and those that are imposed only regulate trees and tree products (e.g., human assisted movement).

Invasive plants (Gordon & Mack)

Main issues/background

- Majority of introductions are deliberate and for aesthetic purposes.
- Number of introductions will increase because of deliberate trade in species with characteristics valued by people (xeriscape), rather than based on biology alone (i.e., weediness).
- Persistence is based on purposeful initial cultivation to some threshold abundance.
- Attributes of species predictive of invasiveness are difficult to characterize, often can only do retrospective assessment. Not all invaders are weedy.

- Transition from persistence to invasion is often triggered by a novel disturbance type or regime, which is sometimes exacerbated by the species itself (e.g., changes to fire regime).
- Predicting ecosystem vulnerability based on native species richness is confounded by factors like opportunity for invasion, past land use, etc.
- Forest management actions (e.g., prescribed fire, road creation, soil disturbance, forest product harvest) can facilitate invasion.
- Widespread use of non-native species in forest land re-vegetation has facilitated spread of invaders.
- Climate matching has value but many exceptions - so predicting eventual range is often difficult.
- Forests in the US have likely not yet experienced the full extent of plant invasions (haven't yet seen dwarf bamboos in the Pacific NW, for example).
- Use of off-site native species and plantations of non-natives can have significant implications for native biodiversity

Key Science Gaps

- Synthesis of MVP for as many species in as many environments as possible.
- Role of environmental stochasticity in fate of small populations.
- Synthesis of categories describing how species with different life histories and vectors spread across the landscape.
- Understanding of the most effective timing and spatial distribution of control efforts for different species.
- Better tools for early detection.
- Mechanism for national level monitoring, early detection, and maintained database of invaders.
- Cost/benefit analyses for commercially available invaders for policy assessment (control, eradication, regulation, etc.).
- Synthesis of the science available for development of a regulatory mechanism to prevent introduction of new likely invaders.
- Summary and translation of scientific understanding of control and prevention activities for practitioners (BMPs).
- Need better evaluation of whether eradication is possible once a species is prevalent enough to be detected - current upper threshold is too low (more compilation of examples and modeling).
- More effective control methods for more species.
- Investigation of how to modify forest management actions to achieve necessary results but without facilitating invasion.
- Need better understanding of the cascading effects through ecosystems of invaders and the economic ramifications. Then need stories translated for public understanding.
- Investigate the role of invasive species in exacerbating climate change - could motivate policy changes and more complete economic analyses.

Specific science needs

- Better documentation of cases of spread from earliest detection forward - for modeling purposes.
- Aerial extent / abundance of most species.
- Comprehensive list of species invasive anywhere by climate and soils.
- Assessment of whether data support precluding introduction of *any* species with fleshy fruit small enough to be dispersed by birds and mammals?
- Better prediction of existing species that are likely to become invasive with introduction of new genotypes or interbreeding of different populations.
- Understanding of which species are most likely to be imported because of "attractiveness" or use (e.g., dry flower arrangements) - human behavior analysis

Aquatic Species and Wildlife (Rahel & Wigley)

What is the nature of the problem?

- NIPFLOs own most of the forest and should be involved if we are to fully address invasive species.
- Landowners are not fully informed about invasive species, how invasives can affect their ownership objectives, alternative strategies for control, etc.
- Forest management goals and practices differ by ownership size and type of owner, which may lead to different issues/vulnerabilities involving invasive species, and require different strategies for addressing invasive species. There is no cohesive strategy for addressing invasive species across multiple ownerships.
- Movement of aquatic and terrestrial wildlife by the public is a significant problem (e.g., bullfrogs, brook trout, rainbow trout).
- There is an incomplete appreciation among the general public for the potential problems caused by invasive species. Invasive vertebrates are viewed as desirable by recreationists, etc.

What are the science gaps?

- Knowledge of incentives that would encourage NIPLOs to be involved in control of invasives.
- Better information about how the dynamics of invasives differ among different ownership sizes and management regimes.
- A more complete understanding about what will motivate the public to not move invasives.
- A public that is better informed about the ecological and economic implications of invasives.

What are the specific science needs?

- A literature review to synthesize information about the performance of selected invasive species under different forest management regimes.
- A survey of NIPFLOs to evaluate perceptions of incentives for implementing alternative strategies for controlling invasives.
- Evaluate current educational programs (e.g., Project WILD) for activities related to invasives and develop activities if needed.

Climate Change (Chornesky and Hansen)

Nature of the Problem

- Biophysical conditions set limits on species distribution and abundance based on species tolerances and on communities and biomes based on available energy, etc. Interact with biotic forces.
- Human activities are modifying biophysical conditions which are driving change in the nature and location of suitable habitats for species, connectivity among habitats (e.g., certain pathways may open, and others may close), and changes in community structure.
- As a result, projected distributions of some (many) native and non-native species will change.
- Because species will vary in their rates and patterns of migration in response to a changing climate, some (many?) ecological communities are likely to disassemble – leaving gaps that are vulnerable to species invasions.
- The expected result will be partially or wholly altered assemblages of species in many locales.
- These will be a mix of species native to the locale, species native to the U.S. but new to the local, and non-native species.
- Under these conditions, it seems likely that previous invasives will be more likely to reach and occupy these sites that become inhospitable to native species assemblages.
- Changes in rates of species invasion are likely to vary geographically (based on energy theory). Greater invasion rates will occur in areas where potential species richness will increase (higher

- latitudes) and where local extinctions are more common and potential species richness will decline (lower latitudes).
- The social, economic, and ecological value of these systems will change dramatically and will often be degraded.
 - New methods will be needed to set biodiversity goals for these altered systems, especially relative to the concepts of native and nonnative species.
 - New approaches will be needed for management. When will we try to inhibit these changes (perhaps infeasible at many places)? Do we try to engineer new ecological systems based on a new set of criteria based on the delivery of ecosystem goods and services? What are these criteria and who decides?

What are the key science gaps and the problems that can be solved by science.

- No conceptual framework exists to help scientists, managers, and policy makers think about the interactions between climate change and invasive species. How will climate change and invasive species interact with each other? How will climate change alter the rates, pathways, patterns and impacts of invasive species?
- How do we set biodiversity and other management goals for ecosystems that are changing? How do we measure and monitor the state of the ecosystem (including vulnerability and goods and services) relative to our management objectives for the system to make choices among alternative management options (or to take no action!). How do we weigh alternative future scenarios in light of the social, economic, and material values society assigns to various species assemblages.
- Need predictive approaches to assess how patterns, processes, and impacts of species invasions will change with climate. This includes a need for qualitative and quantitative descriptions of when and how climate change will affect species invasions and impacts? Is it 20, 40, or 60 years out? Such information will be critical to demonstrate this apparently “long term” issue will have impacts over time scales that are relevant to business cycles, development of government policies, and public values.
- Models predicting species responses to climate change are based on limited information about the autecology of species, particularly dispersal rates. This makes it difficult to parameterize models and reduces their accuracy. Better and more realistic data on dispersal patterns will be essential to improve the models. Given the limited resources for such work, though, can we prioritize which species we need to study most?
- Need ways to set priorities among invasive species for taking action (e.g., related to impact, feasibility, etc.). Will these prioritization criteria be different from those used in the absence of climate considerations?
- Need new management approaches that address the specific issues that will arise from dealing with invasive species under conditions of a changing climate. For example, would it make sense under some conditions to protect an ecological system from invasion so that it could serve as a reservoir for the restoration elsewhere? Would it be possible to engineer an ecological system (a specific suite of species) at a place as a “preemptive strike” against undesired future invasions.

What are the specific science needs (syn, tools, concepts, frameworks, etc)

- (KEY NEED) Develop a conceptual framework for understanding the interactions between climate change and species invasions. This framework should include consideration of ecological systems at multiple levels from species, to communities, to ecosystems and landscapes and the interactions among these levels under climate change.
- Develop ways to set biodiversity management objectives for changing ecosystems. These should include adaptive management approaches that focus on a wide range of management approaches from preserving current communities to engineering new communities.
- Develop various modeling, forecasting, and scenario based approaches for exploring how invasion patterns, processes, and impacts will be altered by climate change – and use these to identify systems at greatest risk; evaluate various management possibilities; develop institutional response capabilities. These models should link local ecosystem dynamics and continental scale biogeography issues.

- Develop new management approaches and methods to preempt, minimize, or reverse the worst impacts of climate change on species invasions.

Spatial scale and decision support (Gottschalk and Davis)

What is the nature of the problem?

- Current approaches to invasive species monitoring and management tend to be reactive and are less effective at prevention, early detection and initial control. The “ounce of prevention” requires better public awareness and alertness, improved ability to anticipate problem species and susceptible environments, better monitoring and in particular integration and analysis of monitoring information across organizations and spatial scales.
- Many invasive species require monitoring and management at multiple scales.
- At multiple scales, multiple owners with varying property sizes create management challenges.
- Information management tools are more essential to managers than decision support tools *per se*.
- Modeling efforts need to tie into planning and other landscape and higher level systems.
- Data and information standards, protocols, and other mechanisms to promote information exchange and sharing are still immature and those that exist not in wide use, especially in private sector and in local governments.

What are the key science gaps? What are the problems that could be solved by science?

- Most broadly, design and implementation of a national invasive species information infrastructure.
- Monitoring to detect new species, distribution of current species, and distribution of hosts
- Incorporating invasive species effects into management modeling tools and planning process (FVS, LMS, forest mgmt planning, etc.).
- Constructing pattern and timing of spread to enable constructing controls.
- Providing information mgmt tools.
- New institutional models needed for multi-owner, multi-scale efforts.
- Informatics and decision support tools for public processes (as opposed to more top-down agency applications).
- Decision support is good at information mgmt and ecological factors, sometimes good with economics, and rarely good with social factors affecting decisions.
- How well are we doing on an ounce of prevention?

What are the specific science needs?

- Provide information management tools that automate processing and deliver quality information to decision-makers.
- Develop new institutional/legal models to manage species across multiple scales and multiple ownerships (i.e. GM STS).
- Develop tools to allow the public to participate in monitoring and detection (i.e. SOD oak mapper).
- Develop economic and social tools to assist in decision support to a level similar to ecological and information mgmt tools.
- There are generally 3 scales that most invasive species operate at: stand, landscape, subcontinental and need appropriate controls for all scales.
- Monitoring systems need to be developed at the appropriate scales for detection of new species, distribution and spread of current species, and distribution of hosts.
- Modeling spread and determining thresholds for controls is needed to design multi-scale management.
- Review and synthesize current prevention and eradication efforts.

Institutional and Social Issues (Shannon & Eskow)

What is the nature of the problem?

- Whatever the US in policy does must be harmonized globally. Otherwise, the problem will be exported and much greater problems created as a result.
- People have to start working on this for it to become a public problem. Has to be a reason why people want to know about it. Need to have activists who define and push the problem onto the public agenda. Need to have information ready to go. Need to engage the political process to pay attention. [This is a continuous process that needs to have information and a strategy ready to respond when the issue emerges on the public agenda.] Need to be ready to demonstrate existing policy gaps and needed institutions.
- Recognize dealing with incredible amount of uncertainty. Therefore, the institutional and legal frameworks need to embrace concepts of “adaptive management.” Dywer opinion in 1994. Organizations need to be able to undertake adaptive management – how create successful learning within organizations?
- Precautionary principle (EU) vs. Risk Assessment (US) – must address this tension. How much experimenting are our institutions and organizations willing to undertake?
- Law – Weak legal framework for invasive species.
- Agriculture, small ownerships, some forestry practices are explicitly exempted from compliance with US environmental laws.
- Only things already known and recognized as pests. Risk assessment processes can be used and the NEPA process.
- Trade rules – APHIS – quarantine and pest laws, but once within the US little legal control – WTO trade barriers?
- Sanitary certificates for export.
- 1990 – industry wanted log exports from countries other than Canada. Did risk assessment to evaluate pests. Challenged in court, found inadequate. Did supplement and upheld. APHIS risk assessments of pests - log imports (ONRC case 1997)
- Enforcement: difficult to find in imports.
- Globalization of Trade. US export of logs to Japan – insect wiped out Japanese natural forests. Now import from Russia – what effects coming?
- Institutional context in US.
- Mechanisms for SFM – not focused on this problem, but could be available. Problem— coordination, understanding, prioritization with other issues dealing with (like endangered forests right now not thinking about ecological issues and connecting them).
- Certification.
- Ownership – diverse goals; different contexts; different values/cultures.
- How evaluate this policy problem and solutions relative to other problems and solutions?
- Barriers like anti-trust law, private property rights, etc.
- Need a participatory/collaborative approach to begin to define and address problems like invasive species
- Uncontrolled development – increased infrastructure for transportation leads to other impacts like highway right of way management.

Key science gaps? What problems could be solved by science?

- We need basic research in the social and policy sciences. Need to understand the basic institutional and legal frameworks in place, gaps, opportunities. Need to understand trade and international policies – differences, similarities, barriers like WTO rules, anti-trust rules.
- Montreal Process: Criterion 7 – legal and institutional
- Dispute resolution mechanisms – what is available, how well fit this problem.
- Whose responsible – coherent and transparent legal/institutional framework

- Question: To what extent need an international legal framework to effectively address this problem?
- Could this problem be one that leads toward the need for forest convention?

Specific science needs?

- Basic research--Understanding existing legal and institutional system. Synthesis of current policy efforts to see what is working/not working. Roles of different actors – industry, NGOs, governments. Need to understand the roles of all actors disturbing the landscape – development, transportation, agriculture, landscaping, forestry, etc. Understand how the international laws, trade laws, national laws, etc. work together or conflict with one another. Understand interests actors, nations, international players – what is needed, what is practical, what is possible.
- Try to look at other frameworks trying to address similar kinds of problems like carbon, global change – Is it possible to develop a “theoretical” basis for a national/international policy framework?
- How understand the relative public priority of this problem compared to other pressing problems? How would this affect selection of policy tools?
- Uncertainty – Policy makers avoid type 2 error so more important to act even if not needed later.
- Near term costs vs. long term gains – need to address through information as well as policy frameworks that make the linkage through incentives, rules, etc.
- Economics – measuring risks and impacts important to sustainable development concept.
- Policy is at the level of the scale of the issue. And policies must be coordinated across scales.
- Cross-sectoral policy coordination and integration – forest sector requires a multi-sectoral framework.

What Can Economics Bring to the Analysis? (Aplet & Wainger)

Goals of Economic Analysis

- Understanding driving forces & feedbacks
- Understanding public and private implications of policy options
- Managing risk
- Identifying efficient management mechanisms for ensuring the public good

Key Issues

- Economic actors will continue to drive new introductions
- Taking a precautionary approach (guilty until proven innocent) will not be acceptable to many of these actors for economic reasons
- Any potential solution may have unintended consequences
- Scientific understanding may be insufficient to show significant harm to the public good (e.g., in legal setting)

Scale-specific questions

- Institutions are scale-specific (county, state, etc)
 - What are the gaps in scales of management?
 - Does regulation/policy produce perverse incentives?
- How does land ownership affect management options?
 - Government
 - Large private
 - Small private**
- How do private incentives interact with ecological landscape to create different risks? Who controls the critical sites?

Mechanisms to achieve goals

- Understand owner incentives
- Identify market failures (externalities)
- Examine alternative management strategies
 - Would they change behavior?
 - Would that change be sufficient to reduce risk (link to ecologists)
- Quantify risks

Examine Benefits, Costs & Risks of Management Strategies

- Benefit Cost Analysis
- Dollar Valuation Techniques
- Cost-Effectiveness Analyses
- Quantitative Benefit Indicators
- Decision Analysis
- Incorporates Risk and Uncertainty in addition to Benefits & Costs

The Economics of Trade and Invasive Species**Resource Implications of Invasive Species Policy and Program Alternatives**

- Deriving economic implications of alternative approaches to invasive pest exclusion, surveillance, management, and/or compensation
- Illuminating tradeoffs and informing resource allocation options in the multi-program context
- Exploring the political economy and welfare implications of invasive species regulation
- Bioeconomic Integration and Risk Assessment
- Advancing the art and science of bioeconomic modeling
- Externalities, public goods, and nonmarket valuation in relation to invasive species
- Incorporating risk and uncertainty into economic decisions concerning invasive species

Links to Ecologists

- Bring realism to analyses of each discipline
- Types of information economists need to do effective analysis
- Objective evidence
- Benefits & Risks in terms that matter to people
- Examine why limits of ecological understanding lead ecologists to avoid risk rather than manage risk
- Examine risks in terms of pressures from human activities
- Examine solutions in terms of targeting specific behaviors and risks

3. KEY THEMATIC AREAS

Four breakout groups identified key thematic areas for further analysis based on the preceding presentations on background information (see Appendix 1 for detailed lists from these breakout groups). These individual lists were compiled into a single list of major themes (1 through 5 below) as well as three important context-setting issues that permeate each of the themes.

Smaller teams developed outlines (pp. 17-26) for each thematic area to lay the foundation for a co-authored paper summarizing the workshop findings.

Introduction (context-setting)

- this is a social problem
- science and policy of differences; addressing multiple scales
- Impacts on all Sustainable Forestry goals (integration of ecological, social and economic)

Consensus of Major Themes (assigned to new breakout groups for developing outlines that follow)

1. Science of Invasion - prevention [Framework: Attributes X Environ Context X Circumstances] and future risk assessment, improve detection methodology, invasion and management protocols/practices
2. Informatics – establish baseline information, data and information technology, tools for managing and analyzing information in spatially explicit formats. Technical decision support.
3. Policy analysis and decision-support. Risk characterization (ecological/economic), assessment and risk management, assessing economic costs, relationship for ecosystem services, management scenarios and invasion risk. Evaluate effects of uncertainty.
4. Social and Organization change – governance, academic capacity, understanding human behavior and invasion (current and future scenarios), cohesive education strategy, advancing effective policy. Communication and effecting behavioral change. Include economics.
5. Global Change and invasion – climate, land use and globalization.

Science of Invasion – Outline

(Bartuska, Mack, Cumming-Carlson, Gordon)

Context:

- Biology of invasion using lag time and exponential growth approach – decision process changes depending on where species is in invasion process
- Management implications and how to react
- Science continually informing management, which integrates across the different approaches

Context for Sustainable Forestry:

- Number of recognized forest pests that influence forest productivity and biodiversity (examples).
- As management practices change potential for invasion increases – and have more and more invaders.
- E.g., smaller block management (moving from large clearcut patches) → Frequent entry, highly mobile small equipment means more roads, higher potential for movement of invaders (more opportunities for nascent foci)
- E.g., As fragmentation increases and more habitation in forest blocks → same kinds of impacts as above and more juxtaposition of potential invaders with forest blocks.
- E.g., As diversify human use and harvest of products in forests, increase frequency of human/forest interaction and pathways for introductions (e.g., fire ants and Japanese climbing fern in pine straw mulch). Trade-offs as change forestry practices and social context may be adding additional pathways (not all uses equal).

Organization: Six categories

I. Emigrants in the donor range

Given: High probability of more woody imports; recognize that movement is in every direction globally

A. Biology

B. Management Implications

-- Contaminated timber and other products or cargo (stowaways)

- Any forest organism within the range of removal and production of shipping and cargo material has the potential to contaminate shipped materials (Asian gypsy moth attracted to lights in ports and therefore to shipping materials – now have ongoing monitoring that leads to eradication on ships in ports)
- Recognize ecological similarities between donor and new range to develop probabilities of invasion
- Need to identify the pathways and address management at appropriate juncture
- High risk of importing any unprocessed timber

-- Deliberate introductions of species that can persist in forests

- Id processes that determine which species have high probability for selection for deliberate introduction – tree species for plantations and other species likely to invade forests (plant, invert, animal)
- Identification of species that have been invasive elsewhere to increase ability to prevent introduction
- Incorporation of this information into risk analysis for deliberate introductions

II. Emigrants in transit

A. Biology

B. Management Implications

- Management in other countries of import affects final who gets to destination (Asian gypsy moth example).
- Need tools for detection and management (changing lights so that moths are not attracted) at export and import locations.

III. Immigrants in new range (initial entry – single population)

A. Biology

- Importance of size of initial population, timing of entry, genetic variability of pop, size/distribution of initial pop; sex ratio, age structure, demographic and environmental stochasticity

B. Management Implications

- Need deliberate process for early detection - new technologies needed (trap pollen across large grid using airborne sampling technology and develop monoclonal antibodies to identify them over large-scale (Mack in press)) (III and IV) – add to EPA air monitoring grid, bark-beetle trap sites, etc.
- For invertebrates – microprobe for larvae, DNA probes
- Broad-based volunteer effort (overlap with informatics)
- Rapid response → eradication (don't watch and see what happens)

IV. Transients (potentially highly unstable small, isolated populations)

A. Biology

- Role of environmental stochasticity in eradication vs. persistence

B. Management Implications

- If monitoring condition of landscape at shorter time-step than historically, potential for early detection increases (see III).
- Forest health monitoring will pick up forest insect and disease impacts using aerial and ground surveys (adding weeds)
- Rapid response → eradication
- New model of governance associated with sustainable forestry – certification?

V. Persistent populations (naturalized)

A. Biology

- Potential metapopulation structure with many, widely spaced populations in the lag phase of indeterminate length.
- Need information about what triggers movement into growth phase – e.g., addition of new genotypes; pollinators or vectors, dispersal to hosts (e.g., Miconia in Hawaii)
- Environmental stochasticity no longer very important

B. Management Implications

- Structure of forest health monitoring system ideally set up for probability-based monitoring of invaders
- Rapid response → eradication

VI. Invasion

A. Biology

B. Management Implications

- Rapid response → eradication if possible (*Nassella tussock* in New Zealand –ask Dick for reference), common barberry could have been (US – Staking 1919; 1929; Freeman 1927; Moody and Mack 1988)
- Slow the spread approach (containment) – e.g., internal quarantine, gypsy moth

Other thoughts

Factors that influence probability of persistence and invasion

Biology of immigrants in terms of which ones are not likely to survive

Prevention

Understanding species likely to be imported – immigrant pool

Taxa groups rather than species by species?

Detection

Pathways

Integrated vector management

Management to avoid invasion

Monitoring

Eradication / Control

Management

Restoration

Informatics Outline

(Haack, Wigley, Davis)

- Need adequate information to design and implement control programs and to avoid adverse economic and ecological effects.
- Need to know what species are present in the US, where they are, rate of spread, ecosystems within which they reside or niches they occupy, how to identify them.
- Some of this information is now readily available through websites such as NAPIS. But this website focuses on species that of pest quarantine significance, insects and diseases.
- Need to have dynamic information. Quarantine maps should be updated on a regular basis to facilitate control, minimize human-assisted movement of pests, to avoid unnecessary economic impacts.

FIA Database

FIA provides a powerful database that could be used to address non-native species in forested ecosystems. Briefly describe the useful variables. It describes the forest ecosystem in sufficient detail that it will help predict geographic spread. For example, where is all of the ash?

- We need to add FIA plots in urban settings.
- Need to strengthen spatial data center recently implemented by FIA.
- Need more data on understory vegetation in FIA. Where are there large numbers of rhododendron growing in the understory? Could be useful in modeling risk of sudden oak death. Must be careful to not overburden the inventory crews, perhaps by adding crews that would focus on other variables of assigning this to the Forest Health Monitoring Program.
- Need links from FIA data to sites that have climatic data, soils data, etc. Also would be helpful to have spatially explicit layers that show locations of wood utilization facilities, Christmas tree plantations, tree

nurseries, etc. For example, to control emerald ash borer, wanted to know where all the nurseries were that were selling ash in Michigan and all the sawmills that were buying ash.

Other Data Needs

- It would be helpful to have better access to import records from different countries. What kinds of products are coming in from what countries? What ports are receiving products and where do the products go after that? Some containers are not ever opened at the port, but only at the final destination. Some States are now able to query all companies that have received goods from China and could send companies notices to inform them to look for a non-native species (e.g., Asian longhorn beetle). This also would help agencies know where to send their inspectors. It would be helpful to link these data with spatially explicit data on climate information, soils, FIA data. Such linkages also would help us determine where to concentrate surveys when funding is limited, e.g., focusing near facilities that have received shipments from countries known to host certain problem species.
- Databases need to be comprehensive in terms of the non-native species they address, not just focusing on federally quarantined species or only on species that cause economic problems. A problem is that there is no mandate on states to monitor for pests unless there is a federal quarantine. Thus, no one working on range maps unless they have to.
- Overcoming barriers in data sharing among ownerships. Anti-trust and competition and lack of data complicate assembling detailed databases that describe forest condition where multiple private landowners are involved.
- It would be useful to have a database of pests from other countries known to be associated with hosts in the US. For example, it would be helpful if we could query a world-wide database for all of the insect pests in China associated with oak or to discover what lives on pine in Japan. It also would be helpful to link such a database to the APHIS database to evaluate what they have found from Japan in the past.
- APHIS records information about species that are "actionable." Would be useful for APHIS to record as much information as possible about the non-natives they discover so we will know all species that have been intercepted. It also would be helpful if countries would share their interception records. APHIS has not summarized their own data and there have been few papers based on it.
- We need to develop decision support tools for managers in the field to identify non-natives, survey for them, hazard ratings, population growth models. Much of the tools exist but access is sometimes difficult for managers. Some models are only available for the "worst" pests, so for others there are not any tools.
- We need to develop spatially explicit GIS layers that show hazard ratings, rates of spread, population dynamics predicted from forest condition. It would be very desirable to link these spatially explicit layers with forest planning programs or spatially explicit harvest scheduling programs. This would allow managers to constrain harvest scheduling by hazard rating or compare hazard ratings among different harvest schedules.
- We need tools that will predict not only outcome of different management regimes or treatments for a single species of concern, but for suites of species or multiple species. For example, a treatment to address an insect might increase susceptibility to a pathogen. We also need computer programs for non-native treatment programs that are similar to drug interaction programs used by pharmacists.
- We need expert systems to help identify pests such as the diagnostic programs physicians use. Digital cameras are good enough to help ID now. Need a single identifier for certain groups of pests. Send it to them from all over the world.

- We need a digital library of pests from the world over and software to compare images to those in the library.
- We need websites where the public can enter reports of non-natives that are found in different locales.
- We also need automated tools for processing information, so we don't have to design queries every time. This would allow the information to be summarized automatically.
- Legal side. Resistance of owners to have spatially explicit information that is specific about conditions on their property and vulnerability to nuisance suits. Need to include implications of this information. Unexpected data layers can have legal significance – such as soil quality as an indicator of productivity and therefore tax value. Privacy issues – only TX has passed law that can't get remotely sensed data on private lands. Intellectual property rights issues. (May need to draw in additional expertise to help with this.) Generating maps for pests of quarantine significance – APHIS currently needs to do this (is a new law not yet challenged in courts).

Decision Support and Policy Analysis Outline

(Wainger, Gottschalk, Chornesky)

Introduction:

- Necessary to set priorities.
- Have some thorny problems; need tools to sort through diverse data, transparently consider diverse objectives.
- Resources limited/opportunities great.
- Certain desired management outcomes may be effectively infeasible or very costly.
- Some actions require agreement among stakeholders and/or meeting diverse objectives simultaneously. Undertaking these actions can be resource intensive, require political capital, or be difficult.
- Difficult to fully and effectively integrate the full range of issues without rigorous analytical tools.
- Providing an objective accessible framework (level playing field) that stakeholders can agree is a fair process would minimize conflicts.
- Existing decision support tools are not always used because they don't capture the full range of information and issues of concern to managers. And because they sometimes take time/effort.
- Some managers act conservatively because they are risk averse – consequently they overuse controls technologies. Development of more accessible risk assessment tools would help managers to understand how risk averse behavior can lead to management inefficiencies.

Who are the decision-makers?

Range from individuals up to international policy-makers. Therefore, a general framework is needed that can be adapted to different situations coupled with a range of tools and approaches that scale to the capacity, resources, and specific problems affecting different decision-makers.

Key Problems to be solved:

- Setting priorities for ecological management (choosing among target invasives; balancing competing demands for resources)
- Setting priorities among places for monitoring/early detection, and management.
- Determining optimal distribution of resources (e.g., spatially and temporally and across multiple ownerships – the distribution of funds and resources to optimize management outcomes).
- Determining optimal policy choices and balance at a national level (e.g., trade policy vs. control).
- Incorporate invasive species into existing management tools (modeling/planning tools; e.g., Forest Vegetation Simulator; Fire risk assessment; FORPLAN; private sector management models).
- Evaluating the true costs and benefits of species invasions to inform policy-making and public opinion.

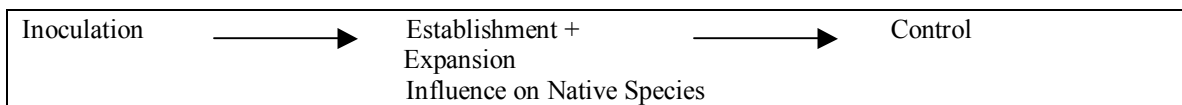
What kinds of decision support tools are needed?

- Systems that adequately capture the full range of ecological, social, and economic issues that are of significance to user groups.
- Tools that fairly allocate costs between current and future generations.
- Includes GIS, expert systems that query databases, data analysis tools, modeling, scenario analysis, and other forecasting approaches.
- Rigorous tools for eliciting best professional judgment where data are lacking. (e.g., survey tools; analytical hierarchy process – application of existing methods to invasive species problems)
- Economic tools that integrate ecosystem services and the ecological functions on which they depend.
- Can be applied to evaluate decisions about individual invasive species in the context of ecosystem functions.
- Matches emerging models of distributed governance and decision-making (e.g., by networking knowledge derived from individual cases and the best available ecological understanding to enable continuous improvement of decision-making approaches).
- Can address rapid assessment (initial screening) as well as in depth assessment.
- Pay attention to data quality to assess and clarify levels of uncertainty.
- Methods for rigorously assessing uncertainty
- Institutional context – decision-making process differing across ownership and across organization. Affects speed of response. Says something about where and how decision support tools can/should be applied.

Social and Organizational Change

(Shanon, Eskow, Britton)

1. Understand the social system of invasion and control



Social Sciences

Biological Sciences

Policy Sciences
Economics

Who are the actors?

- Identify actors
 - i. Sphere of influence
 - ii. How behave and why
 - iii. Institutional social and economic framework
- Interactions among actors X actors X scales and over time
 - i. Make a table???
- What needs to change? SFM context

Policy and Governance framework – Collaboration and Deliberation

- Solid wood packing material example of process and change and relationships of US to International.
- Decision time – need quick response capacity
- CDC + FEMA models + FS goes to fire rules
- National Invasive Species Council – 16 fed agency, chaired by Ag + Interior Secretaries
- SFM protocol model and Kyoto model for developing an international framework

Communication and Education - SFM

- Collaborative Deliberation Public and Scientists.
- Education where communities and children are co-scientists.
- Connection to networked information resources. Shared learning via distributed information resources to catalyze and improve local efforts.
- Risk communication fits.

Global Change and Invasion

(Aplet, Hansen, Rahel)

Introduction

- Invasives are a rapidly increasing problem because of globalization and land use intensification.
- These will increase at accelerating rate in coming decades.
- Will also be human induced climate change.
- Hence range shifts for species are likely to accelerate.
- These changes will challenge us to retain sustainable forests.
- Goal of this section is to summarize state of knowledge on global change relative to invasives in the context of forest sustainability and offer perspectives on new approaches for understanding and managing forests under global change.

What is happening? (scientific context)

- Life history filter gives basis for predicting ecological response under gc
- Rates of climate change sufficient to drive major changes
- Land use and climate interact to favor invasives
- Major disassembly and rearrangement of communities is expected
- Community richness theory predicts where there will be open niches for invasives
- Need to develop new criteria for setting biodiversity objectives.
- Radical management is needed.

- Climate change will open niche spaces. What species to promote, where niche space decreases, what do we do?
- Special opportunity to manage forests under cc because we already manipulate forests. Also, longer time horizon in forests due to slow dynamics.
- Climate change will make restoration of presettlement conditions obsolete. Need to use knowledge of past dynamics as basis for engineering new systems.
- Engineering presumes greater knowledge of ecosystems than we now have. So adaptive mgt needed.
- Climate change will drive disturbance.
- Vulnerability
- Case study:
Juniper?

What should management objectives be?

What is invasive under this context?

Need for new definitions

What is meant by sustainable forestry under climate change?

Give standard definition of sustainable

Forestry to meet the needs of the present without compromising the needs of future generations.

Soil, air, water

Biodiversity

Economic output

Recreation and aesthetics

How this needs to be modified under GC

How do we set biodiversity and other management goals for ecosystems that are changing?

Given that, do we need to redefine what is an invasive?

And that we cannot use presettlement conditions as benchmark, how do we set biodiversity goals?

How do we specify the ecosystem properties that are desired (ecological goods and services, economic outputs, etc), beyond the specific species that may be in a community?

How do we weigh alternative future scenarios in light of the social, economic, and material values society assigns to various species assemblages.

What strategies will achieve these objectives?

- Need to manage forests based on first principles, using past dynamics and conditions as a context, but not as something that can be reproduced.
- Natural model to guide management: Sustain species composition, biological productivity, disturbance.
- Because we have an infrastructure for forest management in place, use forest management to gradually adapt forests to change
- Work with slow dynamics of forests and forest inertia to change to allow manipulation to change.
- Beware of disturbance in legacy forests that will catastrophic, rapid change.
- Wholesale re-engineering when needed as a preemptive strike against invasives.
- Need to measure and monitor the state of the ecosystem (including vulnerability and goods and services) relative to our management objectives for the system to make choices among alternative management options (or to take no action!).
- Use broadscale biodiversity theory to predict where niches will open, where they will be reduced, and use this as a basis for regional scale management planning.

What do we need to learn?

No conceptual framework exists to help scientists, managers, and policy makers think about the interactions between climate change and invasive species in a management context. How will climate change and invasive species interact with each other? How will climate change alter the rates, pathways, patterns and impacts of invasive species?

Need predictive approaches to assess how patterns, processes, and impacts of species invasions will change with climate. This includes a need for qualitative and quantitative descriptions of when and how climate change will affect species invasions and impacts? Is it 20, 40, or 60 years out? Such information will be critical to demonstrate this apparently “long term” issue will have impacts over time scales that are relevant to business cycles, development of government policies, and public values.

Models predicting species responses to climate change are based on limited information about the autecology of species, particularly dispersal rates. This makes it difficult to parameterize models and reduces their accuracy. Better and more realistic data on dispersal patterns will be essential to improve the models. Given the limited resources for such work, though, can we prioritize which species we need to study most?

Need ways to set priorities among invasive species for taking action (e.g., related to impact, feasibility, etc.). Will these prioritization criteria be different from those used in the absence of climate considerations?

Need new management approaches that address the specific issues that will arise from dealing with invasive species under conditions of a changing climate. For example, would it make sense under some conditions to protect an ecological system from invasion so that it could serve as a reservoir for the restoration elsewhere? Would it be possible to engineer an ecological system (a specific suite of species) at a place as a “preemptive strike” against undesired future invasions.

How will vulnerability to invasives change?

What new pathways of introduction might occur?

Synthesis

- a) Develop a conceptual framework for understanding the interactions between climate change and species invasions. This framework should include consideration of ecological systems at multiple levels from species, to communities, to ecosystems and landscapes and the interactions among these levels under climate change.
- b) Develop ways to set biodiversity management objectives for changing ecosystems. These should include adaptive management approaches that focus on a wide range of management approaches from preserving current communities to reengineering new communities.
- c) Develop various modeling, forecasting, and scenario based approaches for exploring how invasion patterns, processes, and impacts will change be altered by climate change – and use these to identify systems at greatest risk; evaluate various management possibilities; develop institutional response capabilities. These models should link local ecosystem dynamics and continental scale biogeography issues.
- d) Develop new management approaches and methods to preempt, minimize, or reverse the worst impacts of climate change on species invasions.

Ecosystem and Landscape Concepts

(Bartuska, Davis, Rahel, Hansen, Aplet, Wainger)

Premises

- Invasive species population processes are occurring in and influenced by the ecosystems and landscapes they exist within.
- Land managers typically deal with multiple species and multiple objectives across large and or complex landscapes.
- Hence, invasive species issues need to integrate population processes into the ecosystem/landscape context and into multiple objective management.
- Great progress has been made in understanding population dynamics in a spatial context and in managing ecosystems across the hierarchy of spatial scales and for multiple objectives. Rapid progress can be made in invasive species science by integrating invasive science into spatially explicit population models and into current ecosystem management approaches.
- Population processes occur over space and time and integration of both is necessary. Invading populations may undergo a phase of inertia and then later explode. The temporal dynamics interact with spatial patterns.

Approach

- Invasive species population processes will be most effective if dealt with in a spatially explicit context and in an ecosystem management context.
- Metapopulation theory provides an excellent context for evaluating these issues. The basic analytic is to use spatially explicit population simulation models to simulate the dynamics of invasive species across real landscapes and to consider the dynamics of invasives under alternative management scenarios. These models could consider how individual invasives interact with the landscape, how do invasive species interact with native species and other invasives. Can assess risk spatially; produce risk maps based on resistance or lack of resistance to spread.
- Integrating spatially explicit (e.g., metapopulation) models with epidemiological models, reaction/diffusion processes makes sense.
- These models can also be used for risk assessment and can be applied at global scales.

How are invasives different? Consideration of these differences may necessitate modifying the spatially explicit (including but not limited to metapopulation) and other models that have been used for endangered species and other issues.

“Manage FOR extinctions”

Invasives are often not habitat limited, like most other species, thus a supply side and dispersal model is more relevant.

Invasives also are not coevolved with predators, competitors, etc and thus may expand rapidly. Invasive populations may be replenished by new immigrants many times, hence biogeography theory is needed.

The goal of invasives management is to “manage for extinction”, so new thinking might help here. Even military war strategies might be relevant.

How can sustainable forests be managed for invasives? This is the heart of where new work is needed because not much good thinking has been done here.

Are fundamentally different approaches needed for a natural system that has a few invaders vs. a system that is already highly altered and is mostly invasives?

Some difficult invaders are host specific, hence monoculture forestry may not be a good strategy under invasions (like corn fields).

- Managing to limit risk of new invasion
 - Managing to impede spread
 - Managing to limit suitable habitat for spread
- (landscape structure – distribution of patches and corridors; disturbance)

4. PRIORITY SCIENCE NEEDS

In order to apply some discipline to the identification of high priority science needs, the group developed a set of prioritization criteria in plenary.

Priority-Setting Criteria

Minimum criteria for each item:

- Feasible.
- Major advance.
- High impact (significantly reduces problems/costs/impacts of invasive species)
- Must have near term benefit (3-5 years).
- In support of the goals of sustainable forestry (meet needs of present without compromising ability of future generations to meet their needs; reforestation, economics, conservation of soil/water/air, biodiversity, wildlife/aquatic habitat, recreation/aesthetics).
- Explicitly identifies contribution/linkage to biodiversity conservation, economic feasibility, AND social acceptance. (e.g., advances in technology have to be socially acceptable)

For evaluating the portfolio of research needs identified by working group:

- Taking an ecosystem approach over a species by species approach.
- Takes a systems approach to policy.
- Easily conveyed message.
- Engages communities.
- Contributes to RA

SHORT LIST OF PRIORITY SCIENCE NEEDS

At the end of the meeting in a separate exercise, each working group member identified 1 to 3 priority science needs they believed met the group's overall prioritization criteria. These were compiled into the list shown in Appendix 4, and then each member voted for 5 items on the list. Votes were tabulated. Then, duplicative items on the list were combined and total votes tallied. The text below summarizes the results and presents them in the form of a Request for Proposals. This material was submitted to NCSSF to help inform the Commission's development of its 2004 RFP.

Three topics emerged as clear, near-term priorities: the policy framework, detection technologies, and forest management practices (items #1-3 below). The working group also gave high scores to decision support methods and related aspects of impact assessment, data development, and information dissemination and curation (items #4-8 below). A final area identified as a high priority by four members (25%) of the working group was climate change. The summary does not include items receiving fewer than 4 votes.

Clear Near-Term Priorities

1. Assess Policy Framework and Identify Promising Models

[combines items 10, 12, 13 – 16 votes]

Assess the current policy framework that addresses invasive species in sustainable forestry including;

- Key entities and organizations in the public and private sectors and relationships among them; and
- Important laws, regulations, programs, and voluntary protocols and approaches.

The assessment should identify and prioritize gaps in the existing policy framework. It also should explicitly consider issues of scale, for example, the spatial or institutional scales at which organizations or laws operate and whether these match the scales at which invasive species problems originate or should be addressed.

Based on this assessment, identify promising policy tools (e.g., incentives, regulations) for NIPLOS and industrial forest owners that would address prevention, eradication and management to reduce the damage caused by invasives species to forest ecosystems. Particular focus should be placed on identifying policy approaches and tools that can be successfully applied across landscapes and multiple ownerships and organizations.

2. Improve Early Detection

[combines items 14, 15, 16, 19 – 13 votes]

Assess the feasibility of developing new advanced technologies – such as monoclonal antibodies, microprobes, DNA probes, PCR, pheromone traps, pollen identification, etc. – as well as other promising new methods for detecting and identifying invasive species. Evaluate the potential for implementing these approaches to detect and reduce the entry of potentially harmful invasive species into the U.S. and/or their establishment and spread within the U.S. (including interstate transit). Evaluate also whether and how such approaches might be effectively deployed across forested landscapes, including through existing monitoring systems (e.g., for air quality, forest inventory, etc.).

For each promising technology, identify the research and development steps that would be required, and the estimated costs, to develop and pilot practical tools for applying the technology in real-world situations. Identify also the key organizations and individuals that would need to be involved in

developing such applications, as well as any barriers or opportunities that would slow or speed widespread adoption and use.

3. Understand How Forest Management Practices Affect Species Invasions and Impacts **[combines items 1, 2, 4, 5 – 12 votes]**

Synthesize existing information on whether and how current forest management practices and natural disturbances affect the *frequency, spatial distribution, and impacts* of invasions of forest ecosystems by various types of organisms (plants, insects, plant and animal diseases, wildlife, aquatic plants and animals). The kinds of management practices covered should include (but should not be limited to) road building, logging, thinning, fire, road use, hunting, and various silviculture approaches.

Identify where existing knowledge suggests certain management practices could reduce the risk of new invasions or the spread and/or impacts of established invaders. Consider whether and how such practices could be applied at large spatial scales to minimize the effects of invasive species on sustainable forestry, including factors that might support or impede broad adoption across ownerships. Identify also where current knowledge is inadequate to evaluate the effects of forest management practices on species invasions and where additional research therefore is needed.

[Decision support is broken into a general section 4, as well as subsections (a) through (d) that cover linked issues.]

4. Decision Support **[combines 23, 25, 27 – 10 votes]**

Review existing decision-support approaches for making choices about the prevention, detection, eradication and management of invasive species in sustainable forestry. The review scope should include approaches for predicting and evaluating biological, ecological, economic, educational, and social aspects of invasive species. The review should include, but not be limited to:

- predictive frameworks for evaluating the ecological and economic risks of potential invaders;
- spatial approaches for targeting monitoring and control efforts based on relative risk;
- benefit/cost methods for designing economically efficient management programs, for weighing invasive species problems against other management concerns, and for evaluating the aggregate costs or benefits of continuing commercial trade in species that can cause ecological or economic harm.

Particular attention should be paid to decision models based on an ecosystem perspective, that is, models which formulate prevention and management choices based on the potential of invasive species to alter ecosystem properties and which address invasive species issues across ownerships and at large spatial scales.

Based on this review:

- Evaluate the relative rigor, transparency, and consistency of current decision-making about the prevention, detection, eradication and management of invasive species in sustainable forestry.
- Identify the areas of greatest need as well as the most effective models presently in use and their potential applicability to these gaps.
- Specify where additional research and development are needed to improve decision-making about invasive species in sustainable forestry.

4a. Information Sharing and Communication **[combines 22, 28 – 5 votes]**

Identify methods to improve communication and sharing of information among decision-makers and affected stakeholders that would help reduce the harmful impacts of invasive species in

sustainable forestry. Such information should include ways to identify risks and to evaluate possible response options.

Assess the implications of current AND emerging governance and decision-making structures and processes (i.e., who makes key decisions and how) for the design of distributed web-based information systems. Evaluate the potential to develop a system that makes available, links, and enables rigorous and informed analysis of:

- data on current and potential invasive species as well as their characteristics and impacts;
- risk maps and other decision-support tools; and
- information on best management practices, technical tools, and case studies.

Identify next steps that would be required to put an effective web-based information system in place, including identification of components presently in place, costs, and key organizations and entities that should be involved.

4b. Data Development and Curation
[combines 24, 26 – 5 votes]

Develop a national database of all known non-native forest diseases, insects, and plants that are established in the continental US. This database should list species, host range, current geographic range, degree of invasiveness, and economic and ecological impacts (including impacts on ecosystem structure). The database should be linked to a national monitoring system that detects new species invasions and provides analyses of trends in species invasions and impacts.

4c. Using Economic Impacts to Evaluate Policy and Management Choices
[combines 30, 31 – 3 votes]

Develop case studies that quantify the aggregate economic costs and benefits for select invasive species during Stages IV-VI. Use these analyses to assess the implications of different management choices with the goal of identifying best practices for the timing and kinds of management actions during the progression of a species invasion.

4d. Understand Impacts on Ecosystem Functions and Services
[17 – 4 votes]

Develop a system for classifying invasive species that affect sustainable forestry according to their relative effects on ecosystem functions and/or services. Categorize past and present invaders according to these criteria and evaluate the potential use of such a system for evaluating and assigning risks to possible future invaders.

5. Climate Change
[combines 6, 7 – 4 votes]

Synthesize existing literature on the effects on the interactions between global change (e.g., climate, land use) and invasive species in sustainable forestry. From this synthesis, develop conceptual framework for addressing these interactions that:

- Evaluates what are reasonable objectives for ecosystem management under these changes;
- Considers how to enhance the resilience of forest ecosystems in the face of multiple change processes; and
- Assesses the feasibility of “engineering” new communities in locations undergoing dramatic change.

5. WORKSHOP OUTCOMES

Meeting findings were disseminated through the following mechanisms:

1. Top science priorities identified by the group were converted into draft language and submitted to the NCSSF to inform development of the organization's annual request for proposals. (June 2003)
2. Working group member Ann Bartuska briefed NCSSF Commission Members on the workshop results and next steps. (June 2003)
3. Proceedings from the workshop were posted on the NCSSF website. (February 2004)
4. A co-authored manuscript has been developed by the working group and presently is going through a round of revision prior to submission to a journal for publication. (Anticipated mid-2004)

APPENDIX 1

REVISED DAILY AGENDAS

DAY 1: Getting Ideas on the Table

Goals: Tap the collective knowledge and expertise of participants to identify the breadth and depth of issues for the working group's consideration. Build the group's shared knowledge.

9:00 – 10:30

Greetings & Introductions

Background on the NCSSF – Ann Bartuska
NCSSF goals and working definition of sustainability

Project objectives, process, and timeline – Liz Chornesky

Introduction of working group participants – Everyone

Plan and ground-rules for the week at NCEAS – Liz Chornesky

10:30 – 10:45

BREAK

10:45 – 11:30

Brainstorming Session

What key problems in sustainable forestry related to invasive species could be solved by scientific research, analysis, or synthesis or the translation of existing scientific knowledge into practical tools?

- Over a 5-10 year period?

- Over a period of greater than 10 years?

What other issues should the working group consider?

What is the most important thing that could be accomplished by this project?

11:30 – 12:00

Assemble Background Knowledge & Information

Instructions to teams

Teams start work

Pathogens – Kerry Britton & Jane Cummings-Carlson

Insect Pests – Bob Haack & Ann Bartuska

Weeds – Doria Gordon & Dick Mack

Aquatic Species & Wildlife – Frank Rahel & Ben Wigley

Climate change – Andy Hansen & Liz Chornesky

Spatial scale & decision support – Frank Davis & Kurt Gottschalk

Social & institutional context – Maggie Shannon & Jessica Eskow

Economic considerations – Lisa Wainger & Greg Aplet

12:00 – 1:00

LUNCH

1:00 – 1:30

Assemble Background Knowledge & Information

	Teams finish work
1:30 – 3:00	Team Presentations: Session #1
3:00 – 3:15	BREAK
3:15 – 5:00	Team Presentations: Session #2
	Wrap-up of Day; Discussion of Homework
5:00 – 6:30	BREAK
6:30 – 8:30	Group Dinner (TBD)

DAY 2: Identifying Key Thematic Areas

Goals: Finish assembling background information. Filter and organize information developed on Day 1 brainstorming and in background summaries. Reach consensus on a conceptual structure to guide the group's work. Start developing outlines for key themes.

8:30 – 9:30	Assemble Background Knowledge & Information
	Teams finish work on their own
	Working Group Members Finish Setting Up Connectivity
9:30 – 11:00	Assemble Background Information: Team Presentations
	~10-15 min. per group
	Each person considers emerging thematic areas
11:00 – 11:15	BREAK
11:15 – 12:30	Assemble Background Information: Finish Presentations
12:30 – 1:15	LUNCH NEARBY
1:15 – 2:00	Identify Key Thematic Areas
	Break into small working groups (4 people per group)
	Each working group identifies up to 5 (?) key thematic areas
2:00 – 3:00	Reach Consensus on Key Thematic Areas
	Report back of working groups
	Vote (if necessary)
3:00 – 3:15	BREAK
3:15 – 5:00	Develop Outlines for Key Thematic Areas
	<i>Form new small working groups</i>

Produce outlines
Identify key references & resources
Identify missing information & expertise

5:00 – 5:15 **Day's Wrap Up; Homework Assignment (complete outlines)**

DAY 3: Building Content

Goals: Develop and organize concepts and information for each thematic area. Identify cross-cutting issues, areas of overlap, and gaps.

8:30 – 10:00 **Small Working Groups Develop Draft Outlines**

Produce detailed outlines that spell out concepts and ideas
Identify key references & resources
Identify missing information & expertise
Review outline to consider relative priority of research needs that it identifies

10:00 – 11:30 **Review of Draft Outlines in Plenary**

For each outline, are any additions, changes, deletions needed?

In the combined review of all outlines:

- *Have new thematic areas or cross-cutting issues emerged?*
- *Does the framework developed on Day 2 still work?*

11:30 – 11:45 Break

11:45 – 12:30 **Prioritization Criteria**

Identify and come to agreement on criteria for setting priorities

12:30 – 1:45 **Working Lunch**

Small working groups apply prioritization criteria to draft outlines

1:45 – 2:30 **Review Priorities in Plenary and Make Writing Assignments**

2:30 – 5:00 **Writing Teams (1-3 person teams)**

Develop text for science and research areas identified as high priorities by the working group

5:00 – 5:30 **Wrap-up of Day**

Revisit journal options
Assign Homework

DAY 4: Final Content Development

Goals: Finish outlines and model development. Identify priority science needs. Start NCSSF RFP.

8:30 – 9:30

Hand out draft paper outline to group

Compile and sort proposed science priorities

9:30 – 11:00

Complete content development (3 or more working groups)

Finish filling outline on “Invasion Science” with particular attention to:

- *Identifying important gaps in information, analytical tools, technologies, or governance performance and*
- *Specifying how these might be met by science syntheses and assessments, new applications of existing tools and approaches, and/or original research*

Identify science needs that arise from an ecosystem perspective

Lay groundwork for NCSSF RFP

11:00 – 11:30

Report Back on Status and Needs from Working Groups

11:30 – 12:00

Next Steps and Timeline

APPENDIX 2

Full List of Key Thematic Areas Identified by Breakout Groups

GROUP 1

I. Background – Introduction and Assumptions

Science and Policy of Difference

Ownership – size related to policy response as well as to policy innovation

Policy

Spatial scales

Ecological scales

Social Problem – vectors of invasion are people

Social behaviors are driving the problem – thus, can it be changed?

Plus, can some processes like certification help to reshape public preferences? Changes in social behavior.

II. Key Topics For Paper

Science of Invasion

How do the different disciplines relate to this interdisciplinary question?

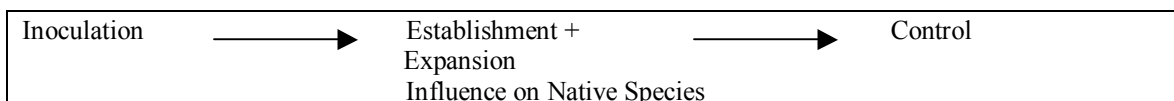
New categories for research – integrating biology and social science

Look at unifying themes across taxa

Taxonomic issues

Pathways – integrated vector management

Research on organisms



Social Sciences

Biological Sciences

Policy Sciences
Economics

Informatics

Data management and flow issue

Foundation of information

Access to information

Need: rapid exchange of information - need organizational capacity – network, clearinghouses --

CDC model + NRCS + FEMA

GROUP 2

- 1) Environmental Economic Assessment:
 - a. Develop Information that influences the public and leads to policy change
 - b. Integrate the ecological and economic approaches
- 2a) Integrate Invasive Concerns into Existing Management protocols (short-term goal)
- 2b) Improve Existing Decision Support tools by incorporating economic and social considerations and by using rigorous risk assessment techniques (long term goal)
 - Systematically Prioritize Existing Threats and Set Management Priorities
 - Develop Improved risk indicators
- 3) Develop research directed at Prevention and Future Risk Assessment:
 - Framework:
Attributes X Environ Context X Circumstances (timing, location, etc.)
 - Categorize invaders in terms of suites of attributes, environmental conditions
 - Categorize whole taxa that represent high risk rather than individual species
- 4) Address Global Change Issues
 - Explore rates of invasion under predicted broad-scale change (from climate change, land use change, etc.) and interactions of these factors
 - How will future invasions feed back to influence climate, land use change etc.
 - Economic globalization changes
- 5) Research how human behavior enhances risks of invasion and how that behavior might be changed through education or other policies

GROUP 3

1. Multi-scale (ownership, strategies, impacts)
2. Impacts of invaders on the ecological, social, and economic goals of sustainable forestry and their integration (research and institutional approaches).
3. Data and information technology / analysis
4. Interdisciplinary synthesis / research for advancing effective policy and identifying best models
5. Evaluating impacts of current communication and implications for developing more effective approaches (changes in social behavior)
6. New tools (identification, monitoring, detection) for known needs in forest systems
7. Understanding of invasion processes (ecosystem level, management impacts, repeated introductions)

GROUP 4

1. Improve detection methodology
Implement available science, linking morphological with molecular techniques
And remote sensing

2. Describe ecological risks in a cost effective way
Moving from “bug of the month” to an ecosystem approach
Biological/ecological/climate/diversity type issues
3. Economic/risk analysis
Prove harm: costs of control; eradication; regulation; incentives (NIPL)
Ownership vs. options
4. What social and organizational changes are needed to achieve our desired goals?
5. Develop a cohesive educational strategy, re invasives and sustainable forestry
Aim for activists; stakeholders; youth audiences
Need solid data on ecological and economic costs
And constructive solutions

APPENDIX 3

Full List of Priority Science Needs Identified by Working Group

[Number in 2nd column represents votes by members of the working group, 15 of 16 members voted, one abstained.]

Synthesis and Surveys = SS

Research and Assessments = RA

Tool Development = TD

Communication and Outreach = (CO)

The following were within Outline text and are included for completeness: (O)

Forest Management Practices	
1. Assessment of current forest management practices as vectors or pathways of invasive species. Use to develop BMP's for sustainable forestry that minimize threat of invasion. (SS)	11111
2. Synthesis of existing data to develop BMPs for forest managers to 1) reduce the risk of invasion or spread; and 2) manage the invaders present on their properties to minimize impact.ts and spread. (SS)	11111
Causes	
3. The assumption is that recreational users of forested ecosystems would change their behavior if they understood the threat of invasive species. Is this a correct assumption? What is necessary to change those behaviors (e.g. incentives?). (SS)	
4. Synthesize interactions between disturbance (natural and human-induced including forest management activities) and invasion by classes of organisms (plants, insects, diseases, animals, forested aquatic) (Stages I, III-VI) <i>Synthesis</i> (SS)	1
5. Review the relationships between species invasions and the kinds of disturbances resulting from forest management (road building, logging, thinning, fire, road use, etc.) (SS)	1
Climate/global change	
6. Develop conceptual framework for addressing the interactions between global change and species invasions in sustainable forestry (synthesis of existing literature). (SS)	11
7. Creative thinking/analysis on sustainable forest management and invasive species under climate and land use change (SS)	11
<ul style="list-style-type: none"> • Evaluate what are reasonable objectives under this change • Consider how to take advantage of inertia to keep them resilient under change • Brainstorm the feasibility of engineering new communities in locations undergoing dramatic change. 	

Policy & Institutional Issues	
8. Assessment and Evaluation of certification systems for adequacy in addressing threat of invasive species at landscape scale. <i>Assessments</i> (RA)	
9. Comparative analysis of “health/human disease” vs “plant/animal-invasives” policy systems. Why can CDC respond quickly to new disease threats, including quarantines, and APHIS (others) are so limited in their response options? (RA)	11
10. Analysis of policy system related to addressing invasive species with a focus on understanding the actors, organizational contexts, legal/policy frameworks. Purpose is to understand how the policy system is currently working, relationships among actors, and evaluation of gaps and needs to address new capacities. Of particular interest is the role of different actors at different scales, how they interact in and across scales, and how their basic policy role is related to the scale of the problem. (RA)	11111 11
11. Identify gaps in institutions that monitor and interact with small private landowners who control the bulk of (?) high biodiversity lands. (RA)	
12. Develop policy tools (e.g., incentives, regulations) for sustainable forestry for NIPLOS and industrial forest owners that would address prevention, eradication and management to reduce the damage caused by invasives to forest ecosystems. (TD)	111111 1
13. New policy tool to work on SFM issues across landscapes and organizations. (TD)	11
Prevention & Early Intervention	
14. Assess the feasibility of developing advanced technology monitoring systems for early detection (pollen, monoclonal antibodies, microprobes, DNA probes, PCR, pheromone traps, etc.) <i>Assessments</i> (Stages II-IV) (RA)	111
15. Same as above with the addition of identifying how those technologies should be effectively deployed across forested landscapes (RA)	1111
16. Improvement in the tools and practice of early detection and rapid response to newly arrived immigrants. (RA)	1111
17. Identify and quantify significant changes in ecosystem functions and/or services due to invasives and work towards classifying invasives by types or magnitudes of effects. (RA)	1111
18. Review current and near-future technologies that can be used to identify disease organisms, insects, and plants. (TD)	
19. Develop new technologies for early detection that be deployed through existing monitoring systems (air quality, forest inventory, etc) (TD)	11

20. Need information about what triggers movement into growth phase. Research and Assessments(O)	
21. Development of alternatives to untreated wood or packing materials (treatment alternatives or non-wood substitutions. Tools Development (O)	
Informatics & Decision-making & Communication	
22. Assess implications of structure of current AND emerging governance and decision-making processes for the design of distributed web-based information systems that make available, link, and enable rigorous/informed analysis of data and information on BMPs, technical tools, case studies, and pest occurrence/characteristics, and risk maps, etc. (assessment based on current knowledge and expert opinion) (Chornesky) (RA)	1111
23. Development of flexible prediction framework for potentially invasive species (RA)	111
24. Develop a database of all known non-native forest diseases, insects, and plants that are known to be established in the continental US, listing species, host range, current geographic range, and degree of invasiveness. (TD)	11
25. Review Decision Support Systems that are available to evaluate biological, economic, educational, and social aspects of invasive species and sustainable forestry. (TD)	11
26. Develop a national monitoring structure to detect and analyze trends in species invasions and their impacts on ecosystem structure (TD)	111
27. Decision models, based on an ecosystem perspective, to detect when and how to take action to prevent and/or manage invasive species. (TD)	111
28. Identify methods to improve information sharing to facilitate risk identification and evaluate appropriate response options (RA)	1
29. Develop a set of generic processes for volunteer efforts to detect, report, and manage invasive species (National Clearinghouse?) (Stages III-VI) (CO)	
Impacts	
30. Develop a case study of using aggregate costs and benefits for an invasive species economic analysis (Stages IV-VI) (TD)	111
31. Develop cost/benefit analyses for a suite of species invasive in forests that are commercially available to identify whether management costs justify continued propagule pressure (TD)	11