Coaster Brook Trout (*Salvelinus fontinalis*)
12-Month Finding

Decision Document

SEPTEMBER 2009

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Decision Analysis for Evaluation of Coaster Brook Trout for Federal Listing Pursuant to the Endangered Species Act of 1973

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Purpose

The purpose of this document is to describe and explain the various decisions that were made in reaching our May 19, 2009 finding on the petition to list the coaster brook trout (*Salvelinus fontinalis*) as endangered under the ESA. This document describes our biological considerations, policy interpretations, and legal precedents that we used in arriving at this finding. This document further outlines our decision making process, including our objectives, alternatives, and sources of uncertainty.

Background

The U.S. Fish and Wildlife Service (Service) was petitioned to list the coaster brook trout pursuant to the Endangered Species Act of 1973, as amended (ESA) in 2006. In March 2008, a positive 90-day finding was published indicating that the petition and the information contained within Service's files suggest that the petitioned action warrants further evaluation. With this finding, the Service then must determine whether coaster brook trout warrants Federal protection under the ESA.

Listing decisions are made by the Service as a whole, with the Director as the final decision making authority. The status assessment and all associated analyses are performed by either the field or regional office. Based on that analysis, the status assessment team then makes a recommendation on the listing decision to the Regional Director. Once approved by the Regional Director, the recommendation is then forwarded on to the Washington Office for further analysis, formatting, and editing. Once this process is complete, the Director then signs the document, making it a final agency decision. The decision is then made public via publication in the Federal Register.

Legal Context - The Endangered Species Act of 1973 defines endangered as "any species that is in danger of extinction," and threatened as "any species likely to become endangered in the foreseeable future." The term species is broadly defined as "any species, subspecies, or distinction population segment of a vertebrate species…" A distinct population segment (DPS) is defined in policy as a population segment that is discrete from other individuals of the species, and significant to the taxon. Regardless of taxonomic status, in practice, listed entities are afforded the same protections. By regulation, threatened entities are afforded the same protection

as endangered unless otherwise noted via a section 4(d) rule. In determining whether an entity is entitled to the protection of the ESA, the Service must first determine whether the entity qualifies as a "species," and if so, whether it is endangered or threatened as defined by the ESA.

Biological Context – The historical range of native brook trout extends along Hudson Bay across the Provinces of Nova Scotia, Quebec, and Ontario in Canada, and from eastern Iowa through Wisconsin and the Great Lakes drainage, through the New England states south to Cape Cod, the Hudson River, Connecticut River and other large New England rivers and in coldwater streams of the Appalachian Mountains south to Georgia in the U.S. Brook trout, like most other salmonids[1] exhibits multiple life history forms: fluvial (stream resident), adfluvial (freshwater lake migrant), lacustrine (lake-dwelling resident), and anadromous (salt-water migrant). The listing petition addressed a specific life form of brook trout known as coasters. The coaster brook trout is defined as "a brook trout that spends all or a portion of its lifecycle in the Great Lakes." Coasters represent the adfluvial and lacustrine life forms of brook trout that occupy the nearshore waters of the Great Lakes. The adfluvial form migrates from the lake into tributaries for spawning and the lacustrine life form completes its entire life cycle within the lake (Huckins et al. 2008). Coasters are not, therefore, a species or subspecies, or even a population unit in the traditional sense, but rather they are two types of life history forms of brook trout that occur within the Great Lakes.

Coasters have been long recognized as unique life forms by local, scientific, and regulatory communities. In "Fishes of Wisconsin," Becker (1983) described coasters as brook trout that spend part of their life in the Great Lakes, but annals are replete with descriptions of fishermen catching lake-dwelling brook trout of record sizes, weights, and longevities long before then (Roosevelt 1884, Behnke 1994). Coasters were a prized game fish in the late 1800s and early 1900s, and the world's largest brook captured was a coaster. Historically, coasters occupied 116+ populations distributed in Lakes Superior, Michigan and Huron (Bailey and Smith 1981, Dehring and Krueger 1985, Enterline 2000, MIDNR 2008). Today, coasters persist in 16 populations in Lake Superior; 4 of these occur within U.S. waters. Because of drastic declines in numbers and distribution, an international, multi-agency effort began formally in 1993 with the establishment of a brook trout sub-committee of the Lake Superior Technical Committee (Great Lakes Fishery Commission). The sub-committee led development of a brook trout rehabilitation plan for Lake Superior. The goal of the plan is to maintain widely distributed, self-sustaining populations of brook trout throughout their original habitats in Lake Superior (Newman et al. 2003).

Decision Problem - In simplest terms, the task before us is to decide whether the coaster brook trout warrants protection under the ESA. We were petitioned to list the coaster brook trout throughout its native range in the coterminous U.S., and if not warranted, then to list the Salmon Trout River population of coaster brook trout.

[1] Salmonids, as a group, have a complex life history. There are three broad classifications of life history strategies: potamodromy, oceanodromy, and diadromy. Within each of these strategies, there are further divisions (e.g., anadromous, catadromous, fluvial, lacustrine) referred to as life history forms. Some species exhibit one life history form, but many express multiple forms. *S. fontinalis* expresses potamodromy and diadromy life history strategies although in the majority of its range, it is potamodromous. Within the potamodromous life history strategy, brook trout can be either fluvial (stream-resident), adfluvial (freshwater lake migrant), or lacustrine (lake-resident). See Appendix 1 for further discussion.

The first step in this decision is determining whether the coaster brook trout is a listable entity pursuant to the ESA. There are three listable entities under the ESA: species, subspecies, and DPS. Coaster brook trout is not a species or subspecies but rather it is a life history form of brook trout that occurs within the Upper Great Lakes. We were petitioned to list the coaster brook trout throughout its historical range in the U.S., or if not warranted, then to list the coaster brook trout within the Salmon Trout River. For a 12-month finding, we are not limited to the petitioned entity. We could look solely at the petitioned entity (coaster brook trout) or we may elect to look at it more broadly (e.g., Eastern brook trout). Given this and the taxonomic status of coasters, there are two possible listable entities: species (eastern brook trout) and a DPS (a subset of the eastern brook trout range that includes coasters). Very early on in our decision process, however, we determined a species level evaluation would not be prudent given the wide range, the great number of seemingly viable populations distributed across its range, and the time constraints associated with a 12-month review. Thus, we focused on the DPS as our listable entity.

Our 1996 Policy on Distinct Population Segments (61 FR 4722: February 7, 1996) states that an admissible distinct population segment is one that is discrete and significant. A population segment may be considered discrete if it satisfies either one of the following conditions. One, it is *markedly separate* from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Two, it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the ESA. The purpose of the discrete standard is to require that an entity be adequately defined and described. The standard adopted does not require absolute separation of a DPS from other members of its species as this can rarely be demonstrated in nature for any population of organisms. The standard adopted allows for some limited interchange among population segments considered to be discrete, so that loss of an interstitial population could well have consequences for gene flow and demographic stability of a species as a whole.

If we determine that a population segment is discrete, we then consider its biological and ecological significance to the larger taxon to which it belongs. This consideration may include, but is not limited to: (1) evidence of the persistence of the discrete population segment in an ecological setting that is unique for the taxon; (2) evidence that loss of the population segment would result in a significant gap in the range of the taxon; (3) evidence that the population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range; and (4) evidence that the discrete population segment differs markedly in its genetic characteristics from other populations of the species. The purpose of the significance standard is to ensure only important elements of a taxon's genetic and natural diversity are protected.

Owing to these requirements, our decision problem is multi-faceted. First, we need to determine whether there are any admissible DPSs of coaster brook trout. If one or more DPSs are identified, we then need to conclude our 12-month finding and determine whether such DPSs are endangered or threatened[2]. Lastly, if threatened or endangered, we need to select a single or an array of DPSs

[2] There are three possible conclusions to a 12-month finding: (1) warranted: the species warrants listing; begins the process of adding the species to the list of threatened and endangered species; (2) warranted, but precluded: the

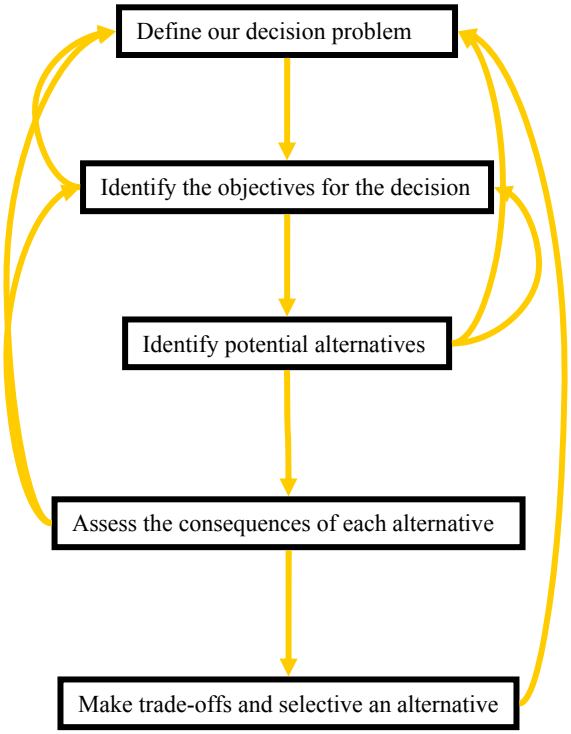
to propose for Federal candidate status[3]. If at any step, we determine that the set of criteria cannot be met, we must conclude "not warranted."

The ultimate decision maker is the Director of the U.S. Fish and Wildlife Service (Service), but for our purposes, the proximate decision makers are the Region 3 Ecological Services managers: the Chief of Endangered Species and Assistant Regional Director of Ecological Services.

Decision Structure

This is a multi-objective, hierarchical (linked), non-iterative decision problem. In structuring our decision, we followed a traditional structured decision making process: defined the decision problem, articulated the decision makers' problem-specific objectives, identified possible alternatives to choose among, analyzed the consequences of each alternative relative to the stated objectives, investigated implications of uncertainty, made trade-offs among objectives, and selected an alternative (Figure 1).

Figure 1: The Decision Structure for the 12-month finding for the petition to list the coaster brook trout.



species warrants listing, but that listing is precluded by other higher priority listing actions; species becomes a candidate for listing; (3) not warranted: the species does not warrant listing at this time; ends the listing process.

[3] We prioritize species for potential listing according to their Listing Priority Number (LPN), which is based on the magnitude and immediacy of threats along with taxonomic status (e.g., species, subspecies). Under our current listing prioritization process, the highest possible LPN for a DPS is 3. This makes other listing actions with LPNs of 1 and 2 as higher priorities. Based on current funding and staffing levels, we are only able to process only listing actions with LPNs of 1 or 2 at this time. Thus, if we come to a 'warranted' determination, it would necessarily be 'precluded' due to our other higher priority listing actions.

Decision Problem

In simplest terms, the task before us is to decide whether the coaster brook trout warrants protection under the ESA. More specifically, we must determine whether any DPSs of coaster brook trout are endangered or threatened, and if yes, to select a single DPS or an array of DPSs to propose for Federal candidate status.

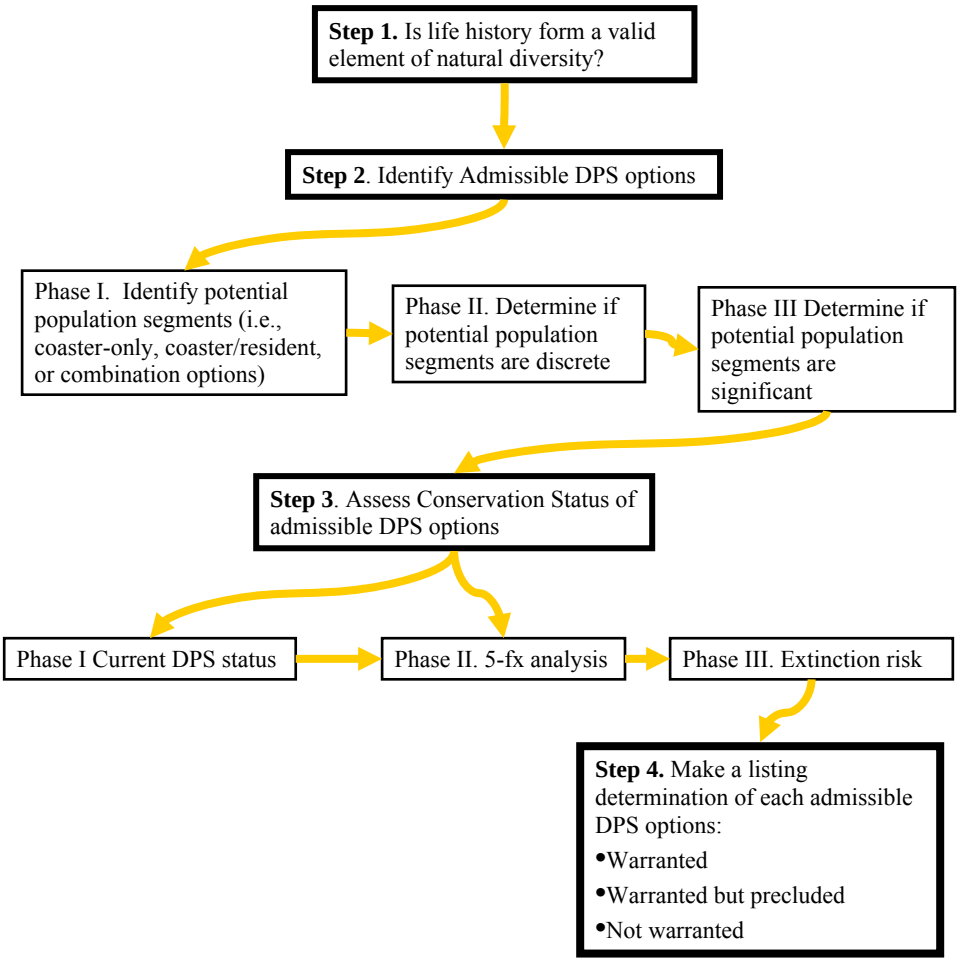
In most listing decisions, the listable entity is typically quite straight-forward albeit there could be many. This decision is more nuanced as the petitioned entity is neither a species nor subspecies. To be responsive to the petition, there are two possible DPS options, with multiple alternatives under each (the description of the DPS options and alternatives are described in the Alternatives section). Ideally, we would identify and analyze all potential admissible DPS alternatives, and choose a single or subset among them based on how well they meet our objectives. Given the 12-month timeframe and the number of potential DPS alternatives to evaluate, however, this is not a practical approach. Instead, we developed a nested hierarchical analytical approach. The hierarchy first entailed choosing between the two broad DPS options, and then analyzing the alternatives nested within the selected DPS option. If we determined that no alternative under the chosen DPS option warranted candidate status, we would circle back and evaluate the alternatives under the other DPS option.

Our decision involves a 4-step process with decisions, analyses, and feedback loops nested within in each step (Figure 2). As a DPS is the only potential listable entity, our decision process is as follows:

> Step 1- determine whether a life history form is an element of diversity that is intended to be conserved by the ESA via a DPS. The answer to this question helps us define the entity we will evaluate and identify the DPS options.
>
> Step 2 - determine whether there are any admissible DPS units. This determination entails a 3-phase analysis: I) identifying potential population segments, II) determining whether any population segments are discrete from other sympatric brook trout population segments, and III) assessing whether any discrete population segments are significant to the taxon.
>
> Step 3 - if one or more population segment is discrete and significant (i.e., admissible DPSs), assess the conservation status of the admissible DPS(s). This step involves threat analyses and extinction risk assessments of the admissible DPSs, and if applicable, at multiple scales within the DPSs.
>
> Step 4 - apply the DPS policy to the risk estimates calculated in step 3. Specifically, we are determining whether the Federal action (i.e., elevation to candidate status) is "warranted," "warranted, but precluded," or "not warranted."[4] If multiple admissible DPSs warrant elevation to candidate status, we must select one or an array of DPS options to elevate. If there are none, then we may either loop back to expand the scope of our analysis beyond the petitioned entity or publish a "not warranted" finding.

[4] There are three possible conclusions to a 12-month finding (see footnote 2 above).

Figure 2: Analytical Process for the coaster brook trout petition



Objectives

In identifying the objectives for this decision, we consulted the Chief of Endangered Species, T.J. Miller. His objectives were important to the decision as objectives for listing program should be consistent among listing decisions within the Region. Although there will be variation among species' situations, we believe a set of objectives will be consistent to all listing decisions, and decisions of the same nature (species, subspecies, or DPS) should be the same. The coaster brook trout decision involves the DPS process, so the objectives for this decision are:

(1) Fully meet the intent of the ESA in applying the DPS policy - As stated in the DPS policy, the U.S. Fish and Wildlife Service and NOAA-Fisheries Service believe the ESA is intended to support the interrelated goals of maintaining natural systems and biodiversity and conserving genetic resources over a representative portion of their historical occurrence. Thus, this objective aims to ensure that the genetic and natural biodiversity of brook trout will be conserved throughout its natural range.

(2) Maximize conservation potential for the listable entity - If multiple DPS alternatives warrant candidate status, we want to select an alternative that provides the greatest potential to achieve recovery. Not unlike other imperiled species, recovery of coasters will require partner coordination and cooperation. Some DPS alternatives may be more biologically, politically, or logistically palatable and provide a better means to conserve and recover the species.

(3) Optimize recovery options - Similarly, if multiple DPS alternatives warrant candidate status, we would like to select the alternative that gives us the greatest flexibility in achieving recovery. For example, if one DPS option will make it more difficult to recover populations than another, but both are essentially equivalent in other aspects, we would choose the one that optimizes recovery.

(4) Minimize regulatory burden. Again, if presented with multiple DPS alternatives, we would like to minimize the burden upon the regulated entities (i.e., private citizens, state and federal agencies). That is, we want to apply the prohibitions only to those portions of the range that are in need of such protections.

(5) Meet 12-month time frame. This is a legal mandate, and hence, becomes an objective constraint. It must be met regardless of the alternative selected. As the likelihood of this time frame being met may differ among the various alternatives, it could be a discriminating objective.

Alternatives

Our alternatives are the set of potential admissible DPS units (Table1). In responding to the petition, we identified two broad DPS options, both of which focus on the petitioned entity—coaster brook trout:

Option 1- Coaster-only DPS: Evaluate coaster brook trout as a distinct entity throughout its historical range or in a portion of its range.

Option 2- All brook trout DPS: Evaluate all sympatric life forms of brook trout throughout the historical range of coaster brook trout or some portion of its range.

In nearly all other similar ESA salmonid listing decisions, the Services used Option 2, including all sympatric life forms with the petitioned entity in describing the DPS. Option 1 was used, however, most recently by NOAA-Fisheries in their listing of multiple steelhead (*Oncorhynchus mykiss*) DPSs on the west coast (71 FR 60, 15666-15680; 70 FR 216, 67130-67134). These DPSs were litigated and recently upheld in a district court (California State Grange v. NMFS, Modesto Irrigation District v. Gutierrez, (Cal. 2008)).

Our first decision (Step 1 of our Analytical process, Figure 2) was to determine whether life history form, in general, is an element of diversity intended to be conserved by the ESA. If the answer to this question is yes, we move onto selecting between the two broad categories of alternatives: Option 1 Coaster-only DPS alternatives and Option 2 Upper Great Lakes brook trout DPS alternatives. If the answer is no, then our decision is simplified, and we are left with only one DPS option. The decision before us becomes "Does the Upper Great Lakes brook trout population, or some segment of it, warrant protection pursuant to the ESA?"

In step 1 of our analysis, we concluded that life history form is an element of diversity intended to be conserved by the ESA (see Appendix 1 for our rationale), and hence, both Options 1 and 2 are valid approaches, and will be used to identify possible alternatives (Step 2 of our Analytical process, Figure 2).

Under both options there could be numerous ways to delineate possible DPS alternatives. Our analysis revealed that all practical alternatives under each of the two broad DPS options are similar; they share geographic boundaries and differ only in the life forms included (Table 1).

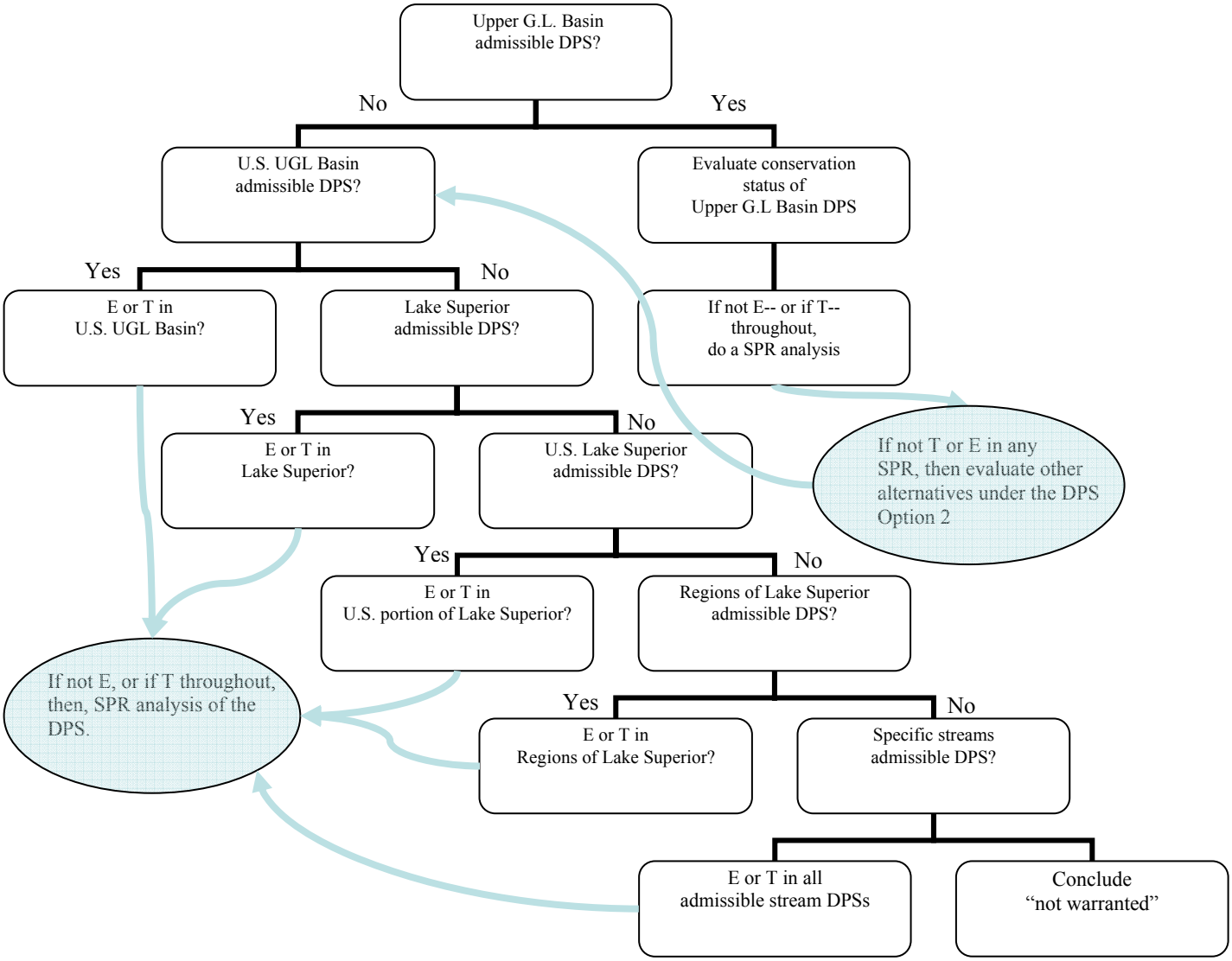
Table 1: A coaster-only population segment includes only the coaster life form (i.e., adfluvial and lacustrine forms) within a delineated area. A brook trout population segment encompasses all brook trout life history forms (i.e., fluvial, adfluvial, and lacustrine forms) occurring within a delineated area. Six DPS alternatives are identified under each broad DPS option.

Option 1: Coaster-Only DPS	**Option 2:All Brook Trout DPS**
Upper Great Lakes Basin	Upper Great Lakes Basin
U.S. Upper Great Lakes Basin	U.S. Upper Great Lakes Basin
Lake Superior Basin	Lake Superior Basin
U.S. Lake Superior Basin	U.S. Lake Superior Basin
Regions within Lake Superior Basin	Regions within Lake Superior Basin
Stream Populations within Lake Superior	Stream Populations within Lake Superior

In choosing between the two broad DPS options, we asked which of the two options would best meet our established objectives. Upon selecting an option, we then sequentially evaluated the alternatives under the selected option beginning with the broadest alternative (Figure 3). The purpose for beginning with the broadest population segment was twofold. First, it is standard FWS practice to assess whether the species is imperiled rangewide and then narrow the geographic scope until a listable entity is discovered or all reasonable options are exhausted.

Second, we believed that if the broadest population segment did not meet the DPS "significance" criterion, the smaller segments were unlikely to be significant as well. In other words, we evaluated the alternatives in order of their likelihood of being valid admissible DPS alternative. As explained previously, we believed this approach was prudent given our time constraints. If a "not warranted" finding was determined for all alternatives under the first selected DPS option, however, we would then circle back to DPS option 2 and evaluate its associated alternatives (Figure 3). Only after evaluating both sets of DPS alternatives, we are able to conclude "not warranted."

Figure 3: The hierarchy of alternatives within a DPS option. As consistently done, the analysis begins with the broadest alternative and sequentially work downward until all potential options are evaluated or a "warranted" finding is determined. Upper Great Lakes Basin includes all of Lake Superior (and its tributaries) and the northern portions of lakes Michigan and Huron (and the tributaries associated with these portions). SPR refers to a "Significant Portion of the Range" analysis. E and T refer to "endangered" and "threatened," respectively.



Although skeptical that such a comprehensive evaluation could be completed in the 12-month timeframe allotted, we believed this was the most practical approach to fully meet our mandate under the ESA. Some within the Service contended that we are required to evaluate the option(s) specifically requested in the petition. Although Option 1 arguably is responsive to the petition, we determined that it was prudent to analyze the other DPS options as well because: (1) we anticipate, in this situation, that the plaintiffs will submit a follow-up petition to list a specific population segment we have not yet considered, and (2) coasters are a Service trust resource (inter-jurisdictional fishery) and we want to ensure we complete a comprehensive review of its status. Thus, we agreed for conservation and resource reasons to commit to this comprehensive review, if needed.

To select a starting DPS option, we assessed how well each alternative would perform relative to the stated objectives. That is, we determined the consequences of selecting each of the two DPS options relative to our objectives.

Consequences

To select between our two broad options, we compared how well each is likely to perform relative to our five stated objectives. Our Team completed this exercise informally. We concluded that both DPS options would perform equally well for all objectives except for two, "minimize regulatory burden" and "meet 12-month timeframe." Regarding "regulatory burden," we believed that areas supporting resident only populations would be afforded the protections of the ESA under the all brook trout Option 2. Conversely, under the coaster-only Option 1, only those populations currently supporting the coaster life form would be afforded the protections of the ESA. In addition, we agreed that the time-constraints mandated by settlement agreement severely limit our ability to evaluate an option broader than the specific petitioned entity. Thus, we chose to begin with the coaster only DPS Option 1.

With this selected DPS option, we conducted the required DPS analysis. We sequentially evaluated the alternatives associated with the coaster-only DPS option (Step 2, Phases I and II, Figure 2), starting with the broadest alternative; the Upper Great Lakes coaster DPS. We found that this alternative is an admissible DPS, i.e., it is both discrete and significant (see Appendix 2 for a discussion of this analysis).

Following our step-wise analytical approach, the next step was to evaluate the conservation status of the Upper Great Lakes coaster-only DPS (Step 3, Figure 2). During the course of completing this analysis, we sought input from species experts, state agencies, and FWS fishery staff. In these efforts, we experienced significant difficulty articulating the elements of the DPS in a way that our audiences could understand and recognize. The primary problem we encountered was with the separation of coasters from the sympatric resident brook trout forms. We discussed this issue with several salmonid experts from NOAA-Fisheries; they questioned why we would separate out the migratory and resident forms in circumscribing a DPS. They acknowledged that this approach was adopted for the recent steelhead decision, but explained that this approach was not ideal from a biological perspective. They contended that from a biological population perspective, all sympatric, inter-breeding life forms comprise a single evolutionary unit and should be managed as a single DPS. Furthermore, through discussions with some of our state conservation partners and with some FWS managers, it became clear that for some it is difficult

to readily accept calling sympatric, interbreeding individuals "discrete" from each other. Most individuals view the term 'population' from a traditional *biological perspective*—interbreeding individuals—and believe it is not logical to call a particular life form "discrete" from other sympatric, interbreeding life forms. Despite our efforts to explain the term "discrete" from the DPS *policy perspective* (i.e., that discrete does not require reproductive isolation), it was apparent that many could neither understand nor accept coasters being labeled "discrete" from the resident form.

Given this conflict, our Team circled back to see if we had missed or failed to fully describe an objective[5]. One of our stated objectives was to "maximize conservation potential." As explained under the Objectives section, this requires partner acceptance of the Service's findings. We discussed the likelihood of our partners coming to the table and being full participants in the recovery of coasters if they did not believe a potential warranted finding was valid. In addition, we also discussed "regulatory burden" objective. Early in the process we assumed that the regulatory burden would be greater for a brook trout DPS, but upon further reflection, we discovered that may not necessarily be true. For example, listing of a coaster-only DPS may have required protection of sympatric resident fish due to the similarity of appearance (i.e., cannot differentiate between the two forms in some situations). This would increase the regulatory burden under a coaster-only DPS, effectively making it more similar to the all brook trout DPS for this objective. With these new insights, we conducted a formal analysis of the 2 broad DPS options relative to the stated objectives.

To assist with this analysis, we constructed a consequences table (Table 2). The cells of the consequence table are predictions of how well the alternative will serve the corresponding objective.

Table 2. Empty Consequences Table for Decision of Selecting a DPS option

Objectives		**Metric**	**Alternatives**	
			Option 1: Coaster DPS	Option 2: All Brook Trout DPS
1. Comply with letter & intent of ESA	Conserve genetic diversity	1-5		
	Conserve species biodiversity	1-5		
2. Maximize conservation potential		Probability		
3. Maximize recovery options		1-5		
4. Minimize regulatory burden		1-5		
5. Meet 12-month timeframe		prob.		

[5] Decision analysis although sequential is an iterative process. Step 1 involves defining your problem, but it is often the case that your problem is not fully realized until you have stepped through the entire decision structure. This is also true of determining objectives; many times the objectives may not be fully described or in some cases pertinent objectives are not identified until you've worked through the process. In this case, you circle back to your objectives and alternatives to reevaluate.

Members of the Team agreed that the predicted outcomes for objectives 1a & b, 3, and 5 will be similar for both options, but disagreed on the outcomes for objectives 2 and 4. The Team agreed that both DPS options were likely to conserve intra-specific genetic diversity and biodiversity nearly equally well. The brook trout DPS option would provide protection for all life forms of brook trout, and while only the coaster form would be listed under the coaster DPS option, we predicted that for practical purposes (and, as is usually done in situations similar to this) it was very likely that the resident form when sympatric with the coaster form would be afforded protection via similarity of appearance[6]. Hence, under both options, the genetic diversity and biodiversity of brook trout in the Upper Great Lakes would be equally conserved. Thus, the objective pertaining to complying with the ESA is irrelevant in choosing between the two alternatives.

Similarly, all believed that both DPS options will equally--or nearly so--maximize recovery options (Objective 3). Under both DPS options, the unit would be delineated to include the lakes as well as the tributaries up to the first barrier. Thus, the areas where recovery actions could be targeted would be the same under both options[7], leading us to conclude that this objective is also irrelevant in choosing between the two alternatives.

We quickly realized that the 12-month timeframe constraint was not relevant to our decision of choosing between the two alternatives. We had to deliver a decision by the agreed upon date regardless of which option was chosen or whether we ultimately evaluated both. So, objective 5 was also irrelevant.

With objectives 1, 3 and 5 deemed irrelevant to the decision, only objectives 2 (maximizing conservation potential) and 4 (minimizing regulatory burden) were left to base our decision. The team was divided on objective 2. Some believed that obtaining partner support and cooperation would be nearly equally under the two alternatives. Another felt that partner buy-in would be stymied under the coaster only option because of the confusion associated with the discrete criterion of the DPS policy. Conversely, one team member believed that a brook trout listing would engender even more confusion and concern about unnecessary regulatory burden by expanding the listing beyond the coater life form.

Team members also disagreed on the outcomes relative to minimizing regulatory burden (Objective 4). The majority of the Team believed that a "similarity of appearance" rule would likely be applied, and hence, the regulatory burden would then be nearly the same. The dissenting contention was that brook trout populations currently lacking coasters would be afforded protections under the brook trout DPS option but not under the coaster DPS option. Hence, there would be a greater regulatory burden with the former DPS option. Through our

[6] Per regulations (50 FR 17.50), species closely resembling a listed species can be afforded protections of the ESA if enforcement will substantially facilitate and further the purposes of the ESA. This rule is referred to as "Similarity of Appearance."

[7] At this stage of the analysis, our working assumption was that brook trout would not likely be endangered or threatened throughout the DPS but could be in a significant portion of the range (SPR). The SPR we envisioned was a coaster portion. Under this scenario, the geographic area and protections afforded to brook trout under either DPS option would be in essence nearly identical. Thus, we believed that recovery potential between the two options would be similar.

deliberations, it was discovered that some were predicting that brook trout would not meet status throughout all of the Upper Great Lakes but possibly in a "significant portion of the range." Individual Team members gave their predictions regarding regulatory burden based on their belief of whether "similarity of appearance" and "significant portion of the range" outcomes are likely.

In the end, there was not agreement among team members on how well the alternatives performed relative to the objectives, nor was there a dominant alternative for any one Team member.

Trade-offs

As neither alternative dominated the other, we needed to make trade-offs among the objectives. The alternatives performed equally well (or nearly so) relative to several objectives; and these objectives were therefore irrelevant for choosing between our alternatives.

We used a multi-objective trade-off technique—Simple Multi-Attribute Tradeoff (Edwards 1971)—to evaluate the overall performance of each alternative relative to objectives 2 and 4. This technique entails assigning weights, via swing weighting, to the objectives based on the range in potential outcomes, and multiplying the outcomes (consequences) by this weight. These weighted scores within each alternative are then summed to yield a single, overall score for each alternative. The alternative with the highest score is the preferred option. For all members, maximizing conservation potential was weighted substantially higher than minimizing regulatory burden such that essentially the latter was not influential in the decision (see Appendix 2 for further details). In the end, the preference between the alternatives within and among Team members was distinguishable but not markedly (Table 3). We agreed to move forward with completing a DPS analysis for the brook trout DPS option. Although we had already completed a discreteness and significance analysis for the coaster-only DPS option, we still needed to identify our preferred option in the event that both options yielded "warranted" findings. These options are mutually exclusive, so in this situation, we needed to choose the alternative with which to move forward. This trade-off analysis indicated that based on our objectives, we should elect a brook trout DPS option over a coaster-only option.

Table 3: The overall weighted scores for each DPS alternative by Team member

Team Member	Coaster Only DPS	Brook Trout DPS
1	0.55	0.64
2	0.77	0.45
3	0.55	0.55
4	0.55	0.70

Distinct Population Analysis

Based on the objectives trade-offs analysis, we elected to begin our evaluation with the set alternatives associated with the brook trout DPS option (Table 1, Figure 3). As indicated above, our approach was to start with the broadest alternative and work sequentially through the list, as

needed. Using this approach we began our DPS analysis of the first brook trout DPS alternative: Upper Great Lakes brook trout DPS.

The DPS analysis (Step 2 on Figure 2) involves 3-phases: I) identifying potential admissible population segments, II) determining whether such population segments are discrete from other brook trout population segments, and III) assessing whether these discrete population segments are significant to the taxon (i.e., to brook trout rangewide). Phase I was completed during the Alternatives step of the decision framework, and Phases II and III are summarized here.

Our analyses determined that the Upper Great Lakes brook trout DPS is both discrete and significant. A synopsis of our analyses is provided here and our interpretations of related policy aspects are detailed in Appendix 3.

Discreteness

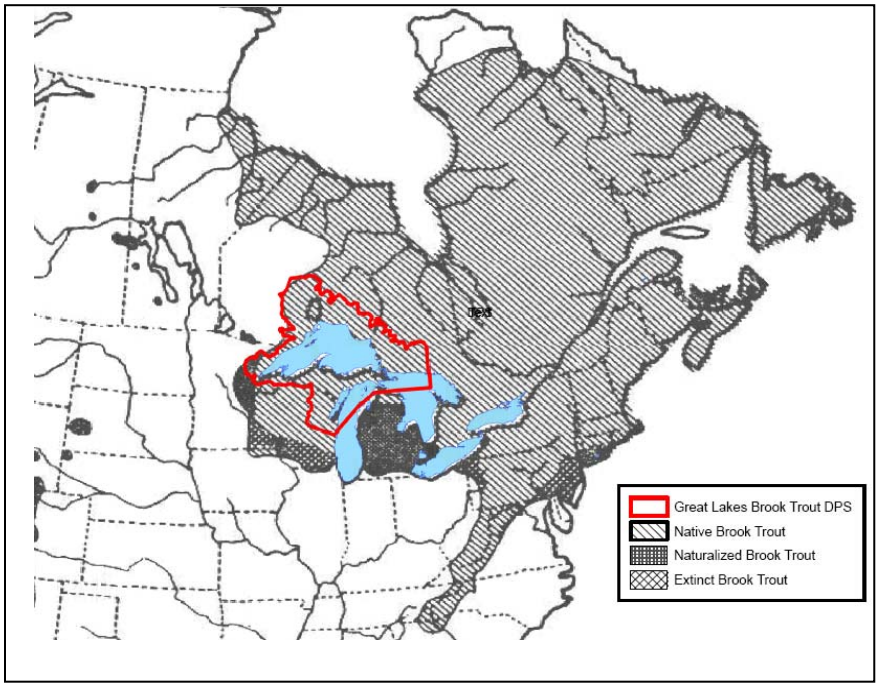
In ascertaining whether a population segment is discrete we must evaluate whether it is *markedly separate* from other members of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors or whether it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act. The purpose of the discreteness criterion is simply to circumscribe the population segment of interest (see Appendix 3 for further explanation).

The Upper Great Lakes brook trout population segment encompasses brook trout populations that currently or historically occupied Lake Superior and the northern parts of lakes Michigan and Huron (Figure 4). Brook trout within this population segment are markedly separate from other members of the brook trout taxon due to physical isolation both within and outside the Great Lakes Basin. Within the Great Lakes basin, best available information indicates that brook trout likely never occupied the southern portions of Lakes Michigan and Huron and all of Lake Erie (Bailey and Smith 1981). Brook trout currently found within these lake areas are the result of stocking for a put-and-take fishery. Although the exact reason that brook trout never occupied these areas is unknown, it is suspected that summer water temperatures in these lake areas exceed brook trout requirements. Regardless, without persistent, successful brook trout use of the lake environs, natural dispersal among stream populations cannot occur. This, in effect, isolates those portions of lakes Michigan and Huron and all of Lake Erie from brook trout populations within the Upper Great Lakes population segment. Outside of the Great Lakes basin, isolation is more distinct with no opportunity for brook trout from the Upper Great Lakes population segment to come in contact with fish outside lakes Superior, Michigan, and Huron.

A population segment may also be delimited by an international boundary. The boundary between U.S. and Canada bisects lakes Superior and Huron. Our approach was to start with the broadest alternative and sequentially move through the list of alternatives as needed. The current alternative under consideration is the Upper Great Lakes population segment which includes populations within both U.S. and Canadian waters. Therefore, an international border analysis is not germane for this DPS alternative.

In conclusion, the Upper Great Lakes brook trout population segment is discrete from the remainder of the brook trout taxon. This discreteness arises from the population segment's physical isolation from the remainder of the taxon. The next step is to determine whether the discrete population segment is significant to the conservation of the taxon.

Figure 4. Outline of the Upper Great Lakes Brook Trout Distinct Population Segment



Significance

The purposes of the significance criterion is to target population segments which: (1) are important to the overall welfare of the taxon by influencing its resiliency, vulnerability, persistence, or survival; (2) maintaining the elements of intraspecific biodiversity—i.e., ecological, biological, or phenotypic diversity--of the taxon, which facilitates the overall adaptability and persistence of the species; and (3) preserving the genetic diversity of the taxon, which allows for the natural evolutionary progression of the taxon. (Appendix 3). In assessing significance, there are 4 stated factors we must consider: persistence in an unusual ecological setting, significant gap in the range, sole remaining occurrence, and genetic distinctiveness.

Persistence in an Ecological Setting Unusual or Unique for the Taxon

The ecological setting of the Upper Great Lakes population segment is significant for the maintenance of the natural diversity, preservation of potential future of the genetic diversity, adaptive capabilities, and the overall welfare of the taxon. Although adfluvial and lake-dwelling forms occur in other places in the range of brook trout, the ecological setting of the Upper Great Lakes population segment exposes brook trout to physical and ecological forces that are unique for the taxon.

The Great Lakes basin, representing the largest freshwater ecosystem in the world, is composed of globally unique habitat types, including sand dunes, marine sanctuaries, coastal wetlands, islands, rocky shorelines, prairies, savannas, forests, alvars, and fens. Associated with this remarkable habitat diversity are rare and unique biological communities (USFWS 2007). Recent surveys identified 130 globally endangered or rare plant and animal species in the basin (USFWS 2007), including an unparalleled freshwater fishery (USFWS 2007). Due to these unique ecological characteristics, the management and conservation of the Great Lakes ecosystem are the focus of several International and State cooperatives and agreements (e.g., Great Lakes Fisheries Commission, Great Lakes Basin Compact, Great Lakes Commission, Boundary Waters Treaty of 1909, Great Lakes Water Quality Agreement, International Joint Commission), and are identified as a priority resource area for the Service's Coastal Program (USFWS 2007), as well as, the Coastal Zone Management Act administered through the National Oceanic and Atmospheric Administration (NOAA).

The Upper Great Lakes represents the largest water body occupied by brook trout throughout their natural range. For example, Lake Superior alone is 80 times larger by volume and 35 times larger by surface area than Lake Mistassini (Quebec, Canada), which is the next largest lake occupied by brook trout outside of the Upper Great Lakes within the natural brook trout range. From this immense size stems an exceptional ecological setting.

The Upper Great Lakes population segment harbors biocomplexity that is unparalleled within the current and historical natural range of brook trout. It comprises several aquatic habitat types, including numerous bays, an extensive nearshore zone (including islands), and 3 open water zones. Within these habitat types there is significant variability in the ecological conditions and the biotic community. Across the open water zones, the fish assemblage changes abruptly with depth due to significant shifts in temperature, light, pressure, and prey abundance (Hoff 2009). The bays foster a significantly different biotic community than the main basin, even where those bays reach significant depths (Hoff 2009). Further, the bays around the DPS vary widely in size and depth, providing another source of within-habitat diversity. The large size of the lakes fosters diversity within fish species. One good example of these influences comes from the 'ciscoes' (*Coregonus* spp.). Within the Great Lakes, this group has undergone significant adaptive radiation, including the evolution of two forms—kiyi and bloater—endemic to the basin. Within this group, the sheer size and ecological complexity of the system has further caused the formation of multiple discrete stocks within Lake Superior (Hoff 2004).

The dominant controlling forces of the Upper Great Lakes are essentially oceanic rather those of "small" lakes typical within the brook trout range (McCormick 1990). Large lakes are dominated by physical characteristics and processes such as wave action, differentiation of water masses (e.g., nearshore, pelagic), upwelling and sinking of water, and the Coriolis force (Beeton 1984). Large lakes are also distinguished by prominent horizontal gradients, which yield marked physical and chemical shifts extending out from the shoreline (Beeton 1984, Edsall and Charlton 1997). Strong water flow significantly influences the coastal zones of the lakes (Zhu et al., 2000, Zhou et al., 2001), with coastal currents in Lake Superior measured at speeds up to 50-65 cm/s (Zhu et al., 2000). These currents provide an unusual blend of lentic and lotic physical conditions for the nearshore biological community. The coastal currents also help form zones of water upwelling, which supply nutrient rich waters to coastal areas that stimulate productivity (Edsall

and Charlton 1997, Zhou et al., 2001). These physical properties combine to provide a diverse array of habitats for the biological communities of the Great Lakes. This habitat complexity in the Great Lakes has fostered equally complex biotic communities and unique species assemblages (Cudmore-Vokey and Crossman 2000, Hoff 2009).

It is in this unique physical and biotic community setting that brook trout within the Upper Great Lakes segment have evolved and adapted . Any special adaptations (e.g., prey and predator interactions, habitat niches) accompanying brook trout living in this unique ecological setting would be lost if the Upper Great Lakes population segment disappears. Maintaining brook trout in the natural diversity of habitats that exist throughout their range is important to persistence of the taxon and to retain the natural evolutionary trajectory of the species. Different ecological settings are unlikely to be influenced by changes or stressors to the same degree or simultaneously, and hence, occupying a diversity of ecological settings effectively "spreads the risk" and increases the chance for species persistence. Concordant with the loss of unique ecological settings is the loss of any adaptive traits acquired by evolving in those areas. Such losses substantially undermine the species' ability to respond and adapt to future environmental changes. It is not always easy to predict or foresee the adaptive advantages that a particular ecological setting may offer, but by maintaining a diversity of natural settings a reservoir of adaptive traits will be preserved to help ensure that brook trout remain evolutionarily "nimble" in light of environmental changes. For example, it may be that the Upper Great Lakes population segment will be important for future adaptation and adjustments to climate change. Under future climate warming scenarios, the Great Lakes represent one of few significant cold-water reservoirs to buffer the species from extinction as streams and other smaller lake habitats exceed brook trout thermal limits and become unsuitable.

Maintaining the diversity of ecological settings is also important to help ensure the evolutionary trajectory of brook trout is not disrupted. Through adaptation, individuals within a unique ecological setting begin to diverge—genetically, morphologically, and ecological–from other members of their taxon. Within the upper Great Lakes, evidence of adaptation is manifesting. The lacustrine form of brook trout, for example, appears to have gone through a process of adaptive radiation to form a separate lake dwelling population at Isle Royale. Thus, loss of the Upper Great Lakes DPS would disrupt the evolutionary trajectory of brook trout.

Undisputedly, the lakes of Superior, Michigan and Huron offer a unique and unusual ecological setting for brook trout. Occupying unique ecological settings is likely to confer unique or unusual adaptations not commonly expressed elsewhere. Conserving an array of adaptations, via preserving a diversity of ecological settings, is prudent to help buffer against future environmental changes be they natural, human induced or both, and to ensure the evolutionary trajectory of a species is not disrupted. For these reasons, we believe the Upper Great Lakes population segment is significant to the brook trout taxon.

*Significant Gap in the Rang*e

Loss of brook trout in the upper Great Lakes, when considered geographically in relation to brook trout throughout the remainder of the species' geographic range in eastern North America, would constitute a loss of approximately 10 percent of the entire geographic range of the taxon and a loss of approximately 45 percent of the geographic range of brook trout in the U.S. Due to the

broad geographic range of brook trout, and the fact that the upper Great Lakes are at the western periphery of natural range, the gap in the range resulting from the loss of brook trout in the upper Great Lakes would not result in a significant gap in the range of the taxon as a whole. Alternatively, if one considers the volume of cold water available for brook trout to inhabit and the thousands of kilometers of nearshore waters, the quantity of suitable habitat represented by the Upper Great Lakes DPS could be a much larger percentage of the range.

Sole Remaining Occurrence
Brook trout in the upper Great Lakes are not the only surviving natural occurrence of the taxon, and hence, this significance factor is not germane to our DPS analysis.

Genetic Distinctiveness
Six distinct genetic mitochondrial (mtDNA) clades have been identified throughout the range of brook trout in eastern North America (Danzmann *et al*. 1998). These mtDNA clades reflect historical isolation in glacial refugia or long periods of isolation in nonglacial areas in the southern part of the species' range. The Wisconsin glacial advance which covered portions of Canada covered all five Great Lakes 15,000 years ago (Bailey and Smith 1981). As these glaciers receded, brook trout recolonized the lakes from the Mississippi and Atlantic refugia (Danzmann *et al*. 1998). Given this pattern of glaciation, genetic diversity is greatest at the southern portion of the species' range and gradually decreases northward (Danzmann *et al*. 1998). As the most geographically isolated (tens of thousands of years), brook trout in the southern part of the species' range (along the Appalachian Mountains south to Georgia) are the most diverse, containing all six mtDNA clades. The Great Lakes contains three of the six mtDNA clades. Throughout the northern portion of their range in Canada, brook trout are the least genetically diverse, with only a single mtDNA clade present.

Results based on microsatellite DNA variation identified nine distinct genetic assemblages of brook trout in the U.S. (King 2009, unpub. data). Assemblages from the nonglacial southern part of the species' range (along the Appalachian Mountains from Pennsylvania to Georgia) in the U.S. are the most genetically divergent, and this divergence among the assemblages generally decreases as the range progresses northward. Populations from Lake Superior and tributaries to Lake Erie form two of the nine assemblages. The Lake Erie populations, representing the northern part of the range in the U. S., are the most divergent assemblage in this portion of the range. Lake Superior populations are similar in the degree of genetic grouping with the average genetic distance between brook trout populations in the U.S. Samples from the rest of the Great Lakes were not available for analysis.

Although brook trout in the Great Lakes do not contain any wholly unique mtDNA clades, they do contain a large amount of the genetic variation in a confined portion of the range (Danzmann *et al*. 1998). Further, other independent, genetically based traits associated with morphological or life history differences may still have developed within Great Lakes brook trout populations during the past 10,000 years in different selective environments, but remain undetected. Indeed, the Lake Superior environment and selective forces since the last glaciation have favored unique genetically distinct adaptations in other Great Lakes fish species, including lake trout (e.g., humper and siscowet lake trout forms; Page *et al.* 2004), which are closely related to brook trout in the same genus (*Salvelinus*).

For more than 100 years, agencies have stocked millions of brook trout into the Great Lakes and its watershed (Schreiner *et al.* 2008, Wisconsin and Michigan DNR fish stocking records). The stocked fish were not behaviorally or evolutionarily adapted to the environment in which they were planted, criteria known to limit survival and reproductive success and thus did not develop viable populations (Schreiner *et al*. 2008).

Studies examining genetic introgression from stocked fish suggest native populations of brook trout in Lake Superior have retained their native genetic characteristics despite the stocking of hatchery fish from sources outside and within the Lake Superior basin. This leads to the conclusion that adaptations specific to the Great Lakes exist for brook trout.

Brook trout are genetically diverse (as measured by Fst values) across its natural range. This pattern is heavily influenced by the ecological and life history characteristics of brook trout populations (e.g., population connectivity or isolation, philopatric tendency). The brook trout in the Upper Great Lakes DPS may be genetically distinguishable from other population segments, but data demonstrating a unique clade within the Upper Great Lakes are lacking. Hence, we conclude that the Upper Great Lakes DPS is not sufficiently significant to qualify under this criterion.

Conclusion
On the basis of the best available information, we conclude that the Upper Great Lakes brook trout are "markedly separate" from all other populations of the same taxon as a consequence of physical factors, and on the basis of the four significance criteria we conclude that the Upper Great Lakes brook trout is significant to the taxon. Therefore, we find that the Upper Great Lakes brook trout is an admissible DPS.

Conservation Status

The next step in our analytical process is to assess the conservation status of the admissible DPS alternative. There are many acceptable approaches to determining conservation status. The ESA simply requires us to evaluate the extinction risk as a result of 5 stated factors (This analysis is commonly referred to as the 5-Factor Analysis). For our decision, we elected to take a 4-phased approach: phase 1 determining the current conservation status of brook trout populations within the DPS; phase 2 conducting the required 5-Factor Analysis; phase 3 identifying the extinction profiles for populations given a particular set of characteristics; and phase 4 integrating the information from phases 1-3 to predict the extinction risk of brook trout into the foreseeable future.

Phase 1 – Current Conservation Status
Our first step in assessing whether brook trout within the Upper Great Lakes DPS are endangered or threatened pursuant to the ESA was to ascertain the current status of the known populations. In conducting this analysis, we looked at three population parameters commonly used as indicators for viability (NOAA 2004): population abundance, population trend, and connectivity.

We evaluated data within our files, reviewed available literature (published, white, gray, and agency records), and communicated with lead fishery biologists from the states of Michigan, Minnesota, and Wisconsin; Tribes; and province of Ontario, as well as, faculty at Michigan Technological University to gather information on coaster population abundance, population trends/productivity, and reproductive connectivity to other populations. Abundance was based on mark recapture population estimates or measures of relative abundance. Population status and trend was assigned as low, moderate, or high based on the population estimate or relative abundance metric of catch per 1000 feet, standardized for surveys for which this data was available. Where population estimates were available, adult abundance was categorized as low (<250 individuals), moderate (250-500 individuals), and high (>500 individuals). When necessary, relative abundance data were used to describe population abundance. Populations were categorized as low where fewer than 50 brook trout/1000 feet were present, as moderate where 50-100 brook trout/1000 feet), or as high where abundance was >100 brook trout/1000 feet. In situations where electrofishing relative abundance information was not available (e.g. Salmon Trout River) available metrics were utilized. Data available from some populations were limited to adult relative abundance. In these situations, we compared available information to mark-recapture or relative abundance data. Reproductive connectivity was examined and determined based on genetic reports and analysis.

Other occurrences of coaster brook trout have been documented or suspected based on environmental conditions in tributaries. However, in these locations there is no evidence of annually reproducing populations nor is there is a reasonable expectation that a wild (unstocked) coaster would be encountered in fishery assessment gear. Both of these events are expected in areas where coaster populations persist. We gathered the same viability information on brook trout populations where sporadic, isolated, or presumed coasters occur around Lake Superior, though this information was not utilized in our DPS analysis.

Phase 2 – 5 Factor Analysis

The second step in our conservation status assessment was to conduct the requisite 5-Factor analysis. We searched brook trout management documents, the listing petition, the 90-day finding, and agency and published literature to identify potential threats. Each threat was analyzed for its existing and likely future impact on brook trout populations within the Upper Great Lakes basin. Due to insufficient study of brook trout within the Great Lakes, our analysis often relied upon research conducted on brook trout outside of the Great Lakes and other closely related trout species. The primary threats identified included habitat destruction, overharvest (primarily recreational angling of coasters, nonnative interactions, and loss of life history diversity.)

Phase 3 – General Brook Trout Population Extinction Risk Analyses

The third phase of our conservation status assessment was to forecast future risk for populations given a set of characteristics. To assist us with Phase 3 of the analysis, we elicited expert judgments to develop general extinction risk profiles for given population scenarios. These judgments were assigned based on a hypothetical brook trout population possessing a specific set of population characteristics (e.g., given a population has low abundance, decreasing trend, and is isolated from other populations, what is the likelihood of extinction within 50 years?). Details of the expert elicitation are found in Appendix 7.

Phase 4 – Extinction Risk of Upper Great Lakes DPS
In the last phase of our conservation status assessment, our intent was to integrate information garnered from phases 1-3 to forecast the extinction risk of the Upper Great Lakes DPS. The approach was to assign using the outcomes from Phase 3 extinction risk estimates to each brook trout population based on their specific characteristics determined in Phase 1. These extinction risk estimates would be modified as appropriate based on the 5-Factor analysis conducted in Phase 2 (i.e., increase or decrease risk estimate based on whether stressors will continue to affect the population). These population extinction profiles would then be used to calculate the overall risk of extinction at the DPS level be it Upper Great Lakes Basin, an individual stream population, or any other DPS configuration.

We established this analytical framework when we were moving forward with the coaster only DPS option. Given the few populations existing, we believed it would be feasible assess the extinction risk for each known population. With our departure from the coaster only to the brook trout DPS option, we needed to modify our approach. The number of populations germane to our assessment greatly increased under the brook trout DPS option, and the information regarding our population parameters was lacking for the majority of these populations. Thus, we modified our approach to assess extinction risk at the DPS level directly. Although our risk assessment no longer focused on coaster viability, most results from the expert elicitation were still germane to the analysis.

To assess extinction risk at the DPS level, we relied upon 4 factors commonly recognized as indicators of viability (based on McElhany et al., 2000): (1) total number of viable populations; (2) geographic distribution of these populations; (3) connectivity among populations; and (4) genetic, behavioral, and ecological diversity among populations.

For each category, we assigned a score reflecting the relative importance of this factor to the extinction of brook trout throughout the DPS. Score of 1 indicates that the factor is unlikely to contribute significantly to risk of extinction, either by itself or in combination with other factors. Score of 2 indicates that the factor is unlikely to contribute significantly to risk of extinction by itself, but there is some concern that it may contribute significantly, in combination with other factors. Score of 3 indicates that this factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the foreseeable future. Score of 4 indicates that this factor contributes significantly to long-term risk of extinction and is likely to contribute to risk of extinction in the foreseeable. Score of 5 indicates that the factor by itself indicates danger of extinction in the foreseeable.

Number of viable populations within the DPS
Best available information suggests that resident brook trout populations may persist in the more than 200 coldwater tributaries to Lake Superior as well as coldwater tributaries to northern portions of lakes Michigan and Huron. The range of many of these populations has retreated towards the headwater reaches, and as explained in the 5-Factor analysis section, threats continue to operate on many of these populations. For these reasons, we assume brook trout population abundance has declined, but the extent of decline is currently unknown. Further, only 15 of these populations currently support the coaster life form. Despite the seemingly reduced abundance,

we do not have evidence that current population sizes are threatening the viability of individual populations. Rather, brook trout managers from the Great Lakes region believe that self-sustaining resident brook trout occur in nearly all streams known to have historically supported the coaster expression (Newman et al. 2003; Quinlan 2008; Schreiner 2008, pers. comm.; Schram 2008 pers. comm; and Scott 2008, pers. comm.). Given this, we assume that a substantial number of the brook trout populations within the DPS are presently viable. The current number of seemingly viable populations poses no significant risk by itself to the DPS viability in the foreseeable future. However, if threats continue unabated, we anticipate further decline in resident populations and populations expressing the adfluvial form in the long term. As further explained in Factor 3, prolonged or further repression of the coaster form may substantially affect the viability of the DPS in the long term.

Geographic distribution of populations within the DPS
Despite substantial declines in the past, brook trout populations throughout the DPS remain widely distributed. As previously stated, resident brook trout populations may persist in more than 200 coldwater tributaries to Lake Superior as well as in many of the coldwater tributaries to northern portions of lakes Michigan and Huron. Although some populations have retreated to the headwater reaches of their streams, the overall distribution of the populations resembles the natural historical range. This wide distribution makes it unlikely that a single catastrophic event will affect all populations simultaneously, and thus, this factor by itself or in combination with other factors poses no significant risk to the DPS viability.

Connectivity among populations within the DPS
As explained in the Background section, the coaster life form is the sole natural vector for dispersal within the Upper Great Lakes brook trout DPS. Dispersal among populations is vital for maintaining gene flow, a functional metapopulation, and rescue effects (see 5-factor analysis). Dispersal is essential for exchange of genetic material among populations, which is necessary to maintain genetic variability within local populations. Dispersal also provides for recolonization of extirpated—or rescue of severely reduced—populations, which is essential for maintaining a stable population structure over the long term. Without the coaster life form, connectivity among populations within the DPS will for all practical purposes be eliminated. Thus, loss of the migratory life form would affect the long-term viability of brook trout within the DPS.

Based on the historical abundance and distribution, current status (see Phase 1) and threats (see 5-Factor analysis), coaster expression has been severely repressed and will likely be further repressed without amelioration of threats. Although once abundant and widespread throughout the northern portions of the Great Lakes, coaster brook trout populations are now limited to a few locations (Dehring and Krueger 1985; Bailey and Smith 1981; Goodyear et al. 1982; Newman et al. 2003; Mucha and Mackereth 2008). Because of the differences in ecology (namely, their migratory behavior, lake dwelling, and larger size), coasters are more susceptible to some threats than the resident expression (e.g., overexploitation). Although some threats are no longer affecting coaster populations to the same magnitude as in the past, these stressors, as well as contemporary factors (e.g., non-natives) continue to substantially repress expression of the coaster form.

As previously explained, loss of the coaster form reduces the resiliency, redundancy, and representation of the brook trout population. Reduction in these factors increases the risk of brook trout to environmental perturbations, demographic stochasticity, and catastrophic events. The loss of the coaster form will exacerbate the negative consequences of reduced gene flow among populations and of disrupted population dynamics. Indeed, evidence of loss connectivity due to the decline in the coaster expression is already discernible in some populations. Based on genetic and fishery data, many populations are reproductively isolated from other brook trout populations (Burnham-Curtis 1996; Burnham-Curtis 2000; Sloss et al. 2008, Wilson et al. 2008, Scribner et al. 2008). In the short-term (i.e., foreseeable future), we do not believe, given the number and the distribution of brook trout within the DPS, the effects of reduced or even loss of gene flow will threaten the viability of brook trout. Over the long term, however, loss of coaster could pose a risk to the brook trout population in the Upper Great Lakes DPS.

The implications of losing the coaster expression over the long term depend upon whether the coaster expression can be easily reconstituted once lost. If coaster expression cannot be readily reconstituted, the negative consequences of reduced gene flow (e.g., increased risk of extirpation due to environmental perturbations, demographic stochasticity, and catastrophic events) may compromise the long-term viability of brook trout within the DPS. Conversely, if the coaster life form can be readily reconstituted from a purely resident population, then temporary loss of the coaster expression will not substantially influence the viability of brook trout throughout the DPS in the long term.

Although believed unlikely for other salmonids (*O. mykiss* for example), brook trout experts contend that if environmental conditions are suitable (i.e., threats are abated), the coaster life form can be readily reconstituted from a purely resident stock (see Residents subsection below). Accepting this supposition, we believe loss of connectivity among populations provided by the coaster form, in its current compromised condition, contributes significantly to long-term risk of extinction, but, given the current status of brook trout throughout the DPS, does not in itself render the Upper Great Lakes DPS in danger of extinction in the foreseeable future.

Genetic, behavioral, and ecological diversity among populations within the DPS
Multiple populations within a DPS increase the likelihood that diversity of phenotypic and genotypic characteristics will be maintained, thus, increasing the DPS' viability in the long term. Genetic studies within Lake Superior reveal that genetic diversity has not been markedly compromised (Burnham-Curtis 1996, and 2001; Wilson et al 2008). Based on a review of microsatellite DNA studies conducted in Lake Superior and Maine and Canada, the genetic diversity as measured by the amount of average heterozygosity, brook trout populations in Lake Superior have levels of genetic diversity that are similar to other populations outside of the Great Lakes Basin (Ardren 2009, pers .comm.). Maintenance of this diversity, however, is contingent upon continued and sufficient expression of the coaster form. Although the best available information indicates that the coaster expression is vulnerable in the foreseeable future, provided the resident form is viable and widely distributed, we assume coaster expression can be reconstituted. Accepting this supposition, we believe genetic diversity throughout the DPS will be maintained over the long term.

As we discussed previously, behavioral and ecological variation is important because species are better adapted to variable environments (whether the variability be due to natural and anthropogenic causes), and hence have a lower risk of extinction (Watters et al., 2003). Life history forms are the essence of behavioral and ecological diversity in brook trout. The coaster form represents two of three life history expressions, and hence, provides a substantial amount of behavioral and ecological diversity for brook trout within the Upper Great Lakes brook trout DPS. The coaster life history form has been substantially repressed and is likely to continue to decline in some locations in the foreseeable future. As argued above, we assume that the coaster expression can be reconstituted once lost, if threats are abated. The temporary loss of coaster form is not likely to incur negative consequences to the overall viability of the brook trout population within foreseeable future. With continued repression of the coaster form, however, we anticipate loss of genetic and behavioral diversity in the long term. For this reason, we conclude that this factor contributes significantly to long-term risk of extinction, but does not in itself render the species in danger of extinction in the foreseeable future.

Defining "Foreseeable Future"

In determining whether listing is warranted, the ESA requires determining whether a species is likely to become endangered within the foreseeable future. The Service's approach to foreseeable future has integrated both biological and policy aspects, and consequently, no single timeframe has been used in making listing determinations. Within the scientific literature, a 100-year time scale is often used in viability analyses as it represents a "long-term" time horizon for evaluating extinction risk (NOAA 2000). Given the lack of clear guidance of an appropriate time-scale, yet the need to select a specific timeframe, we elected to choose a biologically meaningful timeframe. That is, the selected timeframe does not represent "foreseeable future," but rather a guide for our decision makers to apply in their decision. We chose 50 years as our timeframe for the extinction risk analysis. This time horizon represents at least 7 to 13 coaster brook trout generations (12 to 25 resident brook trout generations), which should be sufficient duration for the effects upon viability due to a population's current population trend, abundance and connectivity to be manifested.

Influence of residents on the extinction risk of coasters

From early on, our research led us to believe that if lost, coaster re-expression would not readily occur from a purely resident stock. This supposition was borne from empirical data from Lake Superior in which no known coaster populations have re-established since extirpation, despite over 100 years of effort to increase brook trout abundance, as well as, from statements and positions held for salmonids in the West. In brief, salmonid experts contend that the migratory life form cannot be readily reconstituted from a purely resident stock (see Appendix 1 for further discussion). As explained above, this supposition is fundamental to our analyses. Thus, we elected to pose the question to our experts. The results from the elicitation clearly indicate that the experts do not agree with our initial assumption regarding the interaction among resident and coaster brook trout (Appendix 7). In rejecting this supposition, we are contending that the ecology of brook trout differs from other salmonids. So, we questioned the experts as to how the brook trout model differs from salmon model applied elsewhere. Specifically, we asked why is the widely accepted supposition for salmon not an appropriate assumption to adopt for brook trout.

According to the Great Lakes brook trout experts, brook trout show greater phenotypic plasticity than most other salmonids. Adfluvial brook trout do not—as salmon do—require substantial physiological changes (e.g., smoltification) to successfully migrate and survive in the lake environment. Thus, the fitness costs to maintain the genetic code for plasticity are likely less relative to saltwater dwelling salmonids. Hence, it is reasonable to expect a brook trout population to maintain the ability (genetic code) to express the full array of life forms over longer periods of time. Furthermore, the experts contend that life history strategy is strongly controlled by the environmental conditions or triggers. If this is the case, it is reasonable to conclude that if the necessary environmental conditions or triggers exist, life forms can be expressed even if temporally lost from a population.

Given the lack of data available on this specific issue for brook trout, we must rely on surrogates and expert opinion to guide us. The reasonable rationale provided and the strong agreement among the experts led us to reverse our fundamental assumption. Thus, at present, we believe an appropriate assumption is that if lost, coaster re-expression can occur readily provided a suitable environment is restored.

Conclusion

Numerous brook trout populations within the DPS have retreated to the headwater stream reaches, but remain widely distributed throughout most of the DPS. Based on the best available data, more than 200 brook trout populations persist within the DPS. The coaster life form is substantially repressed and vulnerable; if threats continue we believe coaster expression will continue to decline. The loss of life history diversity reduces the resiliency, redundancy and representation of the Great Lakes brook trout population in the long term. Although the abundance of brook trout is believed to have declined--as evidenced by the contraction of distribution within streams and the threats discussed previously--the best available information indicates that these populations are viable in the foreseeable future. If threats to the coaster form are not ameliorated, however, we believe that the long-term viability of brook trout in the DPS will be compromised. Given the range and the number of populations, however, we believe that the current status and trend in threats are unlikely to render brook trout within the Upper Great Lakes endangered or likely to become endangered throughout the DPS in the foreseeable future.

Significant Portion of the Range

In addition to evaluating the status throughout the DPS, we are also required to ascertain whether any "significant portion of the range" is endangered or threatened. The ESA defines an endangered species as one "in danger of extinction throughout all or a significant portion of its range," and a threatened species as one "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The term "significant portion of its range" is not defined by statute. On March 16, 2007, a formal opinion was issued by the Solicitor of the Department of the Interior, "The Meaning of "*In Danger of Extinction Throughout All or a Significant Portion of Its Range*"(DOI 2007). A portion of a species' range is significant if it is part of the current range of the species and is important to the conservation of the species because it contributes meaningfully to the representation, resiliency, or redundancy of the species. The contribution must be at a level such that its loss would result in a decrease in the ability of the listable entity (i.e., species, subspecies, and DPS) to recover.

The range of a species can theoretically be divided into portions in an infinite number of ways. To identify those portions that warrant further consideration, we determine whether the threats are geographically concentrated in some way. If the threats to the species are essentially uniform throughout its range, no portion is likely to warrant further consideration. If the threats are concentrated, the next step is to determine whether any such concentration of threats occurs in a portion that is significant to the listable entity. If any concentration of threats applies only to portions of the range that are unimportant to the conservation of the species, such portions do not warrant further consideration.

Our analyses indicated that brook trout populations, despite known or suspected population declines and habitat losses, remains widely distributed in apparently stable populations across the DPS. The primary threats--habitat degradation, overutilization, nonnative fishes, and loss of connectivity/life history diversity--appear to be affecting brook trout consistently, in both degree and extent, across the DPS. Thus, we concluded that there were no significant "geographic" portions of the range within the Upper Great Lakes brook trout DPS that warranted further consideration.

However, data suggest that threats may be differentially influencing one of brook trout life forms. So, we also evaluated whether the coaster life form itself constitutes a significant portion of the range and if so, whether it is threatened or endangered. Our initial analysis concluded that the coaster life form represents a "portion of the species' range." Current evidence indicates that coaster life form has experienced a greater decline than resident brook trout over the past 100 years, which suggests differential threats acting upon coasters. Further, coasters occupy a unique ecological setting (the Great Lakes proper) and provide ecological function critical for brook trout persistence within the Upper Great Lakes DPS For these two reasons, we concluded that the coaster life form provides resiliency, redundancy, and representation to the Upper Great Lakes brook trout DPS. In other words, the coaster life form represents a "portion of the species' range."

This initial conclusion, however, was predicated upon the assumption that the coaster life form could not be readily reconstituted once lost. In essence, this means that the brook trout life forms are not ecologically exchangeable. As explained previously, at the recommendation of the Great Lakes brook trout experts, we ultimately rejected this supposition. Given that the coaster life form could theoretically arise from any brook trout population in the DPS, we no longer believe that the coaster life form represented a "portion of the species' range" per our guidance.

Given above, we concluded that brook trout within the Upper Great Lakes DPS are not endangered or threatened throughout or in a significant portion of the DPS.

Additional DPS Alternative Analyses

In accordance with our decision approach, reaching a "not warranted" conclusion requires us to evaluate sequentially the remaining brook trout DPS alternatives as well as the coaster only DPS alternatives. As alluded to above, we initially completed a discrete and significance evaluation of the coaster only DPS option, and found it was an admissible DPS (see Appendix 4). However, for reasons discussed below, we concluded "not warranted" for this DPS option and all other DPS alternatives as well.

For those DPS alternatives that include a subset of the range of coaster brook trout, we do not believe they will meet the significance criterion. Our significance analysis revealed that the only factor relevant to the brook trout DPS is occurrence in a unique or unusual ecological setting. DPS alternatives that include only a portion of the range eliminate the "persisting in a unique ecological setting" significant factor as brook trout occur elsewhere within the Great Lakes. For those DPS alternatives that include all or most of the range of coaster brook trout (e.g., Upper Great Lakes coaster DPS, Lake Superior DPS alternatives), a significance argument could be made, but given our assumption that coasters can be readily reconstituted from a resident population, none of these alternatives would meet the definition of threatened or endangered.

Although the rationales above apply to all of our identified DPS alternatives, to be responsive to the petition, we explicitly analyzed the Salmon Trout River DPS option in the finding. We found that Salmon Trout River population segment does not quality as an admissible DPS. Although discrete from other brook trout, this population segment is not significant to the taxon (For a full analysis see Appendix 5).

Recommendation

Although discrete and significant, the status assessment team found that neither the coaster only DPS nor the Upper Great Lakes brook trout DPS options warrant endangered or threatened status. Thus, our recommendation to the Regional Director was to conclude that the petitioned action was "not warranted."

Uncertainty

Uncertainty is inherent in predicting the extinction risk of a species; we must forecast the species' future abundance in light of its current status and the likelihood of stressors and their degree of magnitude continuing into the future. In our decision, additional biological uncertainties included: (1) determining whether genetic differences exists between brook trout found within the Upper Great Lakes and those elsewhere, and (2) the number and status of many of the resident brook trout populations found within the Upper Great Lakes. Yet another uncertainty was potential public and partners acceptance any proposed listable entity (if one was proposed for listing). This was a concern because we knew that public and partner acceptance of the listable entity would be critical for subsequent participation in and success of any future recovery program. As these are all unknowns, we must make some assumptions and move forward. Fortunately, our decision was not sensitive to these uncertainties. That is, we determined that if we would alter our assumptions on these outcomes, the decision made would remain unchanged.

The reason for this is that there is one fundamental assumption underlying our analysis that preempts all other suppositions. Empirical data on whether the migratory and lacustrine forms of brook trout can be readily reconstituted once lost from a population from a purely resident population are lacking. The answer to this question is pivotal to our analysis. If life forms can be readily reconstituted from populations consisting purely of one life form, then our risk analyses must include the conservation status of all co-occurring life forms. Given the paucity of empirical data for brook trout, we relied on information from surrogate species and expert opinion to inform our decision. Unfortunately, conclusions from these sources of information are conflicting. Much of the empirical and theoretical data suggest that migratory forms of salmonids cannot be

readily reconstituted from a purely resident stock (NOAA 2000, Good et al. 2005). Brook trout experts from within the Upper Great Lakes, however, believe that this is not likely true for freshwater brook trout. This contention is based on the following. Adfluvial brook trout do not—as salmon do—require substantial physiological changes (e.g., smoltification) to successfully migrate and survive in the lake environment. Thus, the fitness costs to maintain the genetic code for plasticity are likely less relative to saltwater dwelling salmonids. Hence, it is reasonable to expect a brook trout population to maintain the ability (genetic code) to express the full array of life forms over time. They further contend that life history strategy is strongly controlled by the environmental conditions or triggers, and thus, it is reasonable to conclude that provided the necessary environmental conditions or triggers exist, life forms can be re-expressed even if temporally lost from a population. Our Team deliberated over the conflicting information, and ultimately, although with some reservations, concluded that the rationale provided by the brook trout experts out-weighed the evidence from the salmonid literature. Thus, we needed to assess the viability of all brook trout within the DPS, i.e., there was no SPR. For a more discussion of the salmonid literature and expert opinion, see Appendices 1 and 7, respectively.

Decision

As just described, based on the results of our SDM process, the Regional Director recommended to the Director that we conclude that the Upper Great Lakes brook trout are discrete and significant and thus qualify as a valid DPS, but are not threatened with extinction within the foreseeable future ("not warranted" finding). However, after further analysis and discussion with our Washington Office, this recommendation was reevaluated. Specifically, additional review questioned whether we had provided sufficient support for the conclusion that the upper Great Lakes is indeed an unique ecological setting for brook trout. The ensuing analysis focused on two aspects: the relative significance of Great Lakes ecological setting and the importance of the Great Lakes as a coldwater refugia. A summary of this analysis follows.

Importance of the Great Lakes setting

Brook trout exhibiting differing life history forms occupy a variety of ecosystems throughout their natural range, from subarctic regions of the Hudson Bay coast, to temperate areas bordering and east of the Great Lakes, and southern coldwater habitats in the Appalachian Mountains of Tennessee and Georgia (Power 1980). Within their large native range in eastern North America, brook trout habitat includes coastal areas and various-sized lakes, streams, and rivers at varying altitudes. Most populations inhabit coldwater streams, but lake-dwelling and lake-spawning (lacustrine form) populations also occur throughout the range, in spring-fed ponds, small- to medium-sized lakes, and a few large, oligotrophic (containing relatively little plant life or nutrients, but rich in dissolved oxygen) lakes. Anadromous populations ("salters") of brook trout use marine habitats in Hudson Bay and along the Atlantic coast.

The upper Great Lakes represent a complex ecological setting for brook trout. The very large size of the Great Lakes watershed creates an environment that more closely resembles oceanic physical conditions (available to the anadromous forms of brook trout) than conditions in smaller lakes (available to other forms of brook trout). With approximately 1,500 tributaries and almost 2,800 miles (4,506 km) of shoreline, Lake Superior also provides brook trout access to a very large freshwater habitat network. Although Great Lakes are the largest, freshwater bodies occupied by brook trout, there are also thousands of large postglacial lakes further north in

Canada that contain populations of the adfluvial and lacustrine forms (e.g., Fraser and Bernatchez 2008). Thus, given the vast diversity of ecological settings occupied by brook trout across it s range, the relative significance of the Great Lakes ecological setting to the brook trout species is limited.

Great Lakes as a potential climate change cold-water refugium
Predicted impacts of climate change will undoubtedly affect brook trout throughout their native range. If predicted rising water temperatures in response to climate change are realized over the entire range of brook trout, the distributions of brook trout populations would likely shift toward cooler waters at higher latitudes and altitudes (Meisner 1990, Magnuson *et al.* 1997, Kling *et al.* 2003). While the upper Great Lakes may provide substantial coldwater habitat for brook trout in the future, brook trout have other abundant coldwater habitats available in the northern latitudes of its range, and habitat in northern North America, presently too cold, may develop into appropriate brook trout habitat under this warming scenario. Thus, there is insufficient evidence that the upper Great Lakes provides a unique a future coldwater refugia for brook trout.

Based the analysis above, the Service determined that at this time there is insufficient information to conclude that the Upper Great Lakes brook trout DPS is an unusual or unique setting of evolutionary significance for the brook trout taxon. For this reason, the Director determined t that none of the DPS options are listable entities. This resulted in a “not warranted” petitioned finding, published on May 19, 2009.

Appendix 1: Origins & Importance of Life History Forms

Determining whether life history form represent an element of diversity intended to be conserved via a distinct population segment

For our decision context, our task was determining whether a specific life history form—coaster brook trout—is an element of biodiversity for *Salvelinus fontinalis*, and if so, is it discrete and significant to the taxon. One complicating and contentious issue in this decision was determining whether a life history form is a distinct entity that warrants protection[8].

There was much debate about whether coasters are simply brook trout that opt to "run to the lake," or whether they are life forms that represent an integral aspect of the natural life history diversity of brook trout. Further complicating the issue was how the DPS policy interplays with these two competing contentions. Our Team spent much of the analysis period struggling to understand the biological complexity and competing hypotheses surrounding coaster life history, and to find a logical, supportable approach to marrying the biology and the policy. After considerable, thoughtful study of the best available data on coasters, salmonid life history, and theoretical discourse, and discussion with salmonid and coaster experts and State agency personnel as well as deliberations among our Team, we concluded that the life history forms of brook trout are:

- undeniable components of the brook trout natural diversity
- induced by genetic and environmental factors
- not easily reconstituted if loss
- vitally important for adaptation capability, gene flow, and evolutionary progression, and thus, the long-term persistence of brook trout

These conclusions led us to determine that coasters are a life history form of brook trout, and that life history form, in general, is an element of diversity that the ESA was intended to conserve.[9] In reaching this determination, we contemplated four primary issues, which became the fundamental conclusions listed above.

This appendix summarizes the basis for these conclusions. Most of the data available on coasters are recent, and although insightful, much is yet unknown about the life form. To aid us in making the most biologically sound decisions, we looked to data from other brook trout life forms and populations and other salmonid species (e.g., *O. mykiss*), which have been studied to a much greater extent. The basis for our conclusions was constructed from synthesizing information from multiple sources and multiple surrogate species in addition to the brook trout literature.

[8] This issue was particularly germane to the coaster-only DPS, but was also relevant to the "significant portion of the range" analysis under the brook trout DPS option.

[9] This determination does not indicate that coasters warranted protection under the ESA. Rather, it simply contends that life history form, in general, is an element of diversity that that ESA intended to conserve, and that coasters represent a life history form of brook trout. This is the decision from Step 1 of our decision framework. Given this conclusion, we then needed to analyze whether coasters are discrete and significant, Step 2.

Issue 1: Is the coaster life history form an element of *S. fontinalis* natural diversity?
The ESA does not define what constitutes a distinct population segment (DPS). Looking to the legislative history accompanying the ESA, the purpose for DPSs is to ensure species imperiled within the U.S. do not become extinct just because they are abundant elsewhere (95th Congress House Report, No. 95-1804, 1978; 96th Congress Senate Report, No. 96-151, 1979). The implementing policy states that DPS option is intended to facilitate the interrelated goals conserving genetic diversity and the biodiversity over a representative portion of a species' range (Fay and Nammack 1996). As the coaster brook trout is not a species or subspecies, the intended purposes articulated in the DPS policy—conserving genetic diversity and biodiversity—are pertinent to our analysis. Thus, our first task is determining whether specific life history forms are elements of biodiversity and thereby eligible for protection under the ESA. Intra-specific biodiversity is the natural variation that exists within a species borne from its evolutionary history and exposure to biotic and abiotic influences in its environment (see Naeem et al., 2006). This biodiversity includes the diversity of habitats or ecosystems occupied, the diversity in genetic characteristics, and the diversity in life history characteristics. It is the latter that we are currently addressing.

Within species there is set of life history traits common among all individuals. The subset of these life history traits that influence survival and reproduction is referred to as a species' life history strategy. The life history strategy for salmonid fishes is often characterized by their migratory patterns—either migratory or non-migratory—with respect to their breeding behavior[10]. There are three broad categories of life history strategies among salmonids: potamodromy, oceanodromy, and diadromy. Potamodromy refers to fish that migrate within freshwater only. Oceanodromy refers to fish that migrate exclusively in saltwater. Diadromy refers to fish that migrate between fresh and saltwater. Within diadromy, which is most common strategy among salmonids, fish may be anadromous (fish that mostly live in saltwater but spawn in freshwater), catadromous (fish that mostly live in freshwater but spawn in saltwater), and amphidromous (fish that move between salt and freshwater but not in response to spawning).

Brook trout express both the migratory and non-migratory life history strategies among and within populations. Although not technically correct, it is common convention to classify both the non-migratory and migratory freshwater brook trout as potamodromous, and to further distinguish among their life history strategies, to refer to brook trout as either fluvial, adfluvial, or lacustrine. Fluvial (stream-resident) brook trout are those that complete their entire lifecycle within a stream system. Adfluvial (freshwater migrant) brook trout are fish that live in a lake but migrate to the stream/tributary to spawn. Lacustrine (lake-dwelling) brook trout are fish that live and spawn within a single lake. The anadromous forms (saltwater migrant) of brook trout are referred to as salters (Karas 2002). Coasters are adfluvial and lacustrine brook trout that occur in Lake Superior, northern Lake Michigan or northern Lake Huron (Becker 1983).

Most individuals that exhibit a particular life history strategy also tend to possess distinct morphological (e.g., body size and weight), physiological (e.g., fecundity), behavioral (e.g.,

[10] Complicating this discussion is the imprecise use of the terms describing migratory behavior. All species move within their home range in response to sheltering, breeding, and feeding requisites. In other words, all species migrate. Within the context of this decision, however, we are focused on the migratory behavior for breeding purposes.

migratory) characteristics (NOAA 2004 and Arden 2008). It is this collection of traits that comprise a life history form. As it represents a particular life history strategy, we believe life history form is unequivocally an element of a species' natural diversity and eligible for protection under the ESA.

Issue 2: What determines which life history form a fish adopts?
Throughout our deliberations, a consistent contention was that coasters are simply brook trout that "run-to-the lake," and given suitable environmental conditions, any individual may elect a migratory life strategy. The logical extension of this argument is that coasters do not represent an entity distinct from any other life form of brook trout, but rather, coasters are simply brook trout expressing phenotypic plasticity (i.e., brook trout responding to environmental conditions). The underlying premise of this argument is that brook trout life form does not have a genetic basis, or more precisely, all brook trout have identical genetic constitutions as it pertains to migratory breeding behavior. Thus, the penultimate question in determining whether life form is an element of natural diversity that warrants protection is, "what determines which life history form a fish will adopt?" This question is multi-faceted. We need to understand how life forms exist (i.e., their spatially and temporal population structure), and the origins and underlying mechanisms that trigger adoption of life forms. The first is addressed directly below and second in Issue 3.

The population structure spectrum in salmonids is believed to exist on a continuum, with life history forms persisting as polymorphisms on one end of the continuum and as independent, reproductively isolated populations at the other end. Data available suggest that the evolutionary processes differ along this spectrum. Prior to the last half of this century, the prevailing thought was that observed phenotypic differences among populations were most likely due to phenotypic plasticity expressed by more or less genetically uniform individuals (see Ricker 1972). More recently, the paradigm has shifted towards the view that much of the observed diversity within and among salmonid populations is both genetically and environmentally influenced, and therefore, is at least partially heritable. Under this paradigm, diversity takes on more significance because it would be difficult to replace once lost (NOAA 2004).

Polymorphic populations are those in which more than one phenotype (in our context, this term is synonymous with life history form) is present. In other words, polymorphism occurs when more than one life form spatially and temporally co-occur during some portion of the annual cycle. The degree of interaction between life forms ranges from discrete, independent, co-occurring life forms to cases where the forms interbreed (see NOAA 2004 for a review). In the former, the life forms essentially co-habit as separate, independent populations. In other polymorphic cases, the association between life forms varies greatly. In some polymorphic populations, each type of parent typically gives rise to both migratory and resident phenotypes. In other locations, however, there appears to be a significant asymmetry in the production one type of fish from a parent of the other type, specifically, that an anadromous parent is more likely to produce a resident offspring than vice-versa (Theriault et al. 2007). One analysis of *O. mykiss*, for example, showed that 17% of anadromous adults to have had resident mothers; conversely, 54-70% of resident adults appear to have had anadromous mothers. Similarly, offspring from the different types of crosses show different propensities for smolting and migratory tendencies (Thrower et al. 2004b). These results are concordant with those from other studies of trout populations. As further examined below, together, these studies indicate that whether an individual migrates is a

complex function of its genetic constitution and the opportunities for growth provided by its environment (Jonsson and Jonsson 1993, Pirhonen and Forsmann 1999).

There is a paucity of data for brook trout, and even more scant information for Great Lakes brook trout. What we know about life history form occurrence, however, suggests that *S. fontinalis* shares the breadth of population structure diversity. Fraser and Bernatchez (2005, 2008), for example, documented historical allopatric origin of two sympatric life forms of brook trout in Mistassini Lake, Quebec, Canada. Boula et al. (2002) documented a similar situation for anadromous (salters) and stream resident brook trout in Laval River, California. On the opposite end of the spectrum, Theriault et al. (2007) found that sympatric anadromous and resident brook trout in the Sainte-Marguerite River in Quebec belonged to a single gene pool, and thus, likely occur as a polymorphic, interbreeding population[11].

Recent genetic work has documented a similar but a somewhat smaller breadth of population structures for brook trout within the Great Lakes Basin. Based on data collected to date, both single-form and polymorphic populations exist in Upper Great Lakes. The brook trout populations occupying Tobin Harbor and Lake Nipigon consist of only the lacustrine life form (Quinlan 1999; Swanson 2001). Many of the other brook trout populations occur polymorphisms where resident and adfluvial brook trout occur sympatrically (e.g., Nipigon River system, ON).

Issue 3: Life history form cannot be easily reconstituted if lost.
An attendant facet to the question broached in Issue 2 is whether brook trout life forms are simply due to phenotypic plasticity. The argument is that any individual brook trout can adopt a migratory or non-migratory life history strategy under the right environmental conditions. It then follows that provided a brook trout population persists any lost life forms will be expressed again once suitable conditions (namely, removal of barriers) are restored.

The implications of this contention are substantially germane to the risk assessment portion of our analytical framework. If a life form can be reliably restored, the long-term persistence of life form can be maintained by the persistence of alternative life forms. If a life form, however, cannot be reconstituted from other life forms, the persistence of alternative life forms will have minimal influence on the long-term persistence of the life form of interest. For both reasons, we believe it was necessary to fully examine the subject contention. To ascertain the validity of this supposition, we must understand the origins and underlying mechanisms of life history forms.

Determining the genesis of a life history form is complicated by the fact that the origins of life history forms vary among species and within species and are difficult to definitively determine empirically. As alluded to above, research has shown that the evolution of salmonid life history forms is varied. Some sympatric life forms evolved from separate ancestral origins (e.g., brook trout in Mistassini Lake, Quebec, Canada) while others have a shared ancestral genesis but have become genetically distinct through adaptive radiation (e.g., brook trout in Tobin Harbor, Isle Royale, Michigan).

[11] Yet, there was significant heritability influencing whether an individual migrated or remained as a resident fish. Anadromous females contributed the most to reproduction in this population and interbreeding most often occurred between resident males and anadromous females (Theriault et al. 2007).

Turning to brook trout, and specifically, within the Great Lakes, we again must rely on a handful of studies germane to Lake Superior to surmise the origins of brook trout life history forms in the Great Lakes. Although Danzmann et al. (1998) demonstrated that Lake Superior contains brook trout that originated from two separate glacial refugia, the work of Burnham and Curtis (2001) provides evidence that the different life history forms do not separate out along these lines. Thus, unlike the brook trout occupying Mistassini Lake, Quebec, there is no evidence of ancestral allopatric origins for sympatric brook trout life forms in the Great Lakes. Based on the glacial history of the Great Lakes and recent genetic studies of brook trout in Lake Superior, there are two plausible scenarios for the evolutionary origins of coasters (see Ardren *in litt*. 2008a).

Scenario 1 is relevant to the adfluvial and lacustrine life forms found on Isle Royale. Given the genetic distinctiveness of these life forms, and their difference in spawning habitats (stream vs lake), it is likely that these forms evolved in postglacial Lake Superior via adaptive radiation and concomitant assortative mating. Scenario 2 suggests that life history forms associated with other brook trout populations within Lake Superior are expressed via phenotypic plasticity with random mating between the life forms within a population. Genetic studies in Salmon Trout River and Nipigon Bay indicate phenotypic plasticity plays a major role in the expression of the adfluvial coaster and stream-resident forms. Scribner et al. (2008) and D'Amelio and Wilson (2008) were unable to find genetic differences between presumed resident and adfluvial brook trout in Salmon Trout River and Nipigon Bay, respectively. As such, it appears that phenotypic plasticity likely plays a major role in the expression of the life forms in these areas of the Upper Great Lakes. Thus, phenotypic plasticity and adaptive radiation appear to represent the continuum of evolutionary processes underlying the expression of life history form variation in populations of brook trout in Lake Superior.

Thus far, we have concluded that brook trout life forms may occur as discrete populations or as polymorphic populations with varying degrees (both at a geographic and temporary scales) of interbreeding between life forms (discussed in Issue 2). We believe that the evolution of the coaster life form in Lake Superior are of postglacial origin and are likely due to phenotypic plasticity and adaptive radiation (discussed above). To fully understand the underlying mechanisms, we needed to further explore the implications of phenotypic plasticity and adaptive radiation induced life history forms. Once we have a firm grasp of the underlying mechanisms, we will have more insights into whether life forms can be readily reconstituted.

Although the origins and the evolutionary processes operating on life history forms are varied, the basis for all life history form is consistent; there is an obligatory genetic constitution associated with life history form development. There is little brook trout-specific data available, but a rich literature within the salmonid arena from which to draw inferences.

The prevailing belief among salmonid scientists is that both genetic and environmental factors trigger the "switch mechanism" (i.e., determines which life history form is adopted). Phenotypic plasticity is the ability to express either life form, thus, in order for fish to possess the ability to express multiple life history forms, the species must have the genetic code for phenotypic plasticity. In other words, the mechanism underlying all life form diversity, regardless of evolutionary history, is phenotypic plasticity. The degree to which is phenotypic plasticity is expressed varies within and among species, and is likely determined by a species genetic

constitution. Phenotypic plasticity has costs over time (Agrawl 2001). Plastic genotypes have and must maintain sensory and developmental pathways to induce plastic responses. The genetic costs (e.g., maintenance of physiological machinery to sense or regulate phenotypic plasticity) involve tradeoffs between the degree or pattern of plasticity and other traits that increase fitness. It then follows that over time the genetic code for phenotypic plasticity would be lost if not used. As the genotype that maintains the ability for phenotypic plasticity can be lost or substantially reduced from a population through selection pressures (Theriault et al. 2008), it also follows that phenotypic plasticity cannot be readily reconstituted even if the environmental conditions favor this life form.

Based on these findings and empirical information, the Science Review Panel for the Northwest Salmon Recovery Team cautioned against complacency concerning extirpations of life history forms. They argued that preserving life history diversity is vitally important to the long-term survival of a species, and that the migratory form either within a polymorphic population or as a component of a larger population cannot be easily reconstituted from a purely resident stock. They contend that in cases where an anadromous run is extinct or not self-sustaining, there is no scientific justification for the claim that the long-term viability of an ESA could be maintained by a landlocked resident population alone, or by a landlocked resident population connected by one-way gene flow into anadromous population. In fact, results from studies suggest that the stronger conclusion is that the weight of scientific evidence is against the feasibility of establishing a viable anadromous population from a pure resident population. They cite the numerous stocking of *O. mykiss* around the world with only one published report on anadromy developing from a resident population. Further, they argued that if it could be done at all, it would be most easily accomplished within a few or perhaps several, but not many, generations after extinction of a self-sustaining anadromous run.

Based on the published literature and opinions of experts working with salmonids, we believe it is appropriate to conclude that the coaster life form cannot be readily re-expressed once lost from a population[12].

Issue 4: Life history diversity is vital for maintaining adaptive ability and gene flow, and hence, influences the evolutionary trajectory and long-term survival of a species.
As discussed above, life history diversity is a key component of a species' natural diversity. Salmonid life history traits often exhibit considerable diversity within and among populations. Some of these varying traits are migration behavior, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at maturity, egg size, developmental rate, male and female spawning behavior, and physiology (NOAA 2004).

Life history diversity influences capability for adaptation and specialization to the inherent variability in their environment, capability for maintenance of gene flow and recolonization

[12] This conclusion was adopted by our group early on in our analysis, but was later replaced by a competing supposition held by the brook trout experts within the Great Lakes. In brief, coaster and Great Lakes brook trout experts believe that the coaster form can be readily reconstituted from a resident stock. See Appendix 7 for further discussion.

potential, and the overall evolutionary progression of a species. As we discuss below, all of these affect the resiliency, redundancy, and hence, the long-term persistence of species.

First, life history diversity is an outcome of natural selection. Natural selection is an evolutionary process that results in favorable phenotypes becoming more common and unfavorable phenotypes less common. Through natural selection, organisms develop adaptations that help them cope with the stressors and pressures in a changing environment. These adaptations can be physiological, structural or behavioral, but all are a direct consequence of selection for specific phenotypes in response to particular environmental conditions. Certain individuals, for instance, may develop specialized morphology or unique behaviors due to exposure to specific environmental conditions. Hence, the greater the life history diversity, the broader breath of adaptations a species may accrue. These adaptations, in turn, provide the means for a species to accommodate greater set of environmental stressors and pressures. In other words, life history diversity helps spread the risk (Rieman and Dunham 2000). Conversely, the loss of diversity or unique adaptations can substantially reduce the ability of a species to respond and adapt to future environmental changes.

A classic example of this was documented with sockeye salmon in Bristol Bay, Alaska (Hilborn et al. 2003). Individual populations display diverse life history characteristics and local adaptations to the variation in spawning and rearing habitats. This biocomplexity has enabled the aggregate of populations to sustain its productivity despite major changes in climatic conditions affecting the freshwater and marine environments during the last century. Different geographic and life history components that were minor producers during one climatic regime have dominated during others, demonstrating that the biocomplexity of fish stocks is critical for maintaining their resilience to future environmental change.

Another example of how life history diversity directly affects persistence is clearly demonstrated with *O. mykiss*. Steelhead viability (the anadromous life form of *O. mykiss*) can affect productivity over the short-term and the probability that the population persists in the long term by maintaining the population's access to ocean habitat and food resources. The number of years spent at sea has a profound influence on their ultimate size whereas the number of years spent in the less productive freshwater habitat has little or no effect. Fecundity of salmonids increases markedly with size; anadromous forms of the coastal rainbow trout are approximately 3 times more fecund that resident forms for example. As the amount of freshwater habitat declines, the fitness of the stream-resident life history form will decrease relative to the anadromous life history form because anadromy allows access to an oceanic environment that promotes greater somatic growth, higher survival and greater fecundity. Selection in this environmental condition will favor an increase in adoption of anadromy and a diminution in frequency or complete loss the resident life history form (NOAA 2004).

As with other migratory salmonids (Reiman and Dunham 2000, Quinn 1993), coasters return to their natal stream to spawn (Wilson et al., 2008, D'Amelio and Wilson 2008). As a result, brook trout form reproductively isolated populations, which allow natural selection to operate on heritable phenotypic traits, and results in an array of locally adapted populations (Dittman and Quinn 1996, Hilborn et al 2003). Depending on environmental conditions, different individuals and populations will perform well at different times and localities. For example, coasters,

because of their morphological and physiological differences are typically larger and more fecund than stream-resident brook trout. Under natural conditions, we expect coasters to be substantial contributors to Great Lakes brook trout productivity. Coasters represent the larger and more fecund individuals in the Great Lakes brook trout population, and differ in age structure, age and size at first reproduction, sex ratio, spatial distribution of individuals, and mate selection. Preserving the different life history strategies and locally adapted populations of brook trout would buffer the species from natural or human related changes, i.e., maintain its resiliency to adapt to future changes.

Second, natural life history diversity is important for gene flow and recolonization potential, particularly for spatially discrete populations (Cole 1954, Thorpe 1989). Isolation of populations allows adaptation to local conditions, but may also lead to reduced genetic diversity due to reduced gene flow and founder effects (Liseca and Allendorf 1995). Gene flow refers to the movement of genes from one population to another via successful reproduction by straying fish. The migratory life forms are the sole vectors for gene flow among subpopulations; and without this source, genetic variability can be reduced in small, isolated populations. Dispersal also provides for rescue effects and recolonization potential. As the sole dispersers, rescue or recolonization would not be possible without the migratory form. Lastly, dispersal facilitates the distribution of unique adaptive traits among populations. Without gene flow, genetic diversity within populations may decline, significantly reducing sustainability and population recovery potential (Hillborn et al., 2003, Reusch et al., 2005, Ryman et al., 1995). Thus, loss of the migratory forms in particular, may have a substantial effect on genetic diversity and long-term persistence of a species.

Although spawning site fidelity occurs strong in brook trout, coasters stray or disperse among streams (D'Amelio and Wilson 2008). As such, brook trout populations within the Lake Superior Basin function as metapopulations, with the coaster life form serving as the dispersers (D'Amelio and Wilson 2008). Straying coasters provide a vector for gene flow among brook trout populations (D'Amelio and Wilson 2008) thereby countering the loss of genetic variation without overwhelming local selective forces and adaptation (Miller and Kapuscinski 2003). Also through dispersal, individuals are available to rescue or recolonize threatened and extirpated populations (Brown 1977, Reeves et al., 1995). Of the brook trout life forms, coasters are the natural providers of this rescue and recolonization function. Coasters in their adaptation to different habitats, differing ecologies, and dispersal abilities provide redundancy and resiliency and buffer the Great Lakes brook trout against extirpation.

Third, maintenance of life history diversity is important for sustaining evolutionary processes (e.g., patterns of mutation, selection, drift, recombination, migration, and population turnover), and hence, ultimately the evolutionary trajectory of a species. The purpose of the ESA is to conserve threatened and endangered species and the ecosystems upon which they depend. To achieve this purpose, we must protect the processes that sustain species and their habitats; this includes both the evolutionary processes and the ecological integrity of populations (Moritz 1999). While it is not the intent of the ESA to determine which populations will play an important future role in the evolution of the species, to effectively achieve this goal we must conserve as many of the important evolutionary building blocks of the species as possible so the course of evolution is unconstrained (Waples 1995).

Phenotypic variation, such as differences in life history characteristics, is an expression of evolutionary processes in operation. Polymorphic populations often display bimodal distribution in their phenotypic traits, and such distributions suggests that the life history polymorphism is maintained by disruptive natural selection against intermediate types, perhaps augmented by assortative mating (NOAA 2004). Extirpation or even substantial reduction of a life history form within a polymorphic population inevitably alters the natural evolutionary trajectory of that population. Sufficient alteration of the evolutionary trajectory of a population can in the long term cause its phenotype to become so distinct that the original species is considered extinct (referred as phyletic extinction or pseudoextinction) (Simpson 1953, Raup and Stanley 1978, Ridley 1996 within NOAA 2004).

Appendix 2: Analysis of Consequences of 2 DPS Options

We established two broad DPS options for addressing the petition request of listing the coaster brook trout throughout its range in the coterminous U.S.: Option 1 was a coaster-only population segment in the upper Great Lakes and Option 2 encompassed all brook trout within the upper Great Lakes. Neither DPS option dominated relative to the stated objectives, thus, we conducted a multiple-objective trade-off analysis to identify the preferred option. We used the "Simple Multiple Attribute Tradeoff" technique to complete this analysis. This technique entails assigning weights to the relevant objectives, multiplying the outcomes associated with the objectives by the respective weights, and summing the weighted scores for each objective within an alternative to obtain an overall weighted score. To determine the weights for the relevant objectives,[13] we used the swing weighting technique. The objective weights were determined by a group consensus (Table 1), and the overall weighted scores for each DPS option were individually determined (Table 2).

Table 1: The Coaster Brook Trout Team Swing Weighting Results

	Conservation Potential	**Regulatory Burden**	**Rank**	**Rate**	**Weight**
Benchmark	0	1	3	0	0.00
Best Case – Conservation	1	1	1	100	0.91
Best Case - Burden	0	5	2	10	0.09
			∑	110	

The swing weighting process included following 4 steps:

Step 1: Establishing Benchmarks. We identified the worst case (benchmark) and the best case scenarios for each objective.

Step 2: Determining Ranks. We asked which would be more desirable, swinging conservation potential from 0 to 1 or regulatory burden from 1 to 5? The objective with most desirable swing was assigned a rank of 1, the worst case scenario (both objectives having their worst outcome possible) assigned 3 and the remaining objective assigned 2.

Step 3: Determining Rates. The ranked 1 and 3 objectives were assigned 100 and 0 points, respectively. We then asked how important is the swing from worst to best of number 2 ranked objective to the swing from worst to best of the number 1 ranked objective (e.g., is it half as important?).

Step 4: Determining Weights. This entailed dividing the objective's Rate by the sum of rates.

Once the weights for each of the two pertinent objectives were assigned, these weights were used to calculate an overall weighted score for each alternative (i.e., the SMART technique).

[13] Only those objectives that we determined influential in our choice between the two DPS options are considered in this analysis. See main document for explanation of why only objectives conservation potential and regulatory burden are pertinent.

The SMART process included the following 3 steps:

Step 1: Standardizing the outcomes. To compare and sum scores across objectives, we put the outcomes (or consequences) on a common scale.

Step 2: Determining weighted scores. We multiplied the normalized value by its respective weight, which was calculated using the swing technique above.

Step 3: Determining overall scores: We summed the weighted scores for each alternative to obtain an overall score for each Team member.

Table 2: The overall weighted scores for the two DPS alternatives by Team member. The preferred alternative for each member is bolded. For Team member 3, the analysis indicates both alternatives will perform equally well.

Team Member	Coaster Only DPS	Brook Trout DPS
1	0.55	**0.64**
2	**0.77**	0.45
3	0.55	0.55
4	0.55	**0.70**

Appendix 3: Policy Interpretations of Discreteness & Significance

Prior to initiating our DPS analysis, we clarified the interpretation of the terms discrete and significant. Our interpretation is based on a study of the statute, the DPS policy, legislative history of the term DPS, and past applications of the policy.

The statute itself does not lend much guidance as to the intent for providing similar protection to distinct vertebrate populations as those allowed for species and subspecies. Insights regarding Congress' intent, however, can be gleaned from the legislative history. Within the report from the 96th congressional session, Congress stated that, "*…the U.S. population of an animal should not necessarily be permitted to become extinct simply because the animal is more abundant elsewhere in the world*" (Senate Report 151, 96th Congress, No. 96-151, 1979). In other words, Congress' intent was to provide a means to prevent extirpation of species within the U.S. regardless of their conservation status in other portions of their range.

To provide consistent interpretation of the term "distinct population segment," U.S. Fish and Wildlife Service and the National Marine Fisheries Service (Services) published a Notice of Policy in 1996 (FR 61(26), pgs 4722-4725). According to this policy, any interpretation of the term "distinct population segment" should be aimed at carrying out the purposes of the ESA[14]. In addition to the stated purposes of the ESA, the policy indicates that the Services understand the ESA to support interrelated goals of conserving genetic resources and maintaining natural systems and biodiversity over a representative portion of their historical occurrence. The policy is intended to recognize both of these intentions without focusing on either to the exclusion of the other. In applying the policy, the terms discrete and significant are intended to have their commonly understood senses. The policy stipulates two criteria—discreteness and significance--which population segment must satisfy in order to be considered a DPS.

Recently, the Solicitor in providing guidance on another aspect of the statute (Solicitor Opinion, March 16, 2007) proffered additional insights we can use in interpreting the term "distinct population segment." He stated that "*Congressional intent in using the word 'extinction' is supported by the way in which the word is used elsewhere in the ESA. In section 2, Congress found that 'various species of fish, wildlife, and plants in the United States' that are of considerable 'value to the Nation and its people have been rendered extinct,' or 'are threatened with extinction' (ESA section 2(a)(1)-(3)). These findings suggest that Congress viewed the disappearance of a species within the part of its range occurring in the United States as constituting 'extinction' in that geographic area, even though the species might be prospering elsewhere."* In other words, requiring the species to be in danger of extinction throughout its entire range without regard to its status in the U.S. could inhibit the ability of the Secretary to achieve one of the primary objectives of the ESA, which is to safeguard, for the benefit of all citizens, the Nation's heritage in fish, wildlife, and plants.

[14] Section 2(b) of the ESA states that the purposes are: (1) to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, (2) to provide a program for the conservation of such endangered species and threatened species, and (3) to take such steps as may be appropriate to achieve the purposes of the treaties and conventions set forth in subsection (a) of this section.

Following from the Congressional history, the DPS policy and legal counsel, we believe the purposes for allowing protection of population segments are twofold. One is to safeguard our nation's heritage of fish, wildlife, and plants. Second, is to protect imperil population segments that are important to the conservation of their taxon. With these purposes firmly in mind, we turn to clarifying the terms "discrete" and "significant."

Discrete

The DPS policy provides lucid guidance as to the purpose of the markedly separate standard. The authors of the policy stated that the "interests of conserving genetic diversity would not be well served by efforts directed at either well-defined but insignificant units or entities believed to be significant but around which boundaries cannot be recognized." Thus, the intent of the markedly separate standard is to require that a population segment can be circumscribed.

In most of our previous DPS decisions, discreteness was based on physical separation of that population segment from other members of the taxon (e.g., Sonoran Desert bald eagle, bull trout, Siskiyou Mountains salamander). Situations where we have recognized discrete populations that are sympatric with other members of the taxon are much less common. In these situations, we need to evaluate whether there is marked separation based on physiological, behavioral, and ecological factors. For example, Lower Kootenai River burbot was found to be discrete from other lacustrine burbot because their migratory behavior resulted in a disparate spawning period that prevented reproductive mixing between the two groups. In another example, NMFS established multiple steelhead-only DPSs by determining that steelhead were markedly separate from resident rainbow trout due to differences in adult size and fecundity, smoltification, differences in prey and predators, and migratory strategy (i.e., differences in physiological, ecological and behavioral characteristics).

Because the term "distinct population segment" automatically leads people to think of "population" in the traditional sense—a collection of individuals reproductively isolated from other individuals belonging to the same taxon—there is often confusion regarding the meaning/intent of the markedly separate standard. The policy is clear, however, that reproductive isolation is not required to meet the markedly separate criterion. The preamble of the policy states, "…logic demands a distinct population recognized under the Act be circumscribed in some way that distinguishes it from other representatives of its species. The standard established for discreteness is simply an attempt to allow an entity given DPS status under the Act to be adequately defined and described" (61 FR 4721, at 4724; February 7, 1996). The caveat is that the difference must be marked (i.e., obvious, distinctive). NMFS' steelhead decision exemplifies this point. Migratory steelhead occur sympatrically with the stream–resident rainbow trout in many locales. Although stream-resident rainbow and migratory steelhead are not reproductively isolated and despite some overlap in ecological, behavioral, and physiological traits, NMFS concluded resident rainbow trout and migratory steelhead are markedly separate per the DPS policy.

Similarly, the DPS policy is very clear that evidence of genetic distinctness is not required to conclude that two groups are markedly separate. Genetic data may be used to demonstrate marked separation and significance. Although seemingly straight-forward, the Service's application of genetic information in recent decisions confounds this issue. In our 1999 proposed

listing of bull trout, we determined that the four life forms are not discrete from each other because they (1) interbreed and (2) are not genetically distinct. In our 2002 withdrawal of the proposed coastal cutthroat listing, we determined that the different life history forms are genetically more closely related within a drainage than are populations from different drainages, indicating that the migratory and non-migratory portions of the population of cutthroat trout represent a single evolutionary lineage and thus part of the same DPS. Although genetic data may be used as supporting evidence for a conclusion that a population is not markedly separate, the contention that this information alone is sufficient evidence for such a conclusion is contrary to explicit statements in the policy. These conclusions indicate that evidence of reproductive exchange and genetic similarity negate any marked separation due to factors that the policy directs us to consider (i.e., ecological, behavioral, and physiological traits). We believe the appropriate application of the policy is to use evidence of reproductive isolation and genetic discontinuity as support for a conclusion that considers all data available regarding physical, ecological, behavioral, and physiological factors.

Based on this reasoning, we believe the markedly separate standard relies primarily on differences in physical, physiological, ecological, and behavioral characteristics, but does not set prerequisites regarding the sources of such differences or preference for data used in the analysis. Specifically, it does not make statements or draw conclusions regarding the biological/ecological origins of those differences, but merely requires that a group can be circumscribed or defined. Thus, a DPS is not necessarily consistent with taxonomic state; indeed it may differ from other biological or ecological groupings to which the population segment belongs. The complex life histories of salmonids make this taxonomic group a quintessential example of such situations.

Significance

Within the legislative history of the ESA, the 96th Congress expressed concerned that use of the vertebrate population clause is vulnerable to misuse and explicitly mandated that we use this listing option "sparingly." The framers of the policy established the significance criterion to explicitly address this Congressional concern. Specifically, we are directed to evaluate the biological and ecological significance of a discrete population segment based on available scientific evidence of its importance to the *taxon* to which it belongs.

We need to rely on the DPS policy for edification on intent of the "significance" standard, specifically. Within the preamble of the DPS policy, the authors explained that the DPS policy is for the purposes of "achieving the two interrelated goals of the ESA: conserving the (1) genetic diversity and (2) biodiversity of a species throughout a representative portion of its historical range.

In devising a policy that achieves both of these goals, the authors acknowledged that "...populations commonly differ in their *importance to the overall welfare of the species* they represent, and it is this importance that the policy attempts to reflect in the consideration of significance." To capture the potential mechanisms in which a discrete population segment may be important to the overall welfare of a species, policy identifies four specific factors we must evaluate. In addition, because it is impossible to prospectively anticipate all potential factors that may be significant, the policy provides a catch-all category that allows for any other factor that may bear on the biological and ecological importance of a population segment.

To address the expressed Congressional concern that we exercise this authority sparingly, the significance analysis is conducted at the taxon level. In doing so, only population segments that are significant to the taxon will be conserved via DPS.

Based on a thoughtful synthesis of the statutory and policy guidance as well as past applications, we believe the significance standard serves the purposes of[15]: (1) improving welfare of the taxon by influencing its resiliency, vulnerability, persistence, or survival; (2) maintaining the elements of intraspecific biodiversity—i.e., ecological, biological, or phenotypic diversity--of the taxon, which facilitates the overall adaptability and persistence of the species; and (3) preserving the genetic diversity of the taxon, which allows for the natural evolutionary progression of the taxon. In evaluating the four significance factors, it is these purposes that we used in determining whether coasters are significant to *S. fontinalis*.

(1) Persistence in an unusual or unique ecological setting for the taxon
There is no specific guidance for defining "…an usual or unique ecological setting" within the policy. Based on past DPS rules, this factor is generally interpreted in its commonly understood meaning, assessing whether the ecological setting is unique or unusual for the taxon. For example, the ecological setting for the Southwestern Washington/Columbia River DPS of coastal cutthroat was considered unique based on the presence of "aquatic systems that feed three large estuaries with extensive intertidal mud and sandflats" which are "very different from estuaries north and south of the DPS." The ecological setting for the Southeast Alaska DPS of the Queen Charlotte goshawk was determined unique because it experiences colder temps and greater snowfall snow than other parts of the taxon's range. Similarly, the ecological setting for the West Coast DPS of the fisher was considered unusual because it lacks the "extensive broadleaf hardwood component that is common in the eastern portions of the species' range" and it is typified by "mild, wet winters and warm, dry summers in comparison to the rest of the range."

One recent finding, however, appears to establish a different analysis for this significance factor. In the delisting rule for the bald eagle species, we determined that the Sonoran Desert discrete population did not constitute a DPS because the ecological setting is "essentially the same as used by bald eagles elsewhere – riparian habitat." The Sonoran Desert population occupies a desert habitat and in response uses different habitats than typical for bald eagles for nesting, has an earlier breeding season than other parts of the range, and has a smaller body size. The Service determined that "the adaptations exhibited by bald eagles in the Sonoran Desert are not unique to this setting. Rather, the variability in bald eagle nest site selection, breeding phenology, and size are noted elsewhere in the range where the species confronts similar limitations, such as the absence of nesting trees or high temperatures." Thus, this finding appears to have expanded the interpretation of this factor to require individuals in a discrete population segment to occupy atypical niche-level habitats or demonstrate unique or exceptional behaviors in response to the habitat, relative to individuals occupying areas outside the discrete population segment. This

[15] It seems that requiring significance to be judged at the taxon level undermines the expressed intent of Congress to safeguard our Nation's biological heritage. We believe to fully comport with the intent of the ESA, the "international border" factor should apply to both discrete and significance. This would allow protection of species imperiled in the U.S. but not elsewhere in the world. The current policy appears to allow for this interpretation with its fifth significance factor, "any other factor…"

interpretation does not seem consistent with a commonly understood interpretation of "persistence in an ecological setting unusual or unique for the taxon."

In our deliberations, we looked to the DPS policy and past applications to guide us in determining how ecological setting specifically achieves the enumerated purposes of the significance standard. The objective of the unique/unusual ecological setting factor is to protect discrete populations that contribute to the overall welfare and that help maintain the natural and genetic diversity of the taxon. A unique or unusual ecological setting may indicate adaptation, which contributes to representation and redundancy of a species. Individuals occupying a unique or unusual ecological setting may be exposed to different selective regimes to which the species is adapted or the species may respond differently to selective forces, such that individuals within such a setting are more resistant to certain catastrophes or environmental change. Discrete populations adapted to unique settings may also be more resistant to significant ecological change, such as natural catastrophes, habitat degradation, species invasion, or climate change (Hilborn et al. 2003). Fish populations, specifically, may adapt to unique settings by developing discrete stocks, which have distinct patterns of growth, recruitment, mortality, and susceptibility to angling and predation (Hilborn et al. 2003, Ruzzante et al 2006). It is unlikely that a stressor will affect different habitat types at the same time, frequency, or intensity. In effect, occupying a diversity of ecological settings "spreads the risk" and decreases a taxon's overall risk of extinction. Such diversity and adaptation in a species, as influenced by the ecosystem upon which it depends, contributes to the representation and resiliency of the taxon. Thus, occurrence in an unusual ecological setting is an indication that a population segment represents a significant resource of the kind sought to be conserved by the Act.

Through precedent, most applications appear to interpret this factor as a simple assessment of the ecosystem occupied by the DPS in comparison to the remainder of the taxon. Thus, consistent with past precedence, we interpret this factor as whether the ecological setting is unusual or unique for the taxon and in a manner that is relevant to the four specific purposes of the significance standard.

(2) Significant gap in the range
Based on past DPS rules, this factor also has a straight-forward interpretation, with the discrete population being evaluated as a geographic portion of the range of the taxon. Where available, DPS findings have used percentage area in their evaluation. For example, this factor has been invoked for the West Coast DPS of the fisher (20% of the historical range), the Queen Charlotte goshawk DPS (33% of the land area and 50% of the productive forest), and the Applegate and Grider DPSs of the Siskiyou Mountains salamander (59% and 41%, respectively, of the overall range). In the coastal cutthroat (proposed listing withdrawn) decision, we found that loss of the Southwestern Washington/ Columbia River DPS would result in a significant gap based on genetic consequences. We concluded that, "Populations may be reproductively isolated because of limited migratory range and timing. The loss of these populations would negatively affect the genetic resources of coastal cutthroat." This finding indicates that elements other than geographic range may also be appropriate.

We believe, based on the past applications and the guiding purposes for the significance standard, that significant gap in the range should be evaluated in light of the effect on the species

persistence (in particular, the loss of redundancy and resiliency) and on the maintenance of the species' natural diversity (i.e., ensuring that the ecological and genetic diversity is well represented).

(3) Differs markedly from other populations of the species in its genetic characteristics
On its face, this factor has also been straightforwardly interpreted, with the detection of genetic differentiation or distinctiveness of a population segment or lack of evidence of gene flow being interpreted as differing markedly. For example, the West Coast DPS of fishers was determined to be genetically distinct from fisher in the remainder of the taxon because "native fishers in California have reduced genetic diversity compared to other populations." Further, for salmonid species such as coastal cutthroat and steelhead, DPS were found to be significant, in part, due to genetic distinctiveness among the major geographic areas upon which the DPSs were delineated.

The policy, however, appears to require that relatively clear evidence of marked genetic differences be available to meet this factor. For example, despite some evidence to the contrary, we concluded that the Sonoran Desert population of bald eagles was not genetically distinct from other populations because "neither enzyme electrophoresis nor DNA fingerprinting resolved any specific genetic markers with which Arizona eagles could be differentiated from other populations. The available genetic studies on bald eagles are dated, the sample size was small, and researchers conducting the studies found the results to be inconclusive."

Any variability in the use of this factor seems to be related to the availability and reliability of the genetic data itself and not interpretation of the policy standard. Based on past application, clearly the burden of proof in establishing significance rests with the agencies. We must demonstrate that the discrete population segment does indeed differ in its genetics characteristics.

(4) Other factors
The DPS policy allows for the consideration of other factors in view of the potential significance of a population segment. This recognizes that circumstances are likely to vary from case to case and that it is not possible to anticipate all the factors that might have a bearing in the biological and ecological significance of a discrete population segment.

One trait that has been considered as an additional significance factor is life history variation. In NMFS' 2006 proposed rule for the Puget Sound steelhead DPS, NMFS asserts that the DPS, which consists entirely of anadromous individuals, represents an "important component in the evolutionary legacy of the *O. mykiss* species" based, in part, on its unique life history strategy (anadromy). Specifically, NMFS contends that this life history trait "helps establish the evolutionary importance of the Puget Sound steelhead ESU and also satisfies the "significance" criterion of the DPS Policy." NMFS further argues that the proposed Puget Sound steelhead DPS, if lost, would represent a significant loss to the life history diversity of the taxon. Another example is found in the Service's 2003 12-month finding for the lower Kootenai River burbot, in which we consider the adfluvial trait as "potentially significant to the remainder of the taxon." (Due to a lack of information regarding life histories in <u>other</u> burbot populations, this finding ultimately did not consider this factor to indicate the significance of this population segment. However, this example highlights how a unique life history or behavior could meet the significance factor.) Consistent with past DPS findings and in light of its importance to the

conservation of a species, we believe life history diversity is an appropriate factor in evaluating whether a discrete population segment is significant.

Appendix 4: Discrete and Significance Analysis for the Upper Great Lakes Coaster DPS

Our analytical approach involves a multi-step process with decisions, analyses, and feedback loops nested within each step. Step 2 of this process is entails determining whether there are any admissible DPS units. This determination entails a 3-phase analysis: I) identifying potential population segments, II) determining whether such population segments are discrete from other sympatric brook trout population segments, and III) assessing whether these discrete population segments are significant to the taxon (i.e., to brook trout rangewide). This appendix summarizes our Phases II and III analyses for the coaster only DPS option.

Background

Coaster brook trout belong to the subspecies *S. fontinalis*. As with most salmonids, brook trout have multiple life history forms (see Appendix 1 for further clarification): fluvial (stream-resident), adfluvial (freshwater-migratory), lacustrine (lake-dwelling), and anadromous (brackish/salt water migratory). Within the Great Lakes Basin, *S. fontinalis* expresses the fluvial, adfluvial, and lacustrine life history forms. Coasters represent the adfluvial and lacustrine life forms of brook trout that occupy the shorelines of the Great Lakes and the islands within the Great Lakes. The adfluvial form migrates from the lake into tributaries for spawning and the lacustrine life form completes its entire life cycle within the lake (Huckins et al. 2008).

Coasters have been long recognized by local, scientific, and regulatory communities. In 1983, Becker in "Fishes of Wisconsin" described coasters as brook trout that spend part of their life in the Great Lakes, but annals are replete with descriptions of fishermen catching lake-dwelling brook trout of record sizes, weights, and longevities long before (Roosevelt 1884, Behnke 1994). The Great Lakes Fisheries Commission (consisting of representatives from the Wisconsin, Minnesota, and Michigan Departments of Natural Resources, Ontario Ministry of Natural Resources, U.S. Fish and Wildlife Service, and numerous tribal nations) recognized the plight of coasters and in 2003 adopted "A Brook Trout Rehabilitation Plan for Lake Superior" (Newman et al. 2003). Although lacking taxonomic distinctiveness, coasters have been long recognized as a distinct entity.

Discreteness

Our task in determining whether coasters are markedly separate from all other brook trout was to establish discreteness between: (1) coasters and brook trout outside the Great Lakes Basin, and (2) coasters and stream-resident brook trout within the Great Lakes Basin. Coasters, as well as resident brook trout within the Great Lakes Basin, are markedly separate from brook trout outside of the Great Lakes basin due to physical separation of the drainage. There are no natural opportunities for intermixing of Great Lakes brook trout with brook trout outside the Great Lakes Basin. Thus, coasters are discrete from brook trout outside the Great Lakes Basin.

Similarly, coasters that occupy the lake year round (i.e., lacustrine brook trout) are discrete from stream-resident brook trout due to physical separation. As discussed below, lake-dwelling coasters are markedly separate from stream-residents in ecological, behavioral, and physiological characteristics, as well.

Evaluating discreteness between coasters and stream-residents occupying the Great Lakes proper is more complicated as physical separation is not absolute in all localities. In some situations, coasters occur as separate subpopulations (e.g., Isle Royale, MI); in other areas (e.g., Nipigon River), they occur as polymorphic populations, with individual fish exhibiting distinct morphological, physiological, and behavioral characters associated with one or the other life history forms. Our analysis is based on what we specifically know about coasters and supplemented with data from other salmonids and theoretical underpinnings from the fields of conservation genetics and biology.

Coasters that occur sympatrically (i.e., adfluvial brook trout) with stream-residents (fluvial brook trout) are not physically separate. However, the distinct life histories associated with the coaster and stream-resident life forms translate into different ecological, behavioral, and physiological characteristics between the two forms (Huckings et al 2008, Huckins and Baer 2008 and Ridgeway 2008). Coasters are markedly separate from resident brook trout in their lake-dwelling and migratory behavior (Hubbs and Lagler 1949, Becker 1983, Newman et al. 2003, Huckins and Baker 2008, Schreiner et al. 2008). Lake-dwelling coasters spend their entire life within the lake environment; migratory coasters move between their natal streams into the lake (Newman 1999 and 2000; Stimmell 2006, Mucha and Mackereth 2008, D'Amelio and Wilson 2008). Stream resident brook trout remain within their natal river system (Becker 1983, Huckins et al. 2008). This behavioral difference leads to ecological separation, as well. As stream-resident fish do not leave their natal stream, coasters and stream-resident occupy different environs during most of the year. While coasters and stream-resident fish may use similar habitat (tributaries) during spawning, coasters spend the majority of their annual lifecycle in the lake. Stream-resident fish may occupy different portions of the tributary, but they do not typically use the lake environ. These differences mark an ecological (i.e., lake versus stream habitat) and a behavioral (i.e., migratory) separation between the two life forms. Further elaboration regarding the ecological differences between stream and lake—specifically, Great Lakes—environs is discussed in the Significance section below.

Coasters and resident brook trout also differ in morphological and physiological traits: marked differences are seen in adult size, longevity, maturity, and fecundity. Adult coasters range in size from 12 - 26 inches (Quinlan 1999, MIDNR 2008, Huckins and Baker 2008, Huckins et al. 2008), but commonly reach lengths of 16 inches, with a known maximum length of 33 inches (Scott and Crossman 1973, Becker 1983, Quinlan 1999, WIDNR and USFWS 2005, MIDNR 2008, Huckins and Baker 2008, Huckins et al. 2008). The body mass of adult coasters typically ranges from 1-6 pounds (Quinlan 1999, WIDNR and USFWS 2005, MIDNR 2008) with a maximum of 14 pounds (Scott and Crossman 1973, Swainson 2001). Adult resident brook trout typically range in size from 6 -14 inches (Becker 1983) and usually weigh less than a pound (WIDNR and USFWS 2005). Coasters typically reach 6-7 years of age (Huckins and Baker 2008, Quinlan 1999), while resident brook trout typically live only to age 3 and rarely reach ages of four or five years (Scott and Crossman 1973, Power 1980, Becker 1983). Female coasters typically mature at age 3 or 4 (Quinlan 1999, Huckins and Baker 2008) while most female resident brook trout mature by age 1 or 2 (Power 1980, Becker 1983). Coaster females produce around 2,000 – 3,000 eggs (Swainson 2001) and resident brook trout fecundity ranges from 100 - 1,000 eggs per female (Scott and Crossman 1973, Power 1980, Becker 1983). Resident males mature as early as their first summer

(Becker 1983) while male coasters mature in their second year, at age 1 (Quinlan 1999, Ward 2007).

Although there is an overlap between coaster and resident brook trout in morphological and physiological traits, this overlap is small, with most coasters and residents clearly occupying non-overlapping portions of the continuum. In polymorphic salmonid populations, these traits are often expressed as continuous but bimodal distributions (NOAA 2004). The data on coasters and stream-residents are consistent with this type of relationship. The coaster life forms comprise one of the bimodal distributions, stream-residents the other, and the overlap in traits between the two forms occurs at the tails. We therefore conclude that there is marked separation in ecological, behavioral, and physiological characteristics of the two life forms of brook trout in the Great Lakes.

Where resident and coaster brook trout co-occur, genetic data indicate there is some level of interbreeding between the two life-history forms (D'Amelio and Wilson 2008), and thus they are not substantially reproductively isolated. These studies also show that coaster and resident brook trout are typically very similar genetically when they co-occur with no physical barriers to migration or interbreeding (D'Amelio and Wilson 2008). These findings are consistent with similar studies in other polymorphic salmonid populations (e.g., NOAA 2004). Despite the reproductive exchange and genetic similarity between stream-resident and coaster brook trout, the two life forms remain markedly separated physiologically, ecologically, and behaviorally. Thus, we conclude that the coaster population segment is discrete from brook trout outside the Upper Great Lakes basin, as well as, stream-resident brook trout within the Upper Great Lakes proper.

<u>International Border</u>
Coasters historically and currently occur in both the U.S. and Canada. By policy, we may use the international boundary to circumscribe a population segment if differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of section 4(a)(1)(D) of the Act.

As explained, our analytical approach was to sequentially evaluate the potential admissible DPS options beginning with the rangewide Coaster DPS option. This option does not invoke the international border criterion, so analysis of international border is not yet completed.

Significance
As we determined that coasters are markedly separate from other brook trout within and outside the Great Lakes Basin, we now move into Phase III of our analysis: determining whether coasters are significant to the taxon. A discrete population segment may be considered significant if: (1) it persists in an ecological setting unusual or unique to the taxon; (2) its loss would result in a significant gap in the range of a taxon; (3) it represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range; (4) it differs markedly from other populations of the species in its genetic characteristics; or (5) any other factor that may bear biological or ecological importance to the population segment.

(1) *Unusual or Unique Ecological Setting*
Coaster brook trout historically occupied the shorelines and embayments of the western Great Lakes of Superior, Michigan, and Huron (Becker 1983, Bailey and Smith 1981). Although adfluvial and lake-dwelling forms of brook trout are found outside the Great Lake Basin, the ecological setting of Great Lakes differs substantially from other lentic (lake) freshwater habitats used by brook trout.

The Great Lakes are the largest freshwater ecosystem in the world, occupying a watershed of 290,000 square miles with 5,000 tributaries and more than 10,000 miles of shoreline (USFWS 2007). The Great Lakes basin is composed of globally unique habitat types, including sand dunes, coastal wetlands, islands, rocky shorelines, prairies, savannas, forests, and fens. Associated with this remarkable habitat diversity are rare and unique biological communities (USFWS 2007). Recent surveys identified 130 globally endangered or rare plant and animal species in the basin (USFWS 2007), including an unparalleled freshwater fishery (USFWS 2007). Consequently, the management and conservation of the Great Lakes ecosystem are the focus of several International and State cooperatives and agreements (e.g., Great Lakes Fisheries Commission, Great Lakes Basin Compact, Great Lakes Commission), and are identified as a priority resource area for the Service's Coastal Program (USFWS 2007).

The ecology of the Great Lakes is unusually complex for a lentic freshwater ecosystem (i.e., lakes, ponds). The Great Lakes are dominated by physical characteristics and processes such as wave action, differentiation of water masses (e.g., nearshore, pelagic), upwelling and sinking of water, and the Coriolis force (Beeton 1984). These lakes are also distinguished by prominent horizontal gradients, which yield marked physical and chemical shifts extending out from the shoreline (Beeton 1984, Edsall and Charlton 1997). Strong water flow significantly influences the coastal zones of the lakes (Zhu et al., 2000, Zhou et al., 2001), with coastal currents in Lake Superior measured at speeds up to 50-65 cm/s (Zhu et al., 2000). These currents provide an unusual blend of lentic and lotic physical conditions for the nearshore biological community. The coastal currents also help form zones of water upwelling, which supply nutrient rich waters to coastal areas that stimulate productivity (Edsall and Charlton 1997, Zhou et al., 2001). These physical properties combine to provide a diverse array of habitats for the biological communities of the Great Lakes. This habitat complexity in the Great Lakes has fostered equally complex biotic communities and unique species assemblages (Cudmore-Vokey and Crossman 2000, Hoff 2009). Fish production is highest in the nearshore waters occupied by coaster brook trout (Edsall and Charlton 1997). The nearshore areas are of particular ecological significance within the Great Lakes with virtually all fish species using these microhabitats in some capacity (Edsall and Charlton 1997).

In conclusion, the ecological setting of the Great Lakes differs greatly from the small lakes and ponds that adfluvial or lake-dwelling brook trout outside of the Great Lakes basin typically occupy (e.g., Curry et al. 1997, Ridgway and Blanchfield 1998). The unique combination of physical, chemical, and biological characteristics of the Great Lakes fosters and supports a diverse fish community. It is this unique mix of characteristics that gave rise to the coaster brook trout, and continue to influence its evolution. Although adfluvial and lake-dwelling forms occur elsewhere in the range of brook trout, the ecological setting of the Great Lakes exposes coasters to physical and ecological forces that are unique for the taxon. Therefore, that ecological setting

of the Great Lakes is significant for the maintenance of the natural diversity of the taxon, the preservation of potential future the genetic diversity of the taxon, and the overall welfare of the taxon.

(2) *Significant Gap in the Range*
We typically apply "gap in the range" as a geographical measurement. There is another aspect to gap in the range, however. Based on the past applications and the guiding purposes for the significance standard, that significant gap in the range may also be evaluated in light of the effect on the species persistence (in particular, the loss of redundancy and resiliency) and on the maintenance of the species' natural diversity (i.e., ensuring that the ecological and genetic diversity is well represented). It is in this light that we evaluated whether the loss of the coaster only population segment represents a significant gap in the range.

The maintenance of natural life history diversity is important for the persistence of spatially discrete populations (Cole 1954, Thorpe 1989). Coasters have a distinct ecological function in maintaining the persistence of its taxon. Spawning site fidelity is strong in brook trout, with stream aggregations forming distinct populations. The coaster life form provides the dispersal function, and hence, the vector for gene flow among brook trout populations (D'Amelio and Wilson 2008). Without the coaster expression, gene flow among brook trout populations in the Upper Great Lakes would be severely reduced. Coasters also, through dispersal, serve a rescue or recolonization function for threatened and extirpated populations (Brown 1977, Reeves et al., 1995). Coasters in their adaptation to different Great Lakes habitats, ecologies, and through their dispersal abilities provide redundancy and resiliency, thus buffering the Great Lakes brook trout against extirpation.

Given the distinct functions that coaster and resident fish provide, these life forms are not ecologically exchangeable. Thus, loss of the coaster form would represent a significant functional loss (i.e., gap) for the Great Lakes brook trout population. In order to meet the significance criterion of the DPS policy, this loss must be, however, significant at the taxon level. As other adfluvial populations of brook trout persist elsewhere and presumably serve similar functions in these other portions of the range, we do not have evidence that loss of coasters will represent a significant loss of these ecological functions rangewide. Hence, loss of the coaster expression will not result in a significant gap in the range.

(3) *Sole Surviving Natural Occurrence*
Coasters do not represent the last surviving natural occurrence of brook trout, thus this factor does not apply and was not further explored by our Team.

(4) *Genetic Distinctiveness*
A large amount of rangewide genetic variation for brook trout is distributed among brook trout populations (large Fst values, values in a fixation index which describe the degree of population differentiation based on genetic polymorphisms). This pattern is heavily influenced by the ecological and life history characteristics of brook trout populations (population connectivity or isolation, philopatric tendency). We lack evidence indicating that the coaster and resident life forms in these populations are genetically distinct from each other, indicating that they are part of one breeding population (D'Amelio and Wilson 2008; Scribner *et al*. 2008).

(5) *Loss of Life History Diversity*
As previously stated, the DPS policy allows for the consideration of additional factors that may indicate the potential significance of a population segment. One such factor that is germane to coasters is natural diversity in life history traits. As we discuss below, life history diversity for brook trout is important for brook trout adaptation and specialization to the inherent variability in their environment, for maintenance of gene flow and recolonization potential, and for the overall evolutionary progression of brook trout. All of these reasons are important for resiliency, redundancy, and ultimately long-term persistence of brook trout.

First, life history diversity is an inherent adaptation mechanism species rely upon for addressing risk. Risk spreading is the idea that naturally diverse populations are more stable in the face of environmental variability (Rieman and Dunham 2000). Because the environment varies over space and time, the relative fitness of individuals and populations will also vary (McPeek and Holt 1992). Some phenotypes or life forms are better adapted to certain changes while other phenotypes are better adapted to different environmental alterations (Watters et al., 2003). These different phenotypes or adaptations allow individuals and populations to maximize fitness and fully exploit the range of available habitats (Watters et al., 2003). Such adaptation to local environmental conditions enhances the productivity (Lannan et al. 1989) and survival of populations. Thus, species with greater natural phenotypic variation, such as life history diversity, are better adapted to fluctuating environments (whether the variability be due to natural and anthropogenic causes) and have a lower risk of extinction (Watters et al., 2003). Behavioral/Morphological/physiological variation may be linked to adaptations to specific environmental conditions, as such the loss of diversity or unique adaptations may substantially reduce the ability of the species to respond and adapt to future environmental changes. An example of how life history diversity directly affects persistence is clearly demonstrated with *O. mykiss*. Steelhead viability (the anadromous life form of *O. mykiss*) can affect productivity over the short-term and the probability that the population persists in the long term by maintaining the population's access to ocean habitat and food resources. The number of years spent by steelhead at sea has a profound influence on their ultimate size, whereas the number of years spent in the less productive freshwater habitat has little or no effect. Fecundity of salmonids, including steelhead, increases markedly with size; anadromous forms of the coastal rainbow trout are approximately 3 times more fecund that resident forms. As the amount of freshwater habitat declines, the fitness of the stream-resident life history form will decrease relative to the anadromous life history because anadromy allows access to an oceanic environment that promotes greater somatic growth, higher survival and greater fecundity. Selection in this environmental condition will favor an increase in adoption anadromy and a diminution in frequency or complete loss of the resident life history (NOAA 2004).

As with other migratory salmonids (Reiman and Dunham 2000, Quinn 1993), coasters return to their natal stream to spawn (Wilson et al., 2008, D'Amelio and Wilson 2008). As a result, brook trout form reproductively isolated populations, which allow natural selection to operate on heritable phenotypic traits, and results in an array of locally adapted populations. Depending on environmental conditions, different individuals and populations will perform well at different times and localities. For example, coasters, because of their morphological and physiological differences due to their distinctive behavioral and ecological strategies, are typically larger and more fecund than stream-resident brook trout. Under natural conditions, we expect coasters to be

substantial contributors to Great Lakes brook trout productivity. Loss of the coaster form would remove the larger and more fecund individuals in the population, skew population age structure, age and size at first reproduction, sex ratio, spatial distribution of individuals, and mate selection. Preserving the different life history strategies and locally adapted populations of brook trout will buffer the species from natural or human related changes.

Second, maintenance of natural life history diversity is important for gene flow and recolonization potential, particularly for spatially discrete populations (Cole 1954, Thorpe 1989). Isolation of populations allows adaptation to local conditions, but may also lead to reduced genetic diversity via genetic drift due to reduced gene flow and founder effects (Liseca and Allendorf 1995). Fragmentation of fish populations over large areas due to reduced connectivity has been implicated in population extirpations (Angermier 1995, Brown 1986, Frissel 1993). The migratory life forms of a species are the sole vectors for gene flow between subpopulations. It is gene flow that maintains genetic variability within local populations; without it, genetic variability can be reduced in small, isolated populations. Thus, loss of the migratory forms in particular, may have a substantial effect on genetic diversity and long-term persistence of a species.

Although spawning site fidelity is strong in brook trout, coasters stray or disperse among streams (D'Amelio and Wilson 2008). As such, brook trout populations within the Upper Great Lakes Basin function as metapopulations, with the coaster life form serving as dispersers (D'Amelio and Wilson 2008). Dispersing coasters provide a vector for gene flow among brook trout populations (D'Amelio and Wilson 2008) thereby countering the loss of genetic variation without overwhelming local selective forces and adaptation (Miller and Kapuscinski 2003). Also through dispersal, individuals are available to rescue or recolonize threatened and extirpated populations (Brown 1977, Reeves et al., 1995). Of the brook trout life forms, coasters are the primary providers of this rescue and recolonization function. Lastly, dispersal facilitates the distribution of unique adaptive traits among populations. Without gene flow by straying coasters, loss of genetic diversity may significantly reduce sustainability and population recovery potential (Hilborn et al., 2003, Reusch et al., 2005, Ryman et al., 1995). Coasters in their adaptation to different habitats, differing behavoirs, and dispersal abilities provide redundancy and resiliency and buffer the Upper Great Lakes brook trout against extirpation.

Third, maintenance of life history diversity is important for sustaining evolutionary processes, and hence, ultimately the evolutionary trajectory of a species. The purpose of the ESA is to conserve threatened and endangered species and the ecosystems upon which they depend. To achieve this purpose, we must protect the processes that sustain species and their habitats; this includes both the evolutionary processes and t*he ecological integrity of populations* (Moritz 1999). While it is not the intent of the ESA to determine which populations will play an important future role in the evolution of the species, to effectively achieve this goal we must conserve the important evolutionary building blocks of the species so the course of evolution is unconstrained (Waples 1995). This implicitly acknowledges the need to retain the ecological integrity of populations and the habitats that sustain them, while also stressing that natural change, mediated via processes of evolution and succession, is vital and must be accommodated.

Phenotypic variation, such as differences in life history characteristics, is an expression of evolutionary processes in operation. As explained previously, polymorphic populations often display bimodal distribution in their phenotypic traits, and such distributions suggests that the life history polymorphism is maintained by disruptive natural selection against intermediate types, perhaps augmented by assortative mating (NOAA 2004). Sufficient alteration of the evolutionary trajectory of a population can in the long term cause its phenotype to become so distinct that it should no longer be considered the species (i.e., phyletic extinction or pseudoextinction).

In summary, populations with complex spatial structures and variable phenotypes (e.g., multiple spawning aggregations, migratory life history strategy) are much more stable in the face of human-caused and natural variation in the environment (Hilborn et al., 2003, Ruzzante et al., 2006, Vance 1980, Wood 1995). In the Great Lakes, coasters are exposed to ecological conditions that are unavailable to stream-resident fish, which has led to a distinctive suite of behavioral, morphological, and physiological characteristics in coasters. Specifically, the loss of coasters will diminish phenotypic variability and the adaptive ability associated with such diversity and will eliminate the sole vectors for dispersal among brook trout subpopulations in the Great Lakes. Loss of these dispersers will disrupt existing metapopulation dynamics by reducing exchange of individuals between streams, and thereby artificially increasing the physical, genetic, and demographic isolation of populations (D'Amelio and Wilson 2008). The loss of coasters would also remove the larger and more fecund individuals in the population and skew population age structure, age and size at first reproduction, sex ratio, spatial distribution of individuals, and mate selection. Clearly, loss of the coaster type would significantly affect the natural structure and phenotypic diversity of brook trout in the Upper Great Lakes and effectively reduce the resiliency and redundancy of brook trout overall.

Life history diversity is important to the resiliency and stability of brook trout. If a species is to persist through the natural and human-cause environmental variability, it must maintain the phenotypic and genetic robustness to accommodate to this diversity of conditions (Naeem et al., 2006). Based on this analysis, we believe that maintaining of a species' entire suite of life history forms is necessary for the long-term persistence of that species. The stream-resident brook trout life form is therefore not a substitute for conservation of the coaster life form. Coasters represent a significant contribution to the life-history diversity of the brook trout in the Great Lakes, and to brook trout overall[16].

[16] This interim conclusion was not upheld in the final published 12-month finding.

Appendix 5: Salmon Trout River/South Shore Lake Superior DPS

We find a specific population segment of brook trout that occupies the Salmon Trout River/South Shore Lake Superior does not meet the required conditions of a DPS per our policy. This population segment encompasses the brook trout population that occupies the Salmon Trout River and adjacent habitat in Lake Superior.

Discreteness

This section evaluates whether the Salmon Trout River/South Shore Lake Superior brook trout population segment qualifies as a DPS. Since the Salmon Trout River contains the only known brook trout population with naturally reproducing coaster on the South Shore of Lake Superior, we can address these two petition requests in one analysis.

Markedly Separate

The brook trout population segment that occupies the Salmon Trout River is markedly separate from other members of the brook trout taxon because they are physically isolated. This physical isolation is supported by recent genetic evidence from Scribner et al. (2008), which found no genetic evidence of Salmon Trout River fish in neighboring streams, indicating that Salmon Trout River coasters are not presently a source of gene flow among streams.

International Border

Since the Salmon Trout River population segment does not cross an international border, we need not address the second discreteness factor (delimitation by an international boundary).

Significance

Unusual or unique ecological setting

The ecological setting for the Salmon Trout River discrete population segment is similar to that of other brook trout populations throughout the upper Great Lakes region. We are unaware of any features that make the Salmon Trout River unique or unusual in terms of brook trout habitat within the Great Lakes. Consequently, this population of brook trout is not significant to the taxon according to this criterion.

Significant gap in the range of the taxon.

This criterion from the DPS policy does not apply to the Salmon Trout River discrete population segment because this population is one of perhaps thousands of brook trout populations existing throughout the range of the taxon and it's loss would represent only a extremely small portion of the range. Consequently, this population of brook trout is not significant according to this criterion.

Only surviving natural occurrence of a taxon

This criterion from the DPS policy does not apply to the Salmon Trout River discrete population segment because it is clearly not a population segment representing the only surviving natural occurrence of the taxon that may be more abundant elsewhere as an introduced population outside its historical range. Consequently, this population of brook trout is not significant according to this standard.

Genetic distinctiveness
Scribner et al. (2008) indicates that Lake Superior brook trout populations, including the Salmon Trout River, are highly genetically structured with low levels of gene flow among populations. The Salmon Trout River contains two genetically distinct populations that are separated by impassable waterfalls (Scribner et al. 2008). Both populations in the Salmon Trout River were equally genetically diverged from the other populations included in the study (Scribner et al. 2008). This pattern of population genetic structuring is common in brook trout throughout the species range because, like many salmonids, this species exhibits spawning site fidelity (Angers et al 1999). This degree of genetic divergence that forms among populations is simply reflective of the reproductive connections (isolation) among the populations.

We are unaware of any information indicating that this population segment differs from the species in their genetic characteristics such that it should be considered biologically or ecologically significant to the taxon based on genetic characteristics. For example, populations that exhibited unique alleles or a high proportion of genetic variability might be considered to be significant to the taxon. Biological and ecological significance under the DPS policy is always considered in light of Congressional guidance (see 96th Congress, Senate Report No. 96-151, 1979) that the authority to list DPSs be used "sparingly" while encouraging the conservation of genetic diversity. Consequently, this population of brook trout is not significant according to this criterion.

Conclusion
On the basis of the best available information, we continue to conclude that the Salmon Trout River brook trout population segment is "markedly separated" from all other populations of the same taxon as a consequence of physical factors, supported by genetic evidence. Consequently, the Service concludes that the petitioned entity is discrete according to the 1996 DPS policy. However, on the basis of the four significance criteria in the 1996 DPS Policy, the Service is unable to conclude at this time that this discrete population segment is significant. Therefore, we find that the Salmon Trout River brook trout population does not qualify as a distinct population segment under the Act.

Appendix 6: Risk Assessment

Assessing Extinction Risk for the Upper Great Lakes Brook Trout DPS

Section 4(b) of the ESA requires the Secretary of Interior to make listing determinations after conducting a review of the status of the species, and after taking into account those efforts, if any, being made to protect the species. The ESA further requires that listing determinations be made solely on the basis of the best scientific and commercial data available to the Secretary. The ESA does not, however, prescribe a specific methodology the Service shall use in determining a species status. It simply states to evaluate the extinction risk of a species as a result of 5 stated factors (This analysis is commonly referred to as the 5-Factor Analysis). Likewise, the Service does not provide a specific analytical approach for determining endangered or threatened status. Hence, there has been a multitude of ways the Service has evaluated status for previous decisions.

Our approach for brook trout assessed extinction risk at the DPS scale by evaluating four viability indicators. We adapted the criteria outlined in the document ''Viable Salmonid Populations'' (McElhany et al., 2000), which are based on a review and synthesis of conservation biology and salmon literature. In conducting this analysis, we considered the performance of naturally spawning populations within the Upper Great Lakes DPS.

The viability of brook trout was characterized by the following 4 factors (McElhany et al., 2000, pages 25-27):

> (1) Total number of viable populations - DPSs with fewer populations are more likely to become extinct due to catastrophic events, and have a lower likelihood that the necessary phenotypic and genotypic diversity will exist to maintain future viability.
> (2) Geographic distribution of these populations - DPSs with limited geographic range are similarly at increased extinction risk due to catastrophic events.
> (3) Connectivity among populations - DPSs with populations that are geographically distant from each other, or are separated by severely degraded habitat, may lack the connectivity to function as metapopulations (i.e., a group of interconnected subpopulations) and are more likely to become extinct.
> (4) Genetic, behavioral, and ecological diversity among populations- DPSs with limited diversity are more likely to go extinct as the result of correlated environmental catastrophes or environmental change that occurs too rapidly for an evolutionary response.

For each category, we assigned a score reflecting the relative importance of this factor to the extinction risk of brook trout throughout the DPS. Score of 1 indicates that the factor is unlikely to contribute significantly to risk of extinction, either by itself or in combination with other factors. Score of 2 indicates that the factor is unlikely to contribute significantly to risk of extinction by itself, but some concern that it may, in combination with other factors. Score of 3 indicates that this factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the foreseeable future. Score of 4 indicates that this factor contributes significantly to long-term risk of extinction and is likely to contribute to risk of extinction in the foreseeable. Score of 5 indicates that the factor by itself constitutes a danger of extinction in the foreseeable.

Our analysis of the DPS viability revealed no single factor places brook trout in danger of extinction in the foreseeable throughout the DPS. Three factors (number of viable populations, connectivity, and natural diversity among populations) in concert pose a risk to brook trout in the long term but not within the foreseeable future. The rationales for these findings are detailed below.

1. Number of viable populations within the DPS. Score: 1-2
Best available information suggests that resident brook trout populations may persist in nearly all of the more than 1,500 coldwater tributaries to Lake Superior, as well as coldwater tributaries to northern portions of lakes Michigan and Huron (see Population Status). The range of many of these populations has contracted towards the headwaters (Figure 1), and as explained in the 5-Factor section, threats continue to operate on many of these populations. For these reasons, we assume population abundance has declined, but extent of decline is unknown. Further, only 15 of these populations support the adfluvial life form. Despite the seemingly reduced abundance, we do not have evidence that current population sizes are threatening the viability of individual populations. Rather, brook trout managers from the Great Lakes region believe that self-sustaining resident brook trout occur in nearly all streams known to have historically supported the coaster expression (Newman et al. 2003; Quinlan 2008; Schreiner 2008, pers. comm.; Schram 2008 pers. comm; and Scott 2008, pers. comm. – these are all from email communication). Given this, we assume that the number of viable populations closely mirrors the number of populations within the DPS. The current number of seemingly viable populations poses no significant risk by itself to the DPS viability in the foreseeable future. However, if threats continue unabated, we anticipate further decline in resident populations and even few populations expressing the adfluvial form in the long term. As further explained in Factor 3, prolonged or further repression of the coaster form may have substantially affected the viability of the DPS in the long term.

2. Geographic distribution of populations within the DPS. Score: 1
Despite substantial declines in the past, brook trout populations throughout the DPS remain widely distributed. Resident brook trout populations may persist in nearly all of the more than 1,500 coldwater tributaries to Lake Superior, as well as coldwater tributaries to northern portions of lakes Michigan and Huron. Although the range of many populations has contracted to the headwater reaches of their streams, the overall distribution of the populations resembles the historical range. This wide distribution makes it unlikely that a single catastrophic event will affect all populations simultaneously, and thus, this factor by itself or in combination with other factors is not a significant risk to the DPS viability.

3. Connectivity among populations within the DPS. Score: 3
As explained in the Background section, the coaster life form is the sole natural vector for dispersal within the Upper Great Lakes brook trout DPS. Dispersal among populations is vital for maintaining gene flow, a functional metapopulation, and rescue effects (see 5-factor analysis). Dispersal is essential for exchange of genetic material among populations, which is necessary to maintain genetic variability within local populations. Dispersal also provides for recolonization of extirpated—or rescue of severely reduced—populations, which is essential for maintaining a stable population structure over the long term. Without the coaster life form, connectivity among populations within the DPS will for all practical purposes be eliminated. Thus, loss of the migratory life form would affect the long-term viability of brook trout within the DPS.

Based on the historical abundance and distribution, current status (see Phase 1) and threats (see 5-Factor analysis), coaster expression has been severely repressed and will likely be further repressed without amelioration of threats. Although once abundant and widespread throughout the northern portions of the Great Lakes, coaster brook trout populations are now limited to a few locations (Dehring and Krueger 1985; Bailey and Smith 1981; Goodyear et al. 1982; Newman et al. 2003; Mucha and Mackereth 2008). Because of the differences in ecology (namely, their migratory behavior, lake dwelling, and larger size), coasters are more susceptible to some threats than the resident expression (e.g., overexploitation). Although some threats are no longer affecting coaster populations to the same magnitude as in the past, these stressors, as well as contemporary factors (e.g., non-natives) continue to substantially repress expression of the coaster form.

As previously explained, loss of the coaster form reduces the resiliency, redundancy, and representation of the brook trout population. Reduction in these factors increases the risk of brook trout to environmental perturbations, demographic stochasticity, and catastrophic events. The loss of the coaster form will exacerbate the negative consequences of reduced gene flow among populations and of disrupted population dynamics. Indeed, evidence of loss connectivity due to the decline in the coaster expression is already discernible in some populations. Based on genetic and fishery data, many populations are reproductively isolated from other brook trout populations (Burnham-Curtis 1996; Burnham-Curtis 2000; Sloss et al. 2008, Wilson et al. 2008, Scribner et al. 2008). In the short-term (i.e., foreseeable future), we do not believe, given the number and the distribution of brook trout within the DPS, the effects of reduced or even loss of gene flow will threaten the viability of brook trout. Over the long term, however, loss of coaster could pose a risk to the brook trout population in the Upper Great Lakes DPS.

The implications of losing the coaster expression over the long term depend upon whether the coaster expression can be easily reconstituted once lost. If coaster expression cannot be readily reconstituted, the negative consequences of reduced gene flow (e.g., increased risk of extirpation due to environmental perturbations, demographic stochasticity, and catastrophic events) may compromise the long-term viability of brook trout within the DPS. Conversely, if the coaster life form can be readily reconstituted from a purely resident population, then temporary loss of the coaster expression will not substantially influence the viability of brook trout throughout the DPS in the long term.

Although believed unlikely for other salmonids (*O. mykiss* for example), brook trout experts contend that if environmental conditions are suitable (i.e., threats are abated), the coaster expression can be readily reconstituted from a purely resident stock (see Appendix 7). This belief is predicated on the following premises. First, brook trout show the great plasticity relative to most other salmonids. Adfluvial brook trout, and other freshwater migrants, do not require substantial physiological changes (e.g., smoltification) to successful migrate and survive in the lake environment. Thus, the fitness costs of maintaining the genetic code for plasticity is likely less relative to saltwater salmonids. Hence, it is reasonable to expect a brook trout population to maintain the ability (genetic code) to express the array of life forms over time. Second, life history strategy is strongly controlled by the environment. As such, it is reasonable to conclude that provided environmental conditions are suitable, all life forms can be expressed.

Accepting this supposition, we believe this factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the foreseeable future.

4. Genetic, behavioral, and ecological diversity among populations within the DPS. Score:2-3
Multiple populations within a DPS increase the likelihood that a diversity of phenotypic and genotypic characteristics will be maintained, and thus, increasing the DPS' viability in the long term. Genetic studies within Lake Superior reveal that genetic diversity has not been markedly compromised. Based on a review of microsatellite DNA studies conducted in Lake Superior and Maine and Canada, the genetic diversity as measured by the amount of average heterozygosity, brook trout populations in Lake Superior have levels of genetic diversity that are similar to other populations outside of the Great Lakes Basin (Ardren 2009, pers .comm.). Maintenance of this diversity is contingent upon continued and adequate expression of the coaster form. Although the best available information indicates that the coaster expression is vulnerable in the foreseeable future, provided the resident form is viable and widely distributed, we assume coaster expression can be reconstituted. Accepting this supposition, we believe genetic diversity throughout the DPS will be maintained over the long term.

As we discussed previously, behavioral and ecological variation is important because species are better adapted to fluctuating environments (whether the variability be due to natural and anthropogenic causes), and hence have a lower risk of extinction (Watters et al., 2003). Life history forms are the essence of behavioral and ecological diversity in brook trout. The coaster form represents two of three life history expressions, and hence, provides a substantial amount of behavioral and ecological diversity for brook trout within the Upper Great Lakes brook trout DPS. The coaster life history form has been substantially repressed and is likely to continue its decline in the foreseeable future. Without abatement of threats, its loss will render the brook trout population more at risk of extinction in the long term.

Synopsis
Many brook trout populations within the DPS have retreated to the headwaters portions of their streams, but remain widely represented within most of the DPS. Based on the best available data, hundreds of brook trout populations persist. The coaster expression is substantially repressed and vulnerable; if threats continue we believe coaster expression is likely to be extirpated. The loss of life history diversity reduces the resiliency, redundancy and representation of the Upper Great Lakes brook trout population in the long term. Although the abundance of brook trout is believe to have declined--as evidenced by the contraction of distribution within streams and the threats discussed previously--information indicates that these populations are viable in the foreseeable future. If threats to the coaster form are not ameliorated, we believe that the long-term viability of brook trout in the DPS will be compromised. Given the distribution and the number of populations, we believe that the current status and trend in threats are unlikely to render brook trout endangered throughout the DPS in the foreseeable future.

Appendix 7: Expert Elicitation

Eliciting Expert Opinion for Forecasting Extinction Risk in the Foreseeable Future

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Purpose

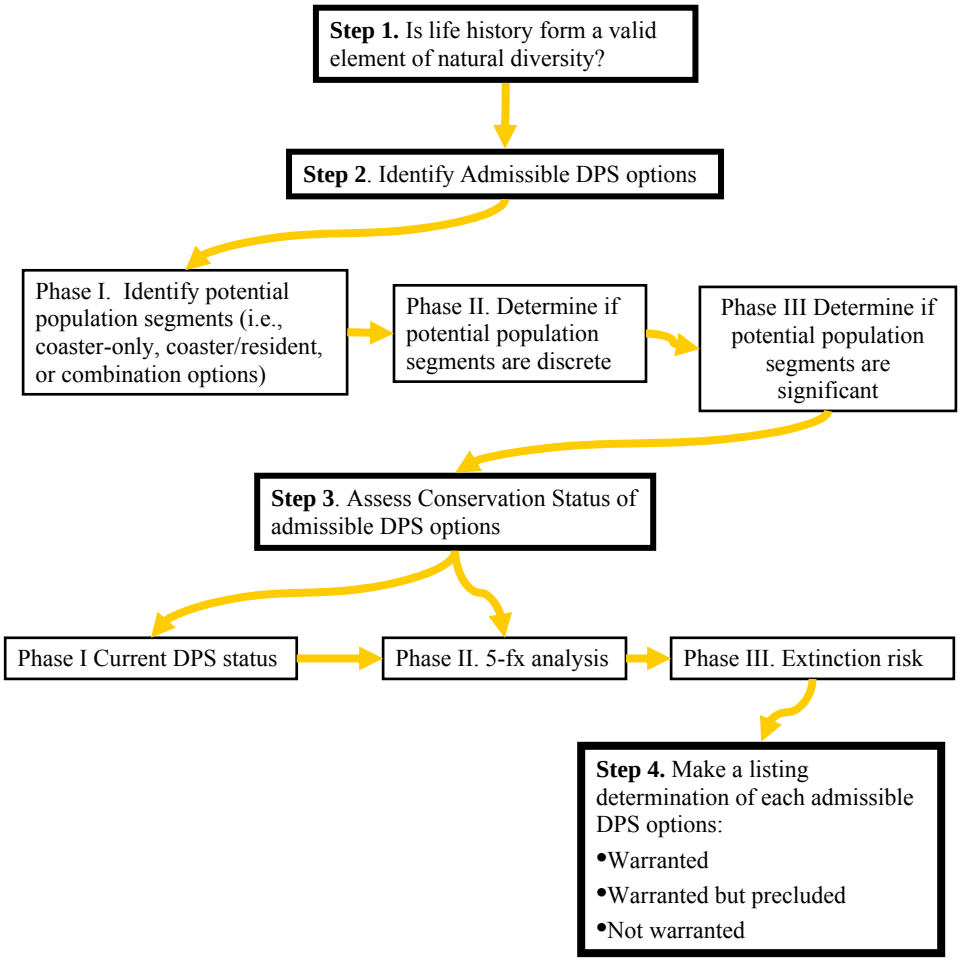
The U.S. Fish and Wildlife Service (Service) was petitioned to list the coaster brook trout (*Salvelinus fontinalis*) pursuant to the Endangered Species Act of 1973, as amended (ESA) in 2006. In February 2008, a positive 90-day finding was published, which indicated that the petition and the information contained within the Service's files suggest that the petitioned entity warrants further evaluation. Following this evaluation, the Service must publish a 12-month finding indicating whether coaster brook trout warrants Federal protection under the ESA. This process entails, among other things, determining whether the petitioned entity is in danger of extinction or likely to become endangered in the foreseeable future.

The 12-month evaluation involved four analytical steps (Figure 1). Step 1 was to identify whether the petitioned entity represents a listable entity (i.e., species, subspecies or distinct population segment). Coaster brook trout is not a species or subspecies, but rather a life form of brook trout. Brook trout occur as one of four types: fluvial (stream resident), adfluvial (fresh water migrant), lacustrine (lake dwelling), and anadromous (salt-water migrant). Coasters are adfluvial and lacustrine brook trout that occupy the upper Great Lakes.

As coaster brook trout is not a species or subspecies, the only potential listable entity is a distinct population segment (DPS) of brook trout. We identified two broad potential DPS options: a coaster-only DPS and a brook trout DPS. The former included adfluvial and lacustrine brook trout only; the latter included all three brook trout life forms occurring within the Upper Great Lakes. Our analyses concluded that both DPS options meet the two criteria—discrete and significant—required to be an admissible listable entity (Steps 1 and 2).

The third step in our evaluation was to assess whether the admissible DPSs are endangered or threatened throughout or in a significant portion of the respective DPS range. This status assessment entailed three phases: (1) establishing current population status, (2) conducting a 5-factor threat analysis, and (3) assessing extinction risk based on current population characteristics. To assist us with Phase 3 of the analysis, we elicited expert judgments to develop general extinction risk profiles. This report summarizes the process and the results of the expert elicitation.

Figure 1: Analytical Approach for Assessing Whether Coaster Brook Trout Warrants Federal Protection Pursuant to the ESA.



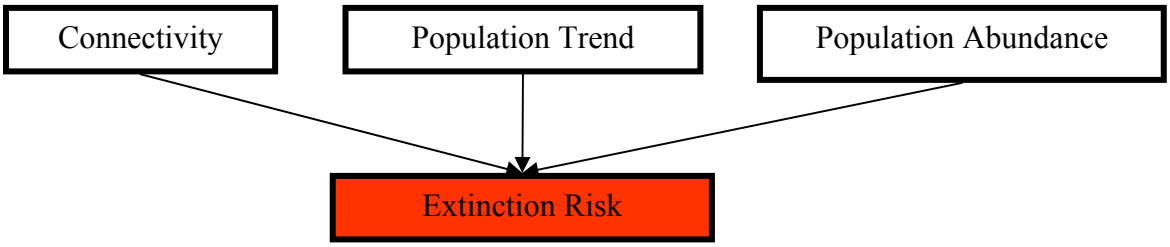
Model Approach

The conceptual model we used for our extinction risk assessment is shown in Figure 2. Our model parameters were population abundance, population trend, and connectivity. The three population parameters were selected as they provide a measure of population viability (see McElhany et al., 2000, pgs 11-23 for a detailed discussion of the parameters). Population trend and abundance together influence extinction risk. Small populations face a host of risks intrinsic to their low abundance; conversely, large populations exhibit a greater degree of resilience.

Population trend serves as an indicator of how well the population is performing in its habitat. Connectivity is important for genetic and population recolonization purposes. Most brook trout populations occur as small, discrete populations. Influx of genes into one population from another is important for maintaining allelic diversity, which is influential in population viability. Influx of fish from other populations is also helpful for recolonizing or bolstering a population that may have been extirpated or nearly so due to a local stressor. This conceptual model was applicable to both DPS options.

The ESA requires that we determine if a species is likely to become endangered within the *foreseeable future*. The term "foreseeable future" is not defined in the ESA, regulations or policy. Within the scientific literature, a 100-year time scale is often used in viability analyses as it represents a "long" time horizon for evaluating extinction risk (McElhany et al. 2000). To date, however, the Service's approach to foreseeable future has integrated both biological and policy aspects, and consequently, no single time-frame has been used in making listing determinations. Given the lack of clear guidance of an appropriate time-scale, we elected to choose a timeframe that has biological meaning in which our decision makers could use as a guide in determining whether the DPS was threatened in the foreseeable future. That is, the time-frame chosen does not represent "foreseeable future," but rather a guide for our decision makers to apply in their decision. We obtained predictions about the likelihood of extinction of a hypothetical population within 50 years given a set of population characteristics. We chose a 50 year time horizon as it represents 7 to 13 brook trout generations, which is a sufficient period of time for the full effects of a population's current status (i.e., population trend, abundance, and connectivity) to be reflected in a population's extinction risk assessment.

Figure 2. Coaster Brook Trout Conceptual Model



Expert Elicitation

The primary purpose of the expert elicitation was to obtain expert opinion regarding extinction risk for a series of brook trout population scenarios. These judgments were assigned based on a hypothetical brook trout population possessing a specific set of population characteristics (e.g., given a population has low abundance, decreasing trend, and is isolated from other populations, what is the likelihood of extinction within 50 years?).

We also queried our experts regarding a fundamental assumption that we were making in our assessment approach; we were assuming that the coaster life form could not be readily reconstituted from a purely resident population. This supposition is supported by the published

statements made for other salmonids (e.g., NOAA-Fisheries 2004, pgs 5-12). In brief, the near consensus opinion from salmonid experts is that although individual fish may give rise to multiple life forms, there is no evidence (indeed, all evidence suggest the contrary) to suggest that a self-sustaining population of the migratory form could be readily reconstituted from a purely resident stock. Given the dearth of information on this issue specific to brook trout, it is appropriate to rely on ecologically appropriate surrogate species. Applying this belief to brook trout seemed appropriate given the similarities in their biology and the observations of brook trout behavior within the Great Lakes. Despite efforts to restore the coaster form in areas within the DPS, coaster re-expression has not occurred. This information, along with the published literature on surrogate salmonids, led us to conclude that the coaster form could not be readily reconstituted once lost. The implications of this supposition are substantially germane to our risk assessment. If a life form can be reliably restored once lost, the long-term persistence of the life form can be maintained by the persistence of alternative life forms alone. If a life form, however, cannot be reconstituted from other life forms, the persistence of alternative life forms will have minimal influence on the long-term persistence of the life form of interest. The former would require us to consider the viability of the residents in our extinction analyses while latter would not. Thus, we posed this issue to our experts.

We also queried our expert regarding the need account for Allee effects in our brook trout population model. As most of the brook trout populations, coasters in particular, exist in small, discrete occurrences, we believed it was necessary to ask whether depensation should be built into our model. Therefore, we ask our experts for their beliefs about whether an Allee threshold exists, and if so, at what population size would the effects be triggered.

To address these issues, we posed the following three questions to our experts:

1. How influential are resident fish in the extinction dynamics of coaster brook trout?
2. Do you believe an Allee threshold exists for brook trout populations?
3. Given a population's abundance, trend, and connectivity to other populations, what is its extinction probability within 50 years?

Expert Selection

To answer the three stated questions, we identified four areas of expertise required of our experts: (1) salmonid extinction dynamics, (2) coaster population ecology, (3) brook trout population dynamics, and (4) conservation biology and genetics. We identified persons with coaster and brook trout expertise within the Great Lakes and sought out assistance from NOAA-Fisheries Service for recommendations of individuals with experience and expertise in salmonid extinction dynamics and conservation. We selected the Great Lakes brook trout expertise based on their degree of recent involvement and ability to provide coaster-specific knowledge. We sought recommendations from Dr. Beth Sanderson (Salmon Recovery Science Review Panel Coordinator, NOAA-Fisheries Service, Northwest Fisheries Science Center, Seattle, WA) for individuals well experienced with assessing salmon extinction risk. The individuals recommended by Dr. Sanderson are not only recognized experts in salmonid biology and the principles of conservation biology and genetics, they also have vast and direct experience with assessing extinction risk of salmonid life forms.

Expert Selection: 11 Experts selected and agreed to participate

Salmonid extinction dynamics	Coaster population ecology	Brook population dynamics	Conservation genetics & principles
E.Holmes	H. Quinlan	H. Quinlan	C. Wilson
R.Waples	R. Swainson	R. Swainson	C. Krueger
J. Hard	C. Huckins	C. Huckins	K. Scribner
C.Garza		C. Krueger	L. Miller

Elicitation Protocol

The elicitation entailed three phases all of which were conducted via webcast and teleconferencing (virtual meetings). In Phase I, we explained the purpose, logistics, and overall expectations of the elicitation. We explained that we are not seeking consensus, but rather we sought their expert opinion based on their experience and knowledge. We provided instructions for exercises that each participant was to complete, described how their opinions would be used in our decision, and explained the importance of documenting their rationale. Not all participants were available concurrently, so we hosted three separate Phase I meetings.

For Phase II, we collated the completed exercises, provided the compiled results to the participants, and discussed the results in an internet hosted meeting. Again, not all experts were available at the same time, so two separate Phase II meetings were held. During these meetings, we highlighted areas of disagreement and sought out explanations for the range in opinions. Each expert was encouraged to share their rationale with the other experts. The purposes of this discussion were to share knowledge among the experts, to allow experts to query one another about outcomes but not to come to consensus. The discussions allowed for us to better understand the sources of the discrepancy in opinions and the range of uncertainty. In Phase III, experts were asked to revise, if they needed to, their opinions based on the discussions in Phase II and to resubmit their final judgments.

In completing the exercises, the experts were instructed to distribute 100 points among one or more of the stated outcomes relative to their strength of belief. By allowing the experts to spread their points across more than one alternative outcome, we were able to capture each expert's uncertainty about their judgments. For example, if an expert was completely confident that outcome A will occur, he would place all of his 100 points under outcome A and zero points under outcomes B and C (Scenario 1). Conversely, if she was completely uncertain of the outcome, she would have assigned 33.3 points to outcomes A, B and C (Scenario 2).

Scenario 1	Outcome A	Outcome B	Outcome C
Your belief that outcome A, B or C will occur	100	0	0

Scenario 2	Outcome A	Outcome B	Outcome C
Your belief that outcome A, B or C will occur	33.3	33.3	33.3

Elicitation Results

Question 1: Influence of residents on the extinction risk of coasters

Our extinction risk approach assumed that coasters could not be readily reconstituted from a purely resident stock if lost from a population. As this supposition was fundamental to our approach, we posed this question to our experts. During our discussions, we clarified that their belief should be based on the assumption that the environment is suitable for coaster re-expression. We asked our experts to:

Give your belief regarding the degree of influence that resident brook trout have on the extinction risk of a co-occurring CBT population. Distribute 100 points according to your strength of belief. For example, if you are certain there is no influence, assign all 100 points to this category. If you are completely uncertain, assign 33.3 points to each of the categories.

Expert	No Influence	Little Influence	Substantial Influence

In the final analysis, the median number assigned to "No," "Little," and "Substantial" outcomes were 0, 30 and 70 points, respectively. Nine out our 11 experts assigned the majority of their points to the "Substantial" outcome; six of whom espoused strong belief (i.e., assigned 70 or more points to the substantial category) that resident fish "Substantially Influence" the extinction risk of coasters. Two experts assigned most of their points to the "Little" outcome, with one distributing points only between the "Little" (85 points) and "Substantial" (15 points) outcomes, and the other distributing points among all three outcomes. Three experts assigned a small portion (10 to 20 points) of their 100 points to "No Influence."

Question 2: Allee threshold

Given that many brook trout populations supporting coaster life forms occur in small, discrete populations, we wanted expert opinion regarding whether Allee effects should be included in our model. We also requested their belief on the range in population size in which Allee effects might be triggered. We asked our experts to:

Give your belief regarding whether an Allee threshold exists for CBT based on your knowledge of CBT and salmonid life history in general. Distribute your 100 pts relative to your strength of belief.

Expert	No Threshold Exists	Threshold Exists

If a threshold may exist, what is the likely range of that threshold?

Low	High

In the final analysis, 9 out our 11 experts believe strongly (i.e., assigned 70 or more points to the substantial category) an Allee threshold exists. From some of the responses received, it is clear that some experts had difficulty with this question given their overall belief that coaster dynamics are closely linked with residents. However, as explained below, our model for assessing extinction risk was altered such that modeling Allee effects were no longer germane. Therefore, we did not circle back with the experts to clarify the question.

Question 3: Extinction Risk
Our analytical process for this phase of our extinction risk analysis entailed two steps. Step 1 elicited expert beliefs regarding extinction risk given a set of population characteristics. Step 2 involved gathering the actual population characteristics for each of the known populations supporting coasters and applying the extinction risk profiles supplied by the experts to the coaster populations in order to ascertain an estimate of extinction risk for the coaster populations. We asked our experts to:

> Give your belief that extinction risk of a population is =<0.1, =<0.2, =<0.3, =<0.4, =<0.50, or >0.50 given a set of population characteristics? E.g., what is your belief that given low abundance, increasing trend and isolation that extinction risk will be <0.1, <0.2, etc. The row must sum to 1. Each expert will give us their beliefs for the scenarios in rows 30-47.

			Extinction Risk within 50 years					
Pop. Abound	**Pop Trend**	**Connectivity**	**=<0.10**	**=<0.20**	**=<0.30**	**=<0.40**	**=<0.50**	**>0.50**
Low	Increasing	Isolated						
Low	Increasing	Connected						
Low	Stable	Isolated						
Low	Stable	Connected						
Low	Decreasing	Isolated						
Low	Decreasing	Connected						
Moderate	Increasing	Isolated						
Moderate	Increasing	Connected						
Moderate	Stable	Isolated						
Moderate	Stable	Connected						
Moderate	Decreasing	Isolated						
Moderate	Decreasing	Connected						
High	Increasing	Isolated						
High	Increasing	Connected						
High	Stable	Isolated						
High	Stable	Connected						
High	Decreasing	Isolated						
High	Decreasing	Connected						

Although in setting up our exercises we assumed that coaster dynamics were independent of resident fish, we believe most experts provided their risk estimates in accordance with their

beliefs regarding the interaction between resident and coaster brook trout (i.e., provided estimates of risk for a population of *brook trout* possessing the specified characteristics). In the final analysis, a diversity of opinion was given for each of the population scenarios evaluated. However, for the reason explained below, we did not summarize the expert information from this exercise.

Synopsis

Question 1: Influence of residents on the extinction risk of coasters

The purpose of this question was to test our supposition that residents do not greatly influence the extinction dynamics of the coaster form. The results from the elicitation clearly indicate that the experts do not agree with our initial assumption regarding the interaction among resident and coaster brook trout. In the Phase II meeting, we questioned the experts as to how the brook trout model differs from salmon model applied elsewhere. Specifically, we asked why is the widely accepted supposition for salmon not an appropriate assumption to adopt for brook trout. One expert offered a response, and the others participating on the call, agreed with the argument presented.

According to the coaster experts, brook trout show greater phenotypic plasticity than most other salmonids. Adfluvial brook trout do not—as salmon do—require substantial physiological changes (e.g., smoltification) to successfully migrate and survive in the lake environment. Thus, the fitness costs to maintain the genetic code for plasticity are likely less relative to the costs for saltwater dwelling salmonids. Hence, it is reasonable to expect a brook trout population to maintain the ability (i.e., the genetic code) to express the full array of life forms over time even if some life forms are no longer expressed. Furthermore, the experts contend that life history strategy is strongly controlled by the environmental conditions or triggers. As such, it is reasonable to conclude that provided the necessary environmental conditions or triggers exist, life forms can be re-expressed even if temporally lost from a population.

Given the lack of data available on this specific issue for brook trout, we must rely on surrogates and expert opinion to guide us. The reasonable rationale provided and the strong agreement among the experts led us to reverse our fundamental assumption. An appropriate assumption is that if lost, coaster re-expression can occur readily provided a suitable environment is restored.

Question 2: Allee threshold

The purpose of this question was to help us determine whether an Allee threshold should be incorporated into our models for individual brook trout population dynamics. This question became moot as our original approach was modified (see below) such that individual populations were no longer modeled.

Question 3: Extinction Risk

The purpose of this question was to obtain estimates of extinction risk given a population's characteristics. These estimates would then be applied to actual coaster or brook trout populations. While eliciting expert judgments for this task, we were concurrently gathering population-specific information for the known coaster and brook trout populations. We were able to obtain a full set information regarding population abundance, trend, and connectivity for only five populations across the Upper Great Lakes DPS. Thus, insufficient information for brook

trout populations in the Upper Great Lakes DPS was available to meaningfully apply the extinction profiles provided by the experts.

For this reason, we abandoned our original approach and pursue a broader approach. Given the lack of detailed information on individual brook trout populations, we assessed extinction risk directly at the DPS level. This analysis evaluated 4 factors (based on McElhany et al., 2000, pages 25-27): (1) total number of viable populations; (2) geographic distribution of these populations; (3) connectivity among populations; and (4) genetic, behavioral, and ecological diversity among populations. The results of this analysis are documented in Appendix 6 and within the 12-month finding.

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