UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Fisheries Science Center
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SEATTLE, WASHINGTON 98112-2097

January 24, 2005

MEMORANDUM FOR: D. Robert Lohn
NW Regional Administrator

FROM: Usha Varanasi
Science and Research Director
NW Fisheries Science Center

SUBJECT: Summary of Scientific Conclusions of the Review of the Status of Cherry Point Pacific Herring (*Clupea pallasii*) and Update of the Status of the Georgia Basin Pacific herring DPS

The Northwest Fisheries Science Center's Biological Review Team (BRT) for Cherry Point Pacific herring met in Seattle on December 1-2, 2004 and January 7, 2005. The BRT discussed information received regarding delineation of a distinct population segment (DPS) that includes the petitioned Cherry Point Pacific herring and extinction risk of this DPS at the December 2-day meeting, and continued discussions on extinction risk of this unit throughout all or a significant portion of its range at the January meeting.

Attached is a BRT report that summarizes the resulting scientific conclusions regarding the following questions that were posed by the Region's September 9th, 2004 memo to the Center:

1) In light of all information, including new information not available at the time of the last status review, does the Cherry Point herring stock meet the criteria necessary to be considered a "distinct population segment" (DPS) as defined by the joint NOAA-FWS DPS policy?
2) If not, what is the DPS that includes the Cherry Point stock?
3) Is the DPS to which the Cherry Point stock belongs in danger of extinction or likely to become so in the foreseeable future throughout all or a significant portion of its range?

In preparing this report, the BRT obtained considerable information from the regional co-managers, both in the U.S. and Canada. Information contained in this summary BRT report will be incorporated into a more comprehensive report that is in preparation and will be available in the near future.

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Summary of Scientific Conclusions of the Review of the Status of Cherry Point Pacific Herring (*Clupea pallasii*) and the Updated Status Review of the Georgia Basin Distinct Population Segment of Pacific Herring under the U.S. Endangered Species Act

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Date
January 21, 2005

SUMMARY

The National Marine Fisheries Service's (NMFS) Biological Review Team (BRT) has completed its review of the status of Cherry Point Pacific herring under the U.S. Endangered Species Act (ESA). The BRT has determined that Cherry Point Pacific herring is not a "species" under the ESA, as it does not meet all the criteria to be considered a Distinct Population Segment (DPS) as defined by the joint NMFS-U.S. Fish and Wildlife Service (USFWS) interagency policy on vertebrate populations (USFWS-NMFS 1996). The BRT was nearly unanimous in concluding that Cherry Point Pacific herring were "discrete;" however, there was no support on the BRT for a finding that Cherry Point Pacific herring were "significant" to the taxon of Pacific herring as a whole, under the provisions of the joint NMFS-USFWS DPS policy.

The BRT has determined that Cherry Point Pacific herring are part of the previously defined Georgia Basin Pacific herring DPS (Stout et al. 2001). Consequently, the BRT initiated an updated review of the status of the Georgia Basin Pacific herring DPS, under the U.S Endangered Species Act (ESA). The BRT concluded that the Georgia Basin Pacific herring DPS is not at risk of extinction in all or a significant portion of its range, nor likely to become so in the foreseeable future.

INTRODUCTION

In 2001, the National Marine Fisheries Service (NMFS) completed a status review (Stout et al. 2001) of Pacific herring, *Clupea pallasii* Valenciennes, 1847, in response to a petition (Wright 1999) seeking to list 18 species of marine fishes, including Pacific herring, in Puget Sound under the Endangered Species Act (ESA). Following acceptance of the 1999 petition, NMFS formed a Pacific herring Biological Review Team (BRT), consisting of scientists from NMFS's Northwest Fisheries Science Center and Alaska Fisheries Science Center, NOAA's National Ocean Service, and the U.S. Fish and Wildlife Service. This BRT concluded that spawning populations of Pacific herring from Puget Sound (including Cherry Point Pacific herring) and the Strait of Georgia (SOG) constitute a Georgia Basin Pacific herring Distinct Population Segment (DPS). The ESA allows the listing of "distinct population segments" of vertebrate species or subspecies as threatened or endangered, if severe declines in abundance indicate substantial risks are facing the species. The Georgia Basin Pacific herring DPS's range includes the marine waters of Puget Sound, the Strait of Georgia, and eastern Juan de Fuca Strait in both the US and Canada. This previous BRT concluded that this Pacific herring DPS, containing the petitioned Puget Sound populations, was neither in danger of extinction nor likely to become so in the foreseeable future throughout all or a significant portion of its range (Stout et al. 2001, NMFS 2001).

On January 22, 2004, and May 14, 2004, NMFS received petitions (CBD et al. 2004, Werntz 2004) seeking to list Pacific herring that spawn at Cherry Point, Washington as a threatened or endangered "species" under the ESA. NMFS evaluated each petition to determine whether the petitioner provided "substantial information" as required by the ESA to list a species. The agency also reviewed other readily available information and consulted with state and tribal biologists to determine whether general agreement existed relative to the uniqueness, distribution, abundance and threats to the petitioned population Additionally, NMFS evaluated whether available information might support the identification of a distinct population segment that might warrant listing as a "species" under the ESA. NMFS determined that the January 22nd petition failed to present substantial scientific and commercial information indicating that the petitioned action may be warranted. However, the agency found that the supplemental information contained in the May 14th petition did present substantial scientific and commercial information, or cited such information in other sources, that the petitioned action may be warranted (NMFS 2004) and subsequently, NMFS initiated a review of the status of Cherry Point Pacific herring.

Two key questions must be addressed in determining whether a listing under the ESA is warranted: 1) Is the entity in question a "species" as defined by the ESA? and 2) If so, is the "species" in danger of extinction (endangered) or likely to become so (threatened)? This document provides a summary of the conclusions of the of the NMFS Biological Review Team[1] for the status review of Cherry Point Pacific herring. A more comprehensive report is being prepared and will be available in the near future.

THE "SPECIES" QUESTION

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. Guidance on what constitutes a "distinct population segment" is provided by the joint NMFS-U.S. Fish and Wildlife Service (USFWS) interagency policy on vertebrate populations (USFWS-NMFS 1996). To be considered "distinct", a population, or group of populations, must be "discrete" from the remainder of the species to which it belongs; and "significant" to the species to which it belongs as a whole. Discreteness and Significance are further defined by the Services in the following Policy language:

> Discreteness: A population segment of a vertebrate species may be considered discrete if it satisfies either one of the following conditions:
> 1. It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors.

[1] The BRT for Cherry Point Pacific herring consisted of the following members: Dr. Tracy Collier, Jonathan Drake, Dr. Michael Ford, Kurt Fresh, Dr. Richard Gustafson, Dr. Jeffrey Hard, Dr. Richard Methot, Heather Stout, Donald Van Doornik, and Dr. Robin Waples from the NWFSC; Mark Carls from the AFSC; and, Dr. Alan Mearns from NOS.

Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.

2. 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 [Endangered Species] Act.

Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered in light of congressional guidance (see Senate Report 151, 96th Congress, 1st Session) that the authority to list DPSs be used "sparingly" while encouraging the conservation of genetic diversity. In carrying out this examination, the Services will consider available scientific evidence of the discrete population segment's importance to the taxon to which it belongs. This consideration may include, but is not limited to, the following:

1. Persistence of the discrete population segment in an ecological setting unusual or unique for the taxon,

2. Evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon,

3. Evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historic range, or

4. Evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.

This joint policy applies to all vertebrate species, but does not elaborate on the information that can be used to assess distinctiveness in species of marine fishes. NMFS has developed a policy on the kinds of evidence that can be considered to evaluate distinctiveness of populations in Pacific salmon species (Waples 1991a, b, 1995), and similar kinds of evidence can be used to assess distinctiveness of populations or groups of populations of marine fishes. The Pacific salmon policy advocates a holistic approach in which all available information is considered, as well as a consideration of the strengths and limitations of such information in delineating distinct population segments. Important information includes natural rates of migration and recolonization, evaluations of the efficacy of natural barriers to migration, and measurements of genetic differences between populations. Data from protein electrophoresis and DNA analyses can be particularly useful for determining distinctiveness, because gene frequency differences among populations may reflect limited gene flow between areas.

The joint policy states that international boundaries within the geographical range of the species may be used to delimit a distinct population segment in the United States. This criterion is applicable if differences in the control of exploitation of the species, the management of the species' habitat, the conservation status of the species, or regulatory mechanisms differ between countries that would influence the conservation status of the population segment in the United States. However, in past assessments of evolutionarily significant units (ESUs) in Pacific salmon and DPSs in marine fish, NMFS has placed the emphasis on biological information in defining DPSs and has considered political boundaries only at the implementation of ESA listings. Therefore, the BRT focused on biological information in identifying DPSs of Pacific herring.

Approaches to the Species Question

The BRT considered several kinds of information to attempt to delineate DPSs of Pacific herring. The first kind of information considered was geographical variability in life-history characteristics and morphology. Such traits usually have an underlying genetic basis, but are also often strongly influenced by environmental factors that vary from one locality to another. Information related to this category included patterns of marine species' distribution (zoogeography) that may indicate changes in the physical environment that are shared with the species under review. The second kind of information consisted of tag and recapture studies, which give insight into the physical movement of individuals between areas. The third kind of information consisted of traits that are inherited in a predictable way and remain unchanged throughout the life of an individual. Differences among populations in the frequencies of markers at these traits may reflect isolation between the populations. The analyses of these kinds of information are discussed briefly in the following sections.

Life History and Morphology

Isolation between populations may be reflected in several variables, including differences in life history variables (e.g., spawning timing, seasonal migrations), spawning location, parasite incidence, growth rates, morphological variability (e.g., morphometric and meristic traits), and demography (*e.g.*, fecundity, age structure, length and age at maturity, mortality), among others. Although some of these traits may have a genetic basis, they are usually also strongly influenced by environmental factors over the life time of an individual or over a few generations. Differences can arise among populations in response to environmental variability among areas and can sometimes be used to infer the degree of independence among populations or subpopulations. Begg et al. (1999) have emphasized the necessity to examine the temporal stability of life history characteristics in order to determine whether differences between populations persist across generations. Many life-history differences are often not correlated with variation at neutral molecular genetic markers.

The analysis of applied or acquired tags can indicate the degree of migration between localities. These tags include physical tags that are attached to a fish and later recovered, parasites that are characteristic of specific regions because of differential resistance or occurrence, and elemental profiles that reflect local environmental conditions or diets. These tags provide evidence of movement of individuals from one place to another, but not necessarily of population connectivity through gene flow. Since these kinds of population markers are not inherited, they must be applied each generation or must arise naturally anew each generation.

Marine Zoogeographic Provinces

Ekman (1953), Hedgpeth (1957), Briggs (1974), and Allen and Smith (1988) summarized the distribution patterns of coastal marine fishes and invertebrates and defined major worldwide zoogeographic zones or provinces. The coastal region from Puget Sound to Sitka, Alaska was considered a "gray zone" or transition zone and could be classified as part of either of two provinces recognized by Briggs (1974); Aleutian or Oregonian. The southern boundary of the Oregonian Province is generally recognized as Point Conception, California and the northern boundary of the Aleutian Province is similarly recognized as either Nunivak or the Aleutian Islands (Allen and Smith 1988). Briggs (1974) placed the boundary between the Oregonian and Aleutian Provinces at Dixon Entrance in southern Southeast Alaska, based on the well-studied distribution of mollusks, but indicated that distributions of fishes, echinoderms, and algae gave evidence for placement of this boundary in the vicinity of Sitka, Alaska. Peden and Wilson (1976) investigated the distributions of inshore fishes in British Columbia, and found Dixon Entrance to be of minor importance as a barrier to fish distribution. A more likely boundary between these faunas was suggested to occur near either Sitka, Alaska or Cape Flattery, Washington (Peden and Wilson 1976, Allen and Smith 1988). In the DPS discussion to follow, the zoogeographic transition zone is defined as the coastal region from Puget Sound to Sitka, Alaska.

Genetic Methods

Differences in life-history traits among populations may provide little information on reproductive isolation between populations, because the genetic basis of many phenotypic and life-history traits is unknown. The BRT also considered molecular genetic evidence that might be used to define reproductively isolated populations or groups of populations of fish in Puget Sound. Most molecular genetic markers appear to be largely unaffected by natural selection, so that geographical differences in gene frequencies can be interpreted in terms of gene flow and genetic drift. The analysis of the geographical distributions of these markers may reveal historical dispersals, equilibrium levels of migration (gene flow), and past isolation. Commonly, evidence for genetic population structure is based on the analysis of protein variants (allozymes), microsatellite loci (variable numbers of short tandem DNA repeats), and mitochondrial DNA (mtDNA).

Herring and the Metapopulation Concept

A metapopulation was defined by Levins (1968) as:

> a population of populations which were established by colonists, survive for a while, send out migrants, and eventually disappear. The persistence of a species in a region depends on the rate of colonization successfully balancing the local extinction rate.

As envisioned by Levins (1968, 1970), two of the central characteristics of a metapopulation were that local subpopulations are linked by migration and subject to periodic extinction (extirpation) and recolonization. Consequently, not all suitable habitats would be simultaneously occupied. Levins ideal metapopulation included the assumptions that subpopulations have independent dynamics, that the exchange rate between subpopulations is so low that it has no affect on local subpopulation dynamics, and that all habitat patches have equal isolation and equal area (Levins 1970). In practice, most of Levins' assumptions have been relaxed and no real metapopulation has been identified that satisfies all these criteria (Hanski and Simberloff 1997).

Hanski and Simberloff (1997) have emphasized that local subpopulations within a metapopulation are spatially structured and migration among the subpopulations has some effect on local subpopulation dynamics. Harrison and Taylor (1997) noted that the underlying concept in the many refinements to Levins' metapopulation model is that "persistence of species depends on their existence as sets of local populations, largely independent yet interconnected by migration." Kritzer and Sale (2004) advocated that linkage of local- and regional-scale population processes beyond extinction-recolonization analysis can be considered under the metapopulation concept for marine fishes. Kritzer and Sale (2004) argued that "the critical feature of metapopulations is the coupling of spatial scales, whereby local populations experience partially independent dynamics but receive some identifiable demographic influence from other populations."

Under the metapopulation concept of herring population structure proposed by McQuinn (1997), local herring populations may be perpetuated through a process he termed the "adopted-migrant hypothesis," where juvenile herring that associate with and synchronize their maturation with schools of adult herring will adopt the migration and homing patterns of the adults. Thus, local spawning populations are maintained by "repeat rather than natal homing to spawning areas, while local population persistence is ensured through the social transmission of migration patterns and spawning areas from adults to recruiting individuals" (McQuinn 1997). In McQuinn's (1997) "adopted-migrant hypothesis," hydrographic forces on larvae and the effects of schooling of juveniles leads to the majority of individuals spawning in their native population. Thus differences in the mean values of meristic and morphometric measurements that reflect environmental differences during development are maintained, although strays from other populations are adopted by local populations and gene flow is significant (McQuinn 1997).

McQuinn (1997) stated that the "adopted-migrant hypothesis" is consistent with genetic studies on herring that have not observed temporally persistent differences, since no genetic differences would be expected between sympatric herring populations with the hypothesized level of gene flow. Although McQuinn's (1997) metapopulation concept and "adopted-migrant hypothesis" were first formulated for Atlantic herring, they have equal application in the case of Pacific herring. Along these lines, Ware and co-authors (Ware et al. 2000, Ware and Schweigert 2001, 2002; Ware and Tovey 2004) have provided evidence indicating that the five major migratory stocks of Pacific herring in British Columbia "are spatially structured and interact as a metapopulation." Dispersal rate and straying in both Atlantic (Huse et al. 2002) and Pacific herring (Ware and Schweigert 2002) appear to be density dependent and increase with abundant recruitment resulting in periodic waves of dispersal that radiate throughout the metapopulation.

Evidence supporting the hypothesis that the five major migratory stocks of British Columbia herring form a spatially structured metapopulation include: 1) the spatially fragmented distribution of spawning habitat (Hay et al. 1989, Ware et al. 2000, Hay and McCarter 2004), 2) evidence of disappearance and recolonization events (Ware and Tovey 2004), 3) evidence of significant migration (straying) between the five main stock assessment regions as indicated by tagging data (Hay et al. 1999, 2001a; Ware et al. 2000) and 4) high levels of gene flow as shown by DNA microsatellite analyses (Beacham et al. 2001, 2002). Smedbol et al. (2002) proposed that to be considered a metapopulation a system must meet the following two criteria: 1) local populations must be shown to exchange low levels of individuals and 2) extinction and recolonization must be documented. Both of these metapopulation criteria have been met for Georgia Basin Pacific herring.

Many authors (McQuinn 1997, Ware et al. 2000, Smedbol et al. 2002, Smedbol and Wroblewski 2002) have emphasized that local subpopulations should be considered the basic fisheries management units and that conservation of subpopulation structure is essential for the preservation of spawning potential and genetic and life-history diversity.

DPS DETERMINATION FOR CHERRY POINT PACIFIC HERRING

BRT Determinations of ESA Discreteness for Cherry Point Pacific herring

The BRT was nearly unanimous in its conclusion that Cherry Point Pacific herring represent a discrete population under the language of the joint NMFS-USFWS DPS policy (USFWS-NMFS 1996). A small minority of the BRT concluded that Cherry Point Pacific herring are not discrete from the remainder of the species. The BRT identified a variety of evidence to support its conclusion that Cherry Point Pacific herring are a discrete population including locally unique spawn timing, occupation of a locally unusual exposed coastline for spawning, and physiological factors such as unusual growth rate characteristics for the locality and differential accumulation of toxic compounds in relation to other local Puget Sound herring populations (J. West, Washington Department of Fish and Wildlife, Nov. 30, 2004, PowerPoint presentation).

Washington State herring reserves were established in 1916 (Pacific Fisherman 1916) at Birch Point and Hales Pass (Hale Passage) from April 1 to June 15, while other areas of Puget Sound were set aside from January to March, indicating that late-spring spawning of Pacific herring has been recognized in the vicinity of Cherry Point for almost 90 years. Cherry Point is the only location in Washington State or in the Canadian Strait of Georgia where herring consistently spawn as late as May and June. Spawning in other locations is usually finished by the end of April. Sporadic past occurrence of Pacific herring spawning during May in the Canadian Strait of Georgia has occurred in the following DFO Pacific Herring Sections: Section 142-Baynes Sound (particularly from 1974-1978); Section 173-Yellow Point (May 2, 1955); Section 135-Cape Mudge (May 3, 1969); Section 152-Powell River (May 15, 1952); Section 293-Boundary Bay (May 7, 1975); and Section 193-Victoria Harbour (May 29, 1995) (Hourston 1980, DFO 2004). Although a portion of the Cherry Point herring population historically spawned in the relatively protected waters of Hale Passage, Birch Bay, Drayton Harbor, and Semiahmoo Bay when abundance of the populations was much larger, at present, spawning is confined to the vicinity of Cherry Point in a generally exposed location that is unlike the small protected bays in which herring typically spawn (Stick 1995, O'Toole et al. 2000). Comparison of growth rates and mean size-at-age data for Cherry Point Pacific herring and other "stocks" in Washington State indicates that Cherry Point Pacific herring are consistently larger at age than the other "stocks" surveyed and continue to grow after maturation.

BRT Determinations of ESA Significance for Cherry Point Pacific herring

Although the BRT determined that Cherry Point Pacific herring represent a discrete population, there was no support on the BRT for Cherry Point Pacific herring to be considered significant to the taxon as a whole, as defined in the joint NMFS-USFWS DPS policy. The previous Pacific herring BRT discussed the significance of Cherry Point Pacific herring with respect to the taxon to which it belongs (i.e., the whole biological species, *Clupea pallasii*) and came to a similar finding as reported in the previous status review (Stout et al. 2001). The BRT noted that Pacific herring are widely distributed across the North Pacific Rim and have a large number of fishery stocks and numerous smaller more distinctive populations distributed throughout their extensive range (Hay et al 2001b). The BRT also recognized that the occurrence of other Pacific herring with unusual spawn timing for their area was not exceptional (Hay 1985, Hay and McCarter 1999, DFO 2004), and that other Pacific herring also spawn on fairly exposed coastlines of inshore waters in the Pacific Northwest that can be subject to high energy wave action [i.e., Crab Bay Flats, Southeast Alaska (Leon 1993)].

Several genetic studies were reviewed by the BRT to assist in the determination of distinct and significant population segments. Two studies, Beacham et al. (2001, 2002) and Small et al. (2004), compared microsatellite DNA allele variation at a number of loci within and between populations of Pacific herring. A third, Bentzen (2004) compared variation in mitochondrial DNA (mtDNA) haplotypes among several populations of Pacific herring and one population of Atlantic herring. The genetic information reviewed suggested that in general Pacific herring are characterized by high levels of gene flow among populations across fairly large geographic areas, consistent with the results of extensive tagging studies (Hay et al 2001a). Overall, the genetic analysis of Beacham et al. (2001, 2002) supported the metapopulation view of Pacific herring populations in British Columbia, at least among the large migratory stocks. Several samples, including the single sample from a single year at Cherry Point, were identified in Beacham et al. (2001, 2002) as being somewhat more distinct. These included samples from later (spring) spawning Pacific herring, samples from remotely sited "resident" herring in mainland inlets, and samples from sites that were geographically distant from British Columbia. Although, these "outlier" samples appeared to cluster together in Beacham et al's (2001, 2002) analysis, it was unclear whether this apparent similarity was an artifact of the analysis or an indicator of past or present genetic exchange. The report by Small et al. (2004), suggests that a number of genetically discrete population aggregations may exist, specifically in Alaska, Puget Sound, and California. Within Puget Sound, there was a small degree of genetic differentiation among sampling sites and in some cases between years within a site. The BRT hypothesized that the Puget Sound herring populations, particularly in the South Sound, may be characterized by a degree of isolation similar to other "inlet" locations in British Columbia. In some cases it was possible for the BRT to hypothesize a mechanism for some level of demographic isolation. For example, temporal differences in spawning time (Cherry Point) or geographic isolation (Squaxin Pass) could result in the observed levels of genetic distinctiveness. Analysis of samples within Puget Sound indicated small but significant levels of genotypic differentiation between most sampling sites. The absolute level of divergence among Puget Sound sites was not large, with only ~0.3% of the total genetic variation partitioned among locations. To provide some perspective, this is 10-fold less than the level of divergence observed among populations within the Oregon Coastal coho salmon ESU (Teel et al. 2003, Ford et al. 2004). The BRT interpreted this as evidence that these Pacific herring sampling sites were somewhat demographically isolated from each other, but concluded that this level of divergence was unlikely indicate an evolutionarily significant level of differentiation. Analysis of mtDNA variation by Bentzen (2004) failed to identify any significantly differentiated sampling sites ranging from California to the Bering Sea. In general, there was substantial variability in mtDNA both between samples and between years from the same sampling site. There were a number of mtDNA haplotypes that were unique to temporal samples within a sampling site. Conversely, there were a number of haplotypes that were common to a large proportion of the sampling sites. Given the large number of rare or unique mtDNA haplotypes more extensive sampling is probably needed to provide a more discriminative analysis of Puget Sound Pacific herring. Given the observed genetic variability within and between Puget Sound sampling sites of Pacific herring (Beacham et al. 2001, 2002; Small et al. 2004; Bentzen 2004), the BRT concluded that the genetic distinctiveness observed for Cherry Point Pacific herring was not of a magnitude that could be characterized as evidence that Cherry Point herring "differs markedly from other populations of the species in its genetic characteristics."

BRT Determination of DPS that Incorporates Cherry Point Pacific herring

To capture the uncertainty in identifying the boundaries of the DPS of Pacific herring that incorporates Cherry Point Pacific herring, the BRT adopted a "likelihood point" method, often referred to as the "FEMAT" method because it is a variation of a method used by scientific teams evaluating options under President Clinton's Forest Plan [Forest Ecosystem Management: An Ecological, Economic, and Social Assessment Report of the Forest Ecosystem Management Assessment Team (FEMAT; http://www.or.blm.gov/ForestPlan/ NWFPTitl.htm)]. This method has also been used in all recent status review updates for federally listed Pacific salmon and steelhead ESUs. In this approach, each BRT member distributes ten "likelihood" points among a number of proposed DPSs, reflecting their opinion of how likely that proposal correctly reflects the true DPS boundaries. Thus, if a member were certain that the DPS that contains Cherry Point Pacific herring was Cherry Point alone, he or she could assign all ten points to that proposal. A member with less certainty about DPS boundaries could split the points among two, three, or even more DPS proposals.

The BRT considered up to eight possible DPS configurations that might conceivably incorporate Cherry Point Pacific herring. Ultimately each BRT member distributed their 10 "likelihood points" amongst these possible configurations. Other possible configurations that encompassed either smaller or larger geographic areas were contemplated, but were not included. In order to try and capture the level of uncertainty on the BRT regarding the decision that Cherry Point Pacific herring were a discrete population, but not significant to the species as a whole, two of the DPS scenarios that were considered delineated Cherry Point Pacific herring as a DPS. The DPSs considered in this evaluation were:

1) Multiple DPSs for Puget Sound Pacific herring based on spawn timing
    a) Cherry Point (Late-spring spawning Pacific herring DPS)
    b) Winter spawning Puget Sound Pacific herring DPS
2) Multiple DPSs for Georgia Basin Pacific herring based on spawn timing
    a) Cherry Point (Late-spring spawning Pacific herring DPS)
    b) Winter spawning Georgia Basin Pacific herring DPS
3) Georgia Basin Pacific herring DPS (current boundaries and definition of DPS - Puget Sound/Strait of Georgia/ Strait of Juan de Fuca).
4) Pacific herring DPS incorporating Puget Sound, Strait of Georgia, and West Coast Vancouver Island spawning locations.
5) Puget Sound to Sitka, Alaska.

6) Puget Sound to Aleutian Peninsula.
7) San Diego to Sitka, Alaska.

There was very little support on the BRT for a separate Cherry Point DPS; less than 8% of the "likelihood points" were distributed amongst DPS scenarios 1 and 2. All remaining "likelihoods points" were distributed among scenarios supporting a DPS at the level of the Georgia Basin (a combination of Puget Sound and the Strait of Georgia) or greater. A majority of the BRT "likelihood points" supported retention of the current Georgia Basin Pacific herring DPS; however, over a third of the total "likelihood points" were distributed among scenarios that represented a DPS configuration that was larger than the Georgia Basin. There was significant support on the BRT for a larger DPS than Georgia Basin based on tagging studies that indicate extensive straying at scales greater than the Georgia Basin (Heyamoto and Pasquale 1961, Buchanan 1986, Hay et al. 2001a); genetic studies of Grant and Utter (1984), Beacham et al. (2001, 2002), and Small et al. (2004) that indicate wide genetic homogeneity of the overwhelming number of herring populations in the Pacific Northwest and British Columbia; and evidence that most herring populations in British Columbia can be described as a metapopulation (Ware et al. 2000; Ware and Schweigert 2001, 2002; Ware and Tovey 2004). However, the BRT did not feel that these were reasons enough to modify the boundaries of the present DPS. The BRT noted that the ecological discreteness of the Georgia Basin (the inshore waters of Puget Sound and the Strait of Georgia) and concordance of age composition of herring among SOG and Puget Sound locations provided support for this decision. As currently defined, the Georgia Basin Pacific herring DPS encompasses spawning locations of Pacific herring in all the marine waters of Puget Sound, the Strait of Georgia, and eastern Juan de Fuca Strait in both the U.S. and Canada.

THE "EXTINCTION RISK" QUESTION

The ESA (Section 3) defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." A "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." The determination of whether a species is threatened or endangered, according to the ESA, should be based on the best scientific information available, after taking into consideration conservation measures that are proposed or in place. The BRT did not evaluate likely or possible effects of conservation measures. Therefore, they did not make recommendations on whether the DPS should be listed as threatened or endangered species, because that determination requires evaluation of factors not considered by the BRT. However, the BRT did draw scientific conclusions about the risk of extinction faced by the DPS under the assumption that present conditions will continue, recognizing that natural demographical and environmental variability is an inherent feature of present conditions. Conservation measures will be taken into account by the NMFS Northwest Regional Offices in making listing recommendations.

Adoption of Risk Procedures Utilized in Recent Salmonid Status Assessments

The Georgia Basin Pacific herring DPS, like Pacific salmonid ESUs, is likely structured as a metapopulation; composed of multiple populations with some degree of interconnection, at least over ecological time periods. This makes the assessment of extinction risk difficult, especially since we have fairly solid evidence in the form of tagging studies that the Georgia Basin DPS is sharing relatively large numbers of migrants with populations outside the DPS. In the previous Pacific herring status review, as in the Pacific salmon status reviews prior to 1999, the BRT used a simple "risk matrix" for quantifying DPS-scale risks according to major risk factors (see Stout et al. 2001). In recent status review updates for Pacific salmon and steelhead, the BRTs adopted a risk assessment method that has been used for Pacific salmon recovery planning and is outlined in the viable salmonid populations (VSP) report (McElhany et al. 2000). In this approach, risk assessment is addressed at two levels: first, the population level, then at the overall ESU (or DPS) level. We have modified the previous Pacific herring BRT approach to DPS risk assessment to incorporate VSP considerations. For the purposes of the Pacific herring status review we will refer to these VSP criteria as population viability criteria.

In this approach, individual populations are assessed according to the four population viability criteria: abundance, growth rate/productivity, spatial structure, and diversity. The condition of individual populations is then summarized on the DPS level, and larger-scale issues are considered in evaluating the status of the DPS as a whole. These larger-scale issues include total number of viable populations, geographic distribution of these populations (to ensure inclusion of major life history types and to buffer the effects of regional catastrophes), and connectivity among these populations (to ensure appropriate levels of gene flow and recolonization potential in case of local extirpations). These considerations are detailed in McElhany et al. (2000).

The revised risk matrix (Table 1) integrates the four major population viability criteria (abundance, productivity, spatial structure, and diversity) directly into the risk assessment process. After reviewing all relevant biological information for the Georgia Basin Pacific herring DPS, each BRT member assigns a risk score (see below) to each of the four population viability criteria. The scores are tallied and reviewed by the BRT before making its overall risk assessment. Although this process helps to integrate and quantify a large amount of diverse information, there is no simple way to translate the risk matrix scores directly into an assessment of overall risk. For example, simply averaging the values of the various risk factors would not be appropriate; a DPS at high risk for low abundance would be at high risk even if there were no other risk factors.

Scoring population viability criteria. Risks for each population viability factor are ranked on a scale of 1 (very low risk) to 5 (very high risk):

1. *Very Low Risk.* Unlikely that this factor contributes significantly to risk of extinction, either by itself or in combination with other factors.

2. *Low Risk.* Unlikely that this factor contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors.

3. *Moderate Risk.* This factor contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future.

4. *High Risk.* This factor contributes significantly to long-term risk of extinction and is likely to contribute to short-term risk of extinction in the foreseeable future.

5. *Very High Risk.* This factor by itself indicates danger of extinction in the near future.

Recent events. The "recent events" category considers events that have predictable consequences for DPS status in the future but have occurred too recently to be reflected in the population data. Examples include a climatic regime shift or El Nino event that may be anticipated to result in increased or decreased predation in subsequent years. This category is scored as follows:

++ — expect a strong improvement in status of the ESU;
\+ — expect some improvement in status;
0 — neutral effect on status;
\- — expect some decline in status;
-- — expect strong decline in status.

Table 1. Template for the risk matrix used in BRT deliberations. The matrix is divided into five sections that correspond to the four VSP "parameters" (McElhany et al. 2000) plus a "recent events" category.

Risk Category	**Score***
Abundance Comments:	
Growth Rate/Productivity Comments:	
Spatial Structure and Connectivity Comments:	
Diversity Comments:	
Recent Events	

* Rate overall risk of DPS on 5-point scale (1–very low risk; 2–low risk; 3–moderate risk; 4–increasing risk; 5–high risk), except recent events double plus (++, strong benefit) to double minus (--, strong detriment)

Results of Modified Risk Matrix for Georgia Basin Pacific herring DPS

Members of the BRT were asked to rate the overall risk to the Georgia Basing Pacific herring DPS using the risk matrix described above, with 1 representing very low risk and 5 representing high risk of extinction in the near future, for the four viability criteria: abundance, growth rate/productivity, spatial structure, and diversity.

Abundance – BRT scores for abundance ranged from 1 to 2, with a modal score of 1. A score of 1 represents "very low risk" and a score of 2 represents "low risk." In this context, very low risk means that it is unlikely that current trends and levels of abundance contribute significantly to risk of extinction for the DPS, either by itself or in combination with other factors. Low risk means that it is unlikely that current trends and levels of abundance contribute significantly to risk of extinction by itself, but some concern that they may, in combination with other factors. Comments on the abundance criterion included consideration that the overall DPS is at historically high levels of abundance since monitoring began in the 1930s, both in estimated tonnage (recent abundance is well over 100,000 metric tons) and numbers of herring (estimated at more than half a billion mature herring); however, the decline of Cherry Point Pacific herring from 24 million fish in 2003 to 14 million in 2004 is troubling.

Growth Rate/Productivity – BRT scores for growth rate and productivity of the DPS ranged from 1 to 2, with a modal score of 2. Again, a score of 1 represents "very low risk" and a score of 2 represents "low risk." In this context, very low risk means that it is unlikely that population productivity (growth rate) contributes significantly to risk of extinction for the DPS, either by itself or in combination with other factors. Low risk means that it is unlikely that population productivity (growth rate) contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors. Comments on the growth rate/ productivity criterion included consideration that overall the DPS is highly productive with the overall population trend and lambda (λ) very positive. This was contrasted with some periods in the past (early-mid 1960s) when the overall DPS was in steep decline. In addition, it was noted that despite these past declines, some subpopulations have shown very high productivity levels, indicating the resiliency and ability to rebound inherent in these subpopulations. It was also noted that the recent short term trend is very positive for the whole DPS and that recruitment is staying high, even though there is an apparent increase in adult mortality possibly correlated with increased harbor seal predation and disease factors (other risk factors are also likely at work here).

Spatial Structure and Connectivity – BRT scores for spatial structure and connectivity ranged from 1 to 4, with a modal score of 2. A large majority of the BRT scored this category as 1–very low risk or 2–low risk. Small minorities of the BRT scored this category as either 3–moderate risk or 4–increasing risk. In this context, very low risk means that it is unlikely that population spatial structure and connectivity contribute significantly to risk of extinction for the DPS, either by themselves or in combination with other factors. Low risk means that it is unlikely that population spatial structure and connectivity contribute significantly to risk of extinction by themselves, but some concern that they may, in combination with other factors. Moderate risk means that population spatial structure and connectivity contribute significantly to long-term risk of extinction, but do not by themselves constitute a danger of extinction in the near future. Increasing risk means that population spatial structure and connectivity contribute significantly to long-term risk of extinction and are likely to contribute to short-term risk of extinction in the foreseeable future. Comments on spatial structure and connectivity criteria included observations that there are no gaps in the geographic range of spawning within the DPS; that all, or most, historically occupied areas continue to experience spawn events; and that there has been little loss of connectivity between any populations, except those with low abundance. It was also noted that although increasing population trends are not uniform across the DPS (Central and Northeastern parts of the DPS show declines), the tagging data indicates that there is likely high connectivity throughout the DPS, so these declining trends would not be a major concern in the context of a metapopulation. It was noted that an estimated 22% of SOG herring emigrate to other regions of British Columbia while 16% immigrate into the SOG from other regions of British Columbia (Hay et al. 2001a; their table 5). Other comments indicated concerns that the bulk of the spawning distribution and most of the abundance and productivity in the DPS has become spatially compacted, especially in the northern half of the DPS. However, this concern was tempered by the feeling that this spatial compaction may be a natural phenomenon.

Diversity – BRT scores for diversity ranged from 1 to 3, with a modal score of 2. A small minority of the BRT scored this category as 1–very low risk, while a larger minority scored this criterion as 3–moderate risk. In this context, very low risk means that it is unlikely that diversity contributes significantly to risk of extinction for the DPS, either by itself or in combination with other factors. Low risk means that it is unlikely that diversity contributes significantly to risk of extinction by itself, but some concern that it may, in combination with other factors. Moderate risk means that diversity contributes significantly to long-term risk of extinction, but does not in itself constitute a danger of extinction in the near future. Comments on the diversity criterion included observations that diversity in spawn timing is still normally distributed around a bell-shaped curve; that there has been little change in the natural range of long term spawn timing within and between populations; that diverse migration still exists in the DPS in the form of nonmigratory and migratory herring; and that that there has been no apparent genetic loss comparable to other marine species, although long term data on this topic are limited. Other comments included concerns that the DPS's life-history diversity has apparently declined over time with a compressed age structure (few old fish), precipitous decline in late-spawning herring populations, and an apparent decline in nonmigratory inlet populations on the mainland or eastern side of the SOG. In addition, it appears that there has been a northward shift in the spawning core area of the DPS, but this may be a natural phenomenon and the DPS is still very productive. It was noted that although life history diversity may be declining, since fewer nonmigratory herring are observed in the SOG, it is difficult to differentiate between "migratory" and "nonmigratory" life history types. It is unclear whether these life history characters are specific to certain populations or present to some degree in all, or most, herring spawning aggregates in the SOG and Puget Sound.

Recent Events – The BRT did not identify any specific "recent events" that might have predictable consequences for DPS status in the future but have occurred too recently to be reflected in the population data. Past events that were recognized as already having had a positive effect on the DPS were the closing of certain fisheries, a possible Pacific Decadal Oscillation (PDO) shift to colder climate conditions, a decrease in predation on herring by Pacific hake due to declining hake size-at-age and loss of larger, older hake in Puget Sound and the SOG; and a decrease in certain pollutants in Puget Sound and the SOG. Past events that were recognized as already having had a negative effect on the DPS were long term temperature increase; declines in local eelgrass beds (Wyllie-Echeverria et al. 2003); an apparent increase in harbor seal predation in inshore waters (Olesiuk 1993, Baraff and Loughlin 2000) and hake predation in offshore waters (Ware and McFarlane 1995); loss of shoreline spawning habitat in PS and the SOG (WADNR 2004, PSAT 2005); and an apparent increase in prevalence of certain parasites like *Ichthyophonus hoferi* (Hershberger et al. 2002).

Approaches to the "Significant Portion of its Range" Question

Pacific herring in this area appear to roughly fit the classical concept of a metapopulation over reasonable spatial and temporal scales (Ware et al. 2000; Ware and Schweigert 2001, 2002; Ware and Tovey 2004; see discussion above). Therefore, it is challenging and difficult to apply the significant portion of the range test to the Georgia Basin DPS, which for the most part functions as a metapopulation, where some populations are always going to be in decline while others are on the rise. Nevertheless, there is also some evidence that some populations in the DPS are more distinctive than others. The vast majority of Pacific herring in the SOG migrate to offshore feeding areas each spring immediately after spawning and then return in the late fall and early winter of each year prior to spawning (Stevenson 1955, Taylor 1964, DFO 2004). In contrast, a number of small resident populations are believed to spend their entire lives in coastal inlets and bays or in the SOG itself and to forgo extensive seasonal offshore migrations (Stevenson 1955, Taylor 1964, Hay 1985). Penttila (1986) also postulated that some proportion of adult herring remain in Puget Sound throughout the summer while others migrate to offshore feeding grounds. However, it is unclear whether Pacific herring nonmigratory life history diversity is structured on a geographic framework or is spread amongst all spawning locations. Spawn timing separation could also promote isolation and thus development of subpopulation structure, as is the case with Cherry Point Pacific herring.

The BRT approached the "significant portion of its range" question for the Georgia Basin Pacific herring DPS in a two step process. Firstly we asked the question: "Are there subpopulations or components of the Georgia Basin Pacific herring DPS that can be identified as relatively independent from one another on the basis of ecological, life-history, or genetic diversity criteria?" The types of data that are relevant to providing an answer to this first question are essentially the same as those examined above in the "Discreteness" section. Secondly, we asked: "Is the DPS at risk in a significant portion of its range, such that loss of the at-risk components or subpopulations would pose a substantial risk to long-term viability of the DPS?" The BRT recognized that the answer to the second question rests largely on the time frame for which the question is asked. In other words, some portions of the DPS may be needed for viability of the DPS in a time frame that is beyond the foreseeable future – long term climate or ecosystem changes may cause certain diversity elements of the DPS to become more important to the DPS's viability over very long time frames (centuries).

In attempting to identify components of the Georgia Basin DPS that may represent independent "subpopulations" we have adapted concepts and methods for identification of "demographically independent populations" developed by McElhany et al. (2000) and various Technical Recovery Teams (TRTs) that are developing recovery plans for Pacific salmon ESUs that have been listed as threatened or endangered under the ESA (see Northwest Salmon Recovery Planning website; http://www.nwfsc.noaa.gov/trt/index.html). The various TRTs have identified current and historical salmon populations using a variety of data sources including: 1) documented historical presence, 2) drainage size and structure, 3) geographic isolation by distance or elevation, 4) genetic attributes, 5) phenotypic characteristics, 6) environmental characteristics, and 7) population dynamics and size. Each of the TRTs have fine-tuned the process and methods for identifying demographically independent populations in ESUs under their purview, and the reader is directed to documents published by the TRTs for details (Puget Sound TRT 2001, Interior Columbia Basin TRT 2003, Myers et al. 2003, Lawson et al. 2004, Lindley et al. 2004). Identifying these population groups may be useful to the TRTs for several reasons. The first is that such groups represent life-history genetic diversity within the ESU, and maintenance of this diversity is important for long-term ESU persistence (McElhany et al. 2000). In addition, the problem of ESU risk would be simplified by identifying "independent" populations whose viability could then be assessed as individual units.

Independent populations of Pacific salmon will generally (but not always) be smaller than a whole ESU, and will generally inhabit geographic ranges on the scale of whole river basins or major sub-basins that are relatively isolated from outside migration. Populations are demographic units within which individuals interact at time scales of a few days to a few generations, whereas ESUs are genetic units in which relevant variation and structure change on time scales of tens to hundreds of generations.

The Pacific herring BRT examined subpopulation structure of the Georgia Basin herring DPS using the above demographically independent approach, which is essentially a metapopulation approach. It was evident that some local subpopulations have distinguishing characteristics such as discrete and persistent spawning location, discrete spawn timing, phenotypic distinctiveness (mean length-at age, weight-at-age, growth rate), contaminant profiles, otolith chemistry, parasite incidence, migration behavior, and genetic distinctiveness (variation in microsatellite DNA allele frequency). Temporal variation (comparison between 1970s and 1990s) in some growth parameters were noted within subpopulations; however, differences between subpopulations were generally stable and maintained over time (see Begg et al. 1999) These data indicate that some subpopulations in the DPS may be more reproductively isolated than others. This observation is most consistent with the "mixed structure" metapopulation model as articulated by Harrison and Taylor (1997), which accounts for more isolated subpopulations operating within a metapopulation where most of the subpopulations are connected by higher rates of exchange.

Description of Possible Subpopulations of the Georgia Basin Pacific Herring DPS

Based on the above information, the BRT concluded the DPS could provisionally be divided into eight demographically identifiable "subpopulations":

1) Cherry Point – microsatellite DNA allele frequency variation, spawn timing, geographical location (exposed spawning location), growth rate, and contaminant profiles indicate that Cherry Point Pacific herring are relatively distinctive compared to most other Pacific herring in the DPS.

2) Squaxin Pass – microsatellite DNA allele frequency variation, geographical location (inlet population), growth rate, and spawning behavior indicate distinctiveness.

3) South/Central Puget Sound (Skagit Bay, Port Susan, Killisut Harbor, Holmes Harbor, Port Gamble, Quilcene Bay, South Hood Canal, Port Orchard/Port Madison, Quartermaster Harbor, and Wollochet Bay) – Difficult to subdivide this WDFW management unit, besides Squaxin Pass. Geographical location (inlet population) of South Hood Canal may indicate distinctiveness, although data is non-existent.

4) Strait of Juan de Fuca (Discovery Bay, Dungeness Bay, Sooke Harbour, Victoria Harbour) – may be distinctive on basis of geographical location (early entry into relatively open ocean conditions of Strait of Juan de Fuca). Relationship to North Puget Sound + Southern SOG is uncertain.

5) Bute Inlet (BC Herring Section 134) – may be distinctive on basis of geographical location (inlet population) and supposed migration behavior.

6) Jervis/Sechelt Inlets (BC Herring Sections 162, 163, 164, 165 plus sections 292 and 280, which have had intermittent spawn) – may be distinctive on basis of geographical location (inlet population) and supposed migration behavior. Schweigert (1991) showed Jervis Inlet as distinct based on multivariate analyses of size-at-age and age composition.

7) Northern SOG (BC Herring Sections 135, 136, 151, 152, 141, 142, 143, 172) – Difficult to subdivide this unit. Relationship to North Puget Sound + Southern SOG is uncertain. This is the large clearly migratory component of the DPS.

8) North Puget Sound + Southern SOG (BC Herring Sections 173, 181, 182, 191, 192, + Semiahmoo Bay, Samish/Portage Bays, NW San Juan Islands, Interior San Juan Islands, and Fidalgo Bay) – Relationship to large Northern SOG migratory subpopulation is uncertain. Lack of data makes it difficult to subdivide this unit. There are past indications of intermingling of spawning locations for nonmigratory and migratory herring.

The distinctiveness of nonmigratory SOG herring [historically identified in Jervis/Sechelt and Bute Inlets (Eastern SOG) and in the Gulf Islands] and nonmigratory Puget Sound herring is largely uncertain, as is the biological distinctiveness among inlet populations.

The number and boundaries of these proposed subpopulations within the DPS are inexact and subject to revision when additional data are acquired. Their main usefulness at this time is for providing some degree of spatial structure to the BRT's analysis of the significant portion of the DPS's range question.

Conclusions: Risk Assessment

The BRT has concluded that the Georgia Basin Pacific herring DPS is not at risk of extinction in all or a significant portion of its range, nor likely to become so in the foreseeable future. Details about how the BRT reached this conclusion are summarized below.

Available information (genetics, life history, tagging studies) suggests that population structure of Pacific herring roughly conforms to the classical concept of a metapopulation, in which local subpopulations are linked demographically by at least episodic migration, and extinction and recolonization of local subpopulations are common over ecological time frames. In this type of system, at any given point in time some local subpopulations are expected to be increasing and some declining, and some suitable habitat patches are expected to be uninhabited.

Available information suggests that the Georgia Basin DPS of herring does not differ substantially in general features of biology from Pacific herring in other areas. Therefore, the BRT concluded that, as a reasonable approximation, the classical metapopulation model provides a framework for assessing extinction risk of the DPS. Under this framework, the fact that some local subpopulations are declining is not by itself cause for concern about the long-term viability of the DPS. Rather, the key question becomes, "Have recent factors, either natural or human-mediated, disrupted the functioning of the metapopulation to such an extent that its long-term viability is compromised?" This question could also be rephrased along the following lines: "Is the DPS at risk in a significant portion of its range, such that loss of the at-risk components would pose a substantial risk to long-term viability of the DPS?"

To make this question more operational, the BRT considered the related question, "Are subpopulation declines more pervasive and more pronounced than we would expect to find in a healthy metapopulation?" To evaluate this last question, the BRT considered trends in eight different areas of the DPS, roughly defined on the basis of geography, life history, and genetics

(Cherry Point, Squaxin Pass, South/Central Puget Sound, Strait of Juan de Fuca, Bute Inlet, Jervis/Sechelt Inlets, Northern SOG, and North Puget Sound + Southern SOG). Overall abundance is declining within some of these areas and increasing in others (see Table 2). Ideally, one would like to be able to compare the current data with what might be obtained from taking a random series of historical "snapshots" from a healthy DPS, as this would provide a baseline against which to evaluate current patterns. Unfortunately, this is not feasible, at least at the present time. However, it is possible to compare patterns within the Strait of Georgia DPS with data for Pacific herring in other areas. This comparison suggests that patterns of abundance and distribution within the Strait of Georgia DPS appear to be fairly typical of what is seen in other herring populations throughout northwestern North America, including many relatively pristine areas in southeastern Alaska and British Columbia (Hay et al. 2001b). Furthermore, overall abundance of the DPS is at historically high levels, and the number of kilometers of coastline used by herring for spawning has also been increasing (Hay and McCarter 1999). Therefore, the BRT concluded that available evidence does not suggest unusual levels of risk to the DPS as a whole, nor to a significant part of the DPS.

However, the BRT also identified reasons for concern about some local subpopulations within the DPS and some potential future developments that would increase risks to the DPS. First, metapopulation theory indicates that in source-sink systems [that is, when some areas ("sources") regularly produce excess migrants that colonize habitat patches with negative net productivity ("sinks")], the existence of sinks can buffer extinction risk of the entire metapopulation compared to a scenario in which the sink areas cease to function at all. Furthermore, habitat patches that are sinks during one environmental regime can become sources if conditions change (and vice versa). Hilborn et al. (2003) recently provided a good empirical example of the importance of temporal changes in relative productivity of different populations of Bristol Bay sockeye salmon in stabilizing long-term, overall abundance. Therefore, a scenario in which currently unproductive habitat is allowed to cease functioning altogether, or to permanently degrade to the point at which it cannot revert to good habitat during favorable environmental regimes, can impair the functioning of the entire metapopulation. Available evidence does not suggest that this factor has contributed significantly to the current patterns of subpopulation declines within the DPS. For example, some of the most depressed (perhaps even extirpated) subpopulations occur in eastern SOG inlets, areas that have relatively pristine habitat. In addition, at Cherry Point, where recent declines are a concern, the most intense herring spawn activity is concentrated in some of the most disturbed habitat—not the pattern that would be expected if habitat factors were impairing metapopulation function. Nevertheless, this issue warrants close monitoring in the future, as human population pressures are expected to increase in many areas used by the DPS.

Second, the BRT recognized that the classical metapopulation concept does not perfectly fit the Georgia Basin herring DPS. The pattern of subpopulation structure in the DPS is more similar to the "mixed structure" metapopulation model of Harrison and Taylor (1997) than to Levins' (1968, 1970) classical metapopulation. Although the DPS is characterized by high levels of homogeneity, the Cherry Point population and some subpopulations such as Squaxin Pass are relatively more distinctive, based on spawn timing, growth rate, contaminant profiles, and genetic differences. And as noted above, the BRT concluded that Cherry Point pacific herring meets the DPS criteria to be considered a "discrete" population. These differences are not of a magnitude that suggests long-term evolutionary divergence, but it is possible that demographic linkages between these and other subpopulations in the DPS are weak enough that they are largely demographically independent on ecological time scales. If this is the case, and if these subpopulations were lost, recolonization might take longer than it would for areas that are part of a classical metapopulation. Still, the BRT did not feel that current risks to these areas represent risks to a significant portion of the range of the DPS as a whole. Cherry Point Pacific herring are characterized by late mean spawn timing, but this timing is not temporally discontinuous and falls within the tail of the distribution for the DPS as a whole, and subpopulations with similar spawn timing occur in other geographic areas, beyond the boundaries of the DPS. Cherry Point Pacific herring represent only one of about 40 recognized assessment regions or "stocks" within the DPS, although historically it may have been one of the largest populations in the central part of the DPS. At its peak several decades ago, Cherry Point Pacific herring represented perhaps about 11% of the biomass of the DPS as a whole, but this proportion is speculative and not necessarily indicative of historical conditions, because at that time many of the larger subpopulations in the DPS were severely depressed due to over-harvesting and poor recruitment conditions.

If Cherry Point and Squaxin Pass are largely independent demographically, they would correspond to independent populations under the criteria established in the Viable Salmonid Populations framework (McElhany et al. 2000). Therefore, it is useful to briefly review the ESA listing status of salmon DPSs comparable in size and complexity to the Strait of Georgia herring DPS. Most salmon DPSs cover roughly comparable geographic areas (e.g., salmon DPSs have been identified at the level of Puget Sound, Georgia Basin, Snake River Basin, California Central Valley) and include a substantial number (typically 20-40) of demographically independent populations/stocks. Thus, the Georgia Basin herring DPS, with perhaps a few demographically independent populations interacting with a larger metapopulation, shows less demographic/genetic structure than most salmon DPSs. Many salmon DPSs include populations with considerable life history/ecological/genetic diversity, on a scale as large or (in most cases) larger than found within the Georgia Basin herring DPS. Conservation of this diversity has been given important consideration in both ESA listing determinations and in ongoing recovery planning efforts (Puget Sound TRT 2001, Interior Columbia Basin TRT 2003, Myers et al. 2003, Lawson et al. 2004, Lindley et al. 2004), and about half of the 50+ salmon and steelhead DPSs recognized in the lower 48 states are now listed under the ESA. The status of these listed DPSs has recently been reviewed and updated (WCSBRT 2003), and several relevant points emerge from a comparison of these results with data for the herring DPS:

1) In no listed salmon DPS is abundance of natural fish anywhere near historic levels;
2) No salmon DPS is listed based on declines in only a small fraction of the component populations;

3) Although life history diversity is considered very important, risks to one or two distinctive populations do not necessarily result in a conclusion of risk to the entire DPS. For example, the Klamath Mountains Province steelhead and upper Klamath River Chinook DPSs are not listed, in spite of concerns for the status of certain life history types (summer steelhead and spring Chinook, respectively).
4) Although risk factors for salmon are many and complex, in all listed ESUs loss and/or degradation of habitat was identified as a factor contributing to population declines. In many cases, it has been possible to roughly quantify the changes in salmon habitat compared to historic conditions, which provides a basis for determining how far from the historic (presumably viable) template current situations are. In contrast, no specific risk factor has been identified as the primary cause of decline in the portions of the herring DPS that are of most concern. This makes it difficult to determine whether the current population trajectories are out of the range of historic patterns.

Therefore, the BRT conclusion that the Georgia Basin herring DPS is not at risk in all or a significant portion of its range appears to be consistent with how previous BRTs have considered risk for complex DPSs of salmon.

Finally, the BRT noted that herring play important roles in the Georgia Basin ecosystem. If the fundamental biological processes necessary for herring were to be disrupted in the future, such that the metapopulation ceased to function effectively, the consequences for other species could be substantial. Although these consequences are difficult to predict, it is worth noting that herring are important forage fish for both salmon and killer whales, so collapse of the herring DPS could have serious negative effects on these other protected species.

Table 2. Estimates of long- and short-term trends, and their 95% confidence intervals for Pacific herring in the Georgia Basin Pacific herring DPS.

Named herring stocks/populations	Data years	LT Trend (CI)	ST Trend (CI) (1990-2004)
North Puget Sound			
Cherry Point	1973-2004	0.92 (0.91-0.93)	0.89 (0.84-0.93)
Semiahmoo Bay	1975-2004[a]	1.01 (0.98-1.03)	0.94 (0.91-0.97)
Northwest San Juan Is.	1976-2004[a]	0.93 (0.84 1.03)	0.79 (0.64-0.96)
Interior San Juan Islands	1976-2004[a]	1.07 (0.98-1.15)	0.99 (0.85-1.15)
Samish/Portage Bay	1975-2003[a]	1.05 (1.01-1.09)	1.03 (0.95-1.10)
Fidalgo Bay	1980-2004[a]	1.02 (0.99-1.05)	.0.93 (0.90-0.97)
South/Central Puget Sound			
Skagit Bay	1976-2004[a]	1.05 (1.00-1.09)	1.16 (0.98-1.37)
Holmes Harbor	1976-2004[a]	1.05 (1.01-1.09)	1.03 (0.95-1.12)
Port Susan	1982-2004	0.97 (0.92-1.01)	1.04 (0.94-1.14)
Quartermaster Harbor	1976-2004	0.98 (0.96-0.99)	1.00 (0.95-1.06)
Port Orchard – Port Madison	1975-2004[a]	0.98 (0.94-1.01)	1.05 (0.97-1.14)
Port Gamble	1976-2004	0.99 (0.98-1.01)	0.95 (0.92-0.99)
Killisut Harbor	1975-2004[a]	1.00 (0.97-1.03)	0.98 (0.90-1.07)
Quilcene Bay	1976-2004[a]	1.13 (1.07-1.20)	1.25 (1.13-1.38)
South Hood Canal	1976-2004[a]	0.97 (0.95-1.00)	0.98 (0.90-1.06)
Squaxin Pass	1975-2004[a]	1.05 (0.99-1.11)	1.08 (0.94-1.23)
Strait of Juan de Fuca			
Discovery Bay	1976-2004	0.89 (0.84-0.94)	0.86 (0.70-1.06)
Dungeness Bay	1980-2004[a]	0.98 (0.91-1.05)	0.81 (0.70-0.92)
Puget Sound total [b]	1973-2004	0.99 (0.98-1.00)	1.00 (0.98-1.02)
Canadian Strait of Georgia	1971-2003	1.02 (1.01-1.04)	1.05 (1.02-1.08) [c]
DPS subpopulations			
Bute Inlet	1973-2004	0.97 (0.95-0.99)	0.92 (0.84-1.01)
North SOG	1973-2004	1.04 (1.03-1.05)	1.05 (1.03-1.07)
Eastern SOG Inlets	1973-2004	0.89 (0.80-0.99)	1.10 (0.79-1.55)
North PS + South SOG	1973-2004	1.00 (0.98-1.02)	1.00 (0.94-1.06)
Cherry Point	1973-2004	0.93 (0.92-).94)	0.89 (0.85-0.94)
South / Central Puget Sound	1975-2004	1.03 (1.10-1.04)	1.06 (1.03-1.08)
Squaxin Pass	1975-2004	1.05 (0.99-1.11)	1.08 .(094-1.23)
Strait of Juan de Fuca	1976-2004	0.92 (0.90-0.94)	0.90 (0.84-0.95)
Georgia Basin DPS [b]	1973-2003	1.01 (1.00-1.03)	1.04 (1.02-1.05) [c]

a, Missing several years of biomass estimates; b, Based on biomass estimates of a varying number of stocks per year; c, Data years 1990-2003.

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