BEFORE THE SECRETARY OF COMMERCE

PETITION TO LIST THE LYNN CANAL DISTINCT POPULATION SEGMENT OF PACIFIC HERRING (*CLUPEA PALLASI*) UNDER THE ENDANGERED SPECIES ACT

Juvenile Pacific Herring (NOAA Fisheries, Alaska Regional Office; http://www.fakr.noaa.gov/habitat/FishAtlas/speciespage.htm)

Juneau Group of the Sierra Club

Submitted April 2nd, 2007

EXECUTIVE SUMMARY

The Juneau Group of the Sierra Club ("JGSC") formally requests that the Secretary of Commerce, through the National Marine Fisheries Service ("NMFS" or "NOAA Fisheries"), list the Lynn Canal Distinct Population Segment of the Pacific Herring (*Clupea pallasi*) as threatened or endangered under the federal Endangered Species Act ("ESA"), 16 U.S.C. §§ 1531-1544. The JGSC also requests that NMFS designate critical habitat for Lynn Canal Herring concurrently with any listing.

The Pacific Herring population in the vicinity of Lynn Canal, including Auke Bay and Berners Bay, southeastern Alaska (hereafter: Lynn Canal Herring) is a distinct and imperiled population. Lynn Canal Herring qualify as a distinct vertebrate population segment ("DPS") under the ESA because the population is both discrete and significant to the taxon. Lynn Canal Herring qualify as either threatened or endangered under the ESA based on the five statutory listing factors.

Although the Pacific Herring species as a whole is widespread in the North Pacific Ocean, the taxonomy of the species is in flux, and recent studies indicate that new taxonomic designations are appropriate for many populations. This is particularly true for Lynn Canal Herring. Under the DPS policy for listing distinct population segments under the ESA, a population must be both discrete and significant. Factors that make Lynn Canal Herring discrete from other herring include genetics, physiology, morphology, spawning time and location, and wintering and feeding location and migration. Factors that make Lynn Canal Herring significant to the taxon include a unique ecological setting, a significant gap in the range of taxon, marked genetic differences, significance to the ecosystem, evolutionary potential and cultural significance. In sum, Lynn Canal Herring are discrete and significant enough to warrant the protections of the ESA.

Lynn Canal Herring have suffered an estimated 90-99% reduction in overall abundance in the last 35 years alone. Major spawning grounds are reduced from more than 30 linear miles in the 1950s, to 2-5 miles at present. Fishery managers at the Alaska Department of Fish and Game (ADFG) categorize Lynn Canal Herring as a collapsed stock, and the fishery has been closed since 1982. Since the collapse of Lynn Canal Herring, the population has not recovered and is continuing to spiral towards extinction, despite the cessation of fishing pressure.

Historic overfishing habitat losses are responsible for the initial reduction in Lynn Canal Herring numbers. However, the ongoing destruction of spawning beds, degradation of water quality and pollution associated with human developments now threaten the remaining spawning grounds for Lynn Canal Herring. Taken individually and cumulatively, these large scale disturbances threaten to wipe out what remains of the once numerous Lynn Canal Herring.

Only the protections afforded by the ESA can rescue the Lynn Canal Herring from extinction. Petitioner requests that NMFS act without delay to list the Lynn Canal Herring as threatened or endangered and designate critical habitat.

NOTICE OF PETITION

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Mark Rorick
Chair
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Pursuant to Section 4(b) of the Endangered Species Act ("ESA"), 16 U.S.C. § 1533(b), Section 553(3) of the Administrative Procedures Act, 5 U.S.C. § 553(e), and 50 C.F.R. § 424.14(a), the Juneau Group of the Sierra Club hereby petitions the Secretary of Commerce, through the National Marine Fisheries Service ("NMFS" or "NOAA Fisheries"), to list the Lynn Canal Distinct Population Segment ("DPS") of the Pacific Herring (*Clupea pallasi*) as threatened or endangered under the federal Endangered Species Act ("ESA"), 16 U.S.C. §§ 1531-1544.

The Sierra Club is a national grassroots conservation organization with approximately 750,000 members. The Sierra Club's interest in Alaska started with the founding of the Club in 1892, spans the entire 20th century, and continues today. In the late 1800's the Clubs founder, John Muir, traveled the waters of S.E. Alaska, including Lynn Canal and Berners Bay, marveling at the abundance of wildlife to be found there. In Alaska the Sierra Club is represented by the Juneau Group of the Sierra Club ("JGSC"). JGSC was formed almost 40 years ago as part of an effort to protect the habitat of Berners Bay and Lynn Canal, then threatened by a proposal to

establish a pulp mill at Echo Cove. JGSC has members residing in nearly every community of S.E. Alaska with approximately 275 of these members residing in the communities of Lynn Canal.

NMFS has jurisdiction over this Petition. This Petition sets in motion a specific process, placing definite response requirements on NMFS. Specifically, NMFS must issue an initial finding as to whether the Petition "presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). NMFS must make this initial finding "[t]o the maximum extent practicable, within 90 days after receiving the petition." Id. Petitioners need not demonstrate that listing of the Lynn Canal Herring is warranted, rather, Petitioners must only present information demonstrating that such listing may be warranted. While Petitioners believe that the best available science demonstrates that listing of the Lynn Canal Herring as threatened or endangered is in fact warranted, there can be no reasonable dispute that the available information indicates that listing the species as either threatened or endangered may be warranted. As such, NMFS must promptly make a positive initial finding on the petition and commence and complete a status review as required by 16 U.S.C. § 1533(b)(3)(B).

Petitioners also request that critical habitat be designated for the Lynn Canal Herring concurrently with the species being listed as threatened or endangered, pursuant to 16 U.S.C. § 1533(a)(3)(A) and 50 C.F.R. § 424.12.

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INTRODUCTION

The Lynn Canal population of Pacific Herring (*Clupea pallasi*) is a distinct population segment that is vulnerable to extinction. Historic overfishing depleted the population initially, but the destruction and degradation of spawning grounds are the primary reason for the herring's failure to recover. In addition, several other factors including oceanic warming, oil pollution and anthropogenic noise are complicating factors that combine with the loss of habitat to endanger the Lynn Canal Herring. The most imminent threat to the herring is the development of a highway, gold mine, and marine terminal facilities in the region of Berners Bay. Past developments adjacent to and within historic spawning grounds around Auke Bay have destroyed spawning areas in once important breeding sites. The proposed developments around Berners Bay, now the last stronghold for the herring, will likely sound the death knell for this once numerous schooling fish.

In Southeast Alaska, Pacific Herring are grouped into roughly 5 major populations that correspond to spawning aggregations. One of these major populations inhabits the waters in and around Lynn Canal (See Figure 1). The Lynn Canal Herring population inhabits the Auke Bay, Berners Bay and Lynn Canal areas of Alaska. The scope of this petition is limited to Lynn Canal Herring, and does not apply to Pacific Herring in other parts of Southeast Alaska.

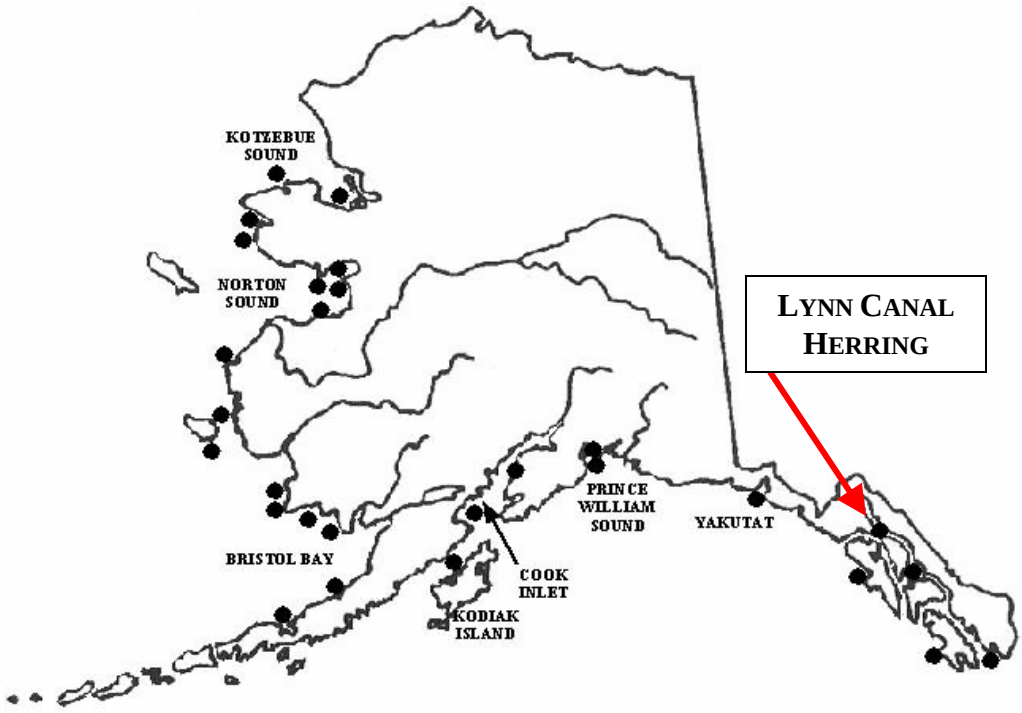

Figure 23. Geographical distribution of major Pacific herring spawning locations in south-central and western Alaska. Solid circles (●) represent approximate locations of Pacific herring spawning localities listed in Rounsefell (1930), Wespestad (1978), Barton and Wespestad (1980), Hay (1985), ADFG (1985), and Burkey (1986).

Figure 1: Major Pacific Herring spawning aggregations in Alaska (Figure from Stout et al. 2001).

This petition is divided into four main sections and an appendix.

Section One provides an overview and species account of the Pacific Herring generally and Lynn Canal Herring where specific information is available.

Section Two provides a detailed summary of information on the abundance and population trends of Lynn Canal Herring.

Section Three evaluates the Lynn Canal Herring population in light of the definition of a "species" under the ESA, 16 U.S.C. § 1532 (16), and the definition of a "distinct vertebrate population segment" under the joint U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) Policy Regarding the Recognition of Distinct Vertebrate Population Segments (DPS Policy) (USFWS-NMFS 1996). This petition concludes that the Lynn Canal Herring population satisfies the DPS Policy, and therefore should be considered a "distinct vertebrate population segment" under the ESA.

Section Four analyses the conservation status of Lynn Canal Herring in the context of the five factors considered for listing a species as threatened or endangered under the ESA.
Appendix A provides an overview and summary of relevant genetic data on herring.

I. SPECIES ACCOUNT

A. Species Description

Pacific Herring are small fish in the family *Clupeidae* which gather in large oceanic schools. They have bluish green dorsal sides which contrast with a silvery ventral surface (Lassuy 1989). Guanine crystals growing in the skin of herring create the silvery layer that reflects light, used to both confuse predators and camouflage large schools.

Pacific herring are easily identified by their silvery color, and lack spots, adipose fin, teeth, and head scales or striae. The herring's slender, elongate body has large cycloid scales. Adults are generally about 8 inches long but can grow as large as 18 inches in some populations. Pacific herring have compressed heads with a mouth directed upward and a lower jaw that extends to a point below the eye (Lassuy 1989).

B. Taxonomy

Cuvier and Valenciennes (1847) first described Pacific herring as a subspecies of Atlantic Herring (*Clupea harengus*). Since that time, taxonomists revised herring taxonomy and identified Pacific herring as a distinct species, *Clupea pallasi*, rather than a sub-species of herring (Rass and Wheeler 1991). The currently recognized nomenclature for the Pacific Herring species is *Clupea pallasi* Valenciennes.

Several subspecies or races of Pacific Herring are defined by numerous authors (See Grant and Utter 1984 for a review). According to Grant and Utter (1984), some researchers

define Pacific Herring along North America's west coast as a subspecies of Pacific Herring called *Clupea pallasi mirabilis*.

> Populations of herring along the west coast of North America from the Bering Sea to California were described as a separate variety (*C. p. mirabilis* Girard), which was thought to consist of an uninterrupted series of transitional forms (Shmidt 1950, Svetovidov 1952, Andriyashev 1954).

(Grant and Utter 1984: 860). Given the uncertainty in the taxonomic status of Pacific Herring, this petition considers Lynn Canal Herring to be either: 1) a population of the species *Clupea pallasi*; or 2) a population of the subspecies *Clupea pallasi mirabilis*.

C. Geographic Distribution and Habitat

1. Range-wide Distribution

The Pacific Herring species has numerous populations throughout the North Pacific Ocean and adjacent seas. In the western North Pacific, they are found throughout the Western Bering Sea to Kamchatka, the Sea of Okhotsk, Hokkaido, Japan, and south and west to the Yellow Sea (Figure 2, Hay et al. 2001b). In the eastern North Pacific Ocean herring range Baja California north to the Beaufort Sea (Figure 3, Hay et al. 2001b). Pacific Herring are also found in the Russian Arctic from the Chukchi Sea to the White Sea (Hay et al. 2001b).

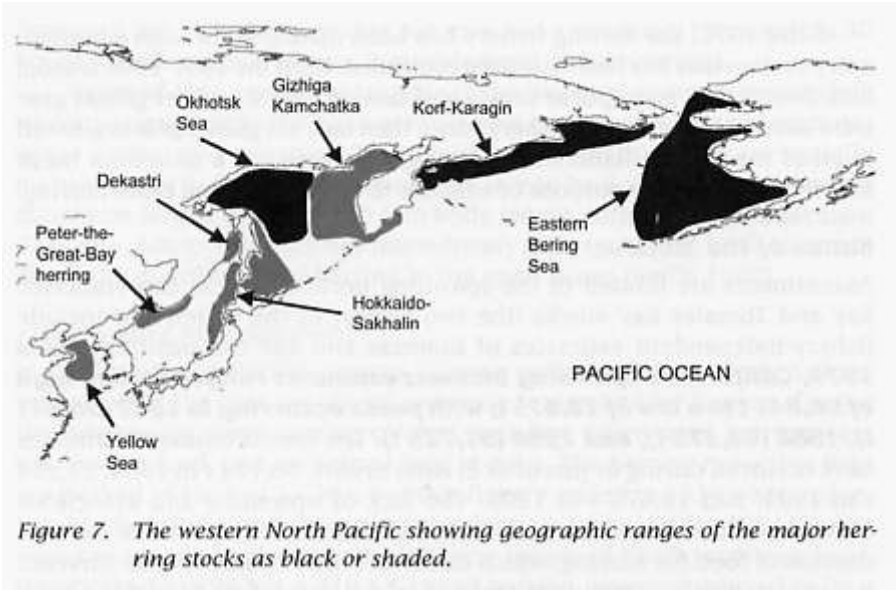

Figure 2: Pacific Herring populations in the western North Pacific Ocean (Figure from Hay et al. 2001b).

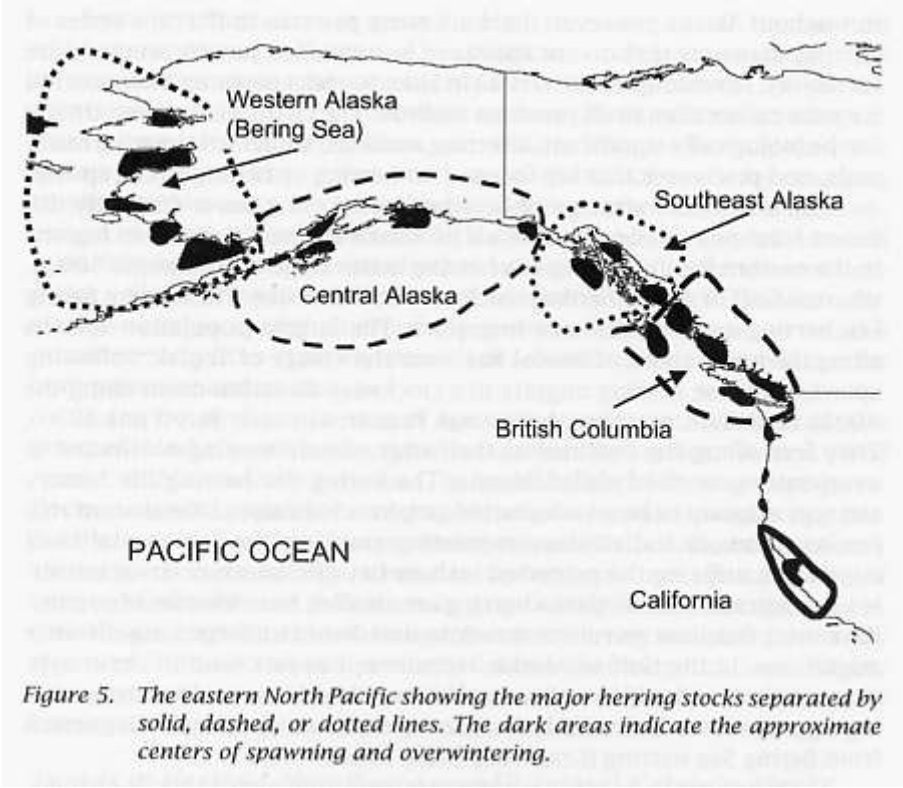

Figure 3: Pacific Herring populations in the eastern North Pacific Ocean (Figure from Hay et al. 2001b). These populations comprise the subspecies *C. p. mirabilis* referenced in Grant and Utter (1984).

2. Southeast Alaska

In Southeast Alaska, at least five major herring populations are presently identifiable based on Skud (1959) (See Figure 4). Carlson (1980) concluded that five major stocks are defined by their concentration on certain wintering grounds: "(1) Sitka; (2) Auke Bay; (3) Craig-Hydaburg; (4) Deer Island-Etolin Island (near Wrangell); and (5) Ketchikan stocks."

The "Auke Bay" stock referred to by Carlson (1980) is synonymous with "Lynn Canal Herring" subject to this petition.

3. Lynn Canal Herring

Lynn Canal Herring are confined to the waters of Lynn Canal, Berners Bay, Auke Bay, northern Stephens Passage and portions of Icy Strait (See Figures 4 and 5). Lynn Canal is a 90 mile long inlet east of Glacier Bay and north of Juneau. Its northern terminus is near the town of Skagway and the southern end extends to Admiralty Island and northern Stephens Passage. Berners Bay and Auke Bay are on the eastern side of Lynn Canal and are of particular importance to herring.

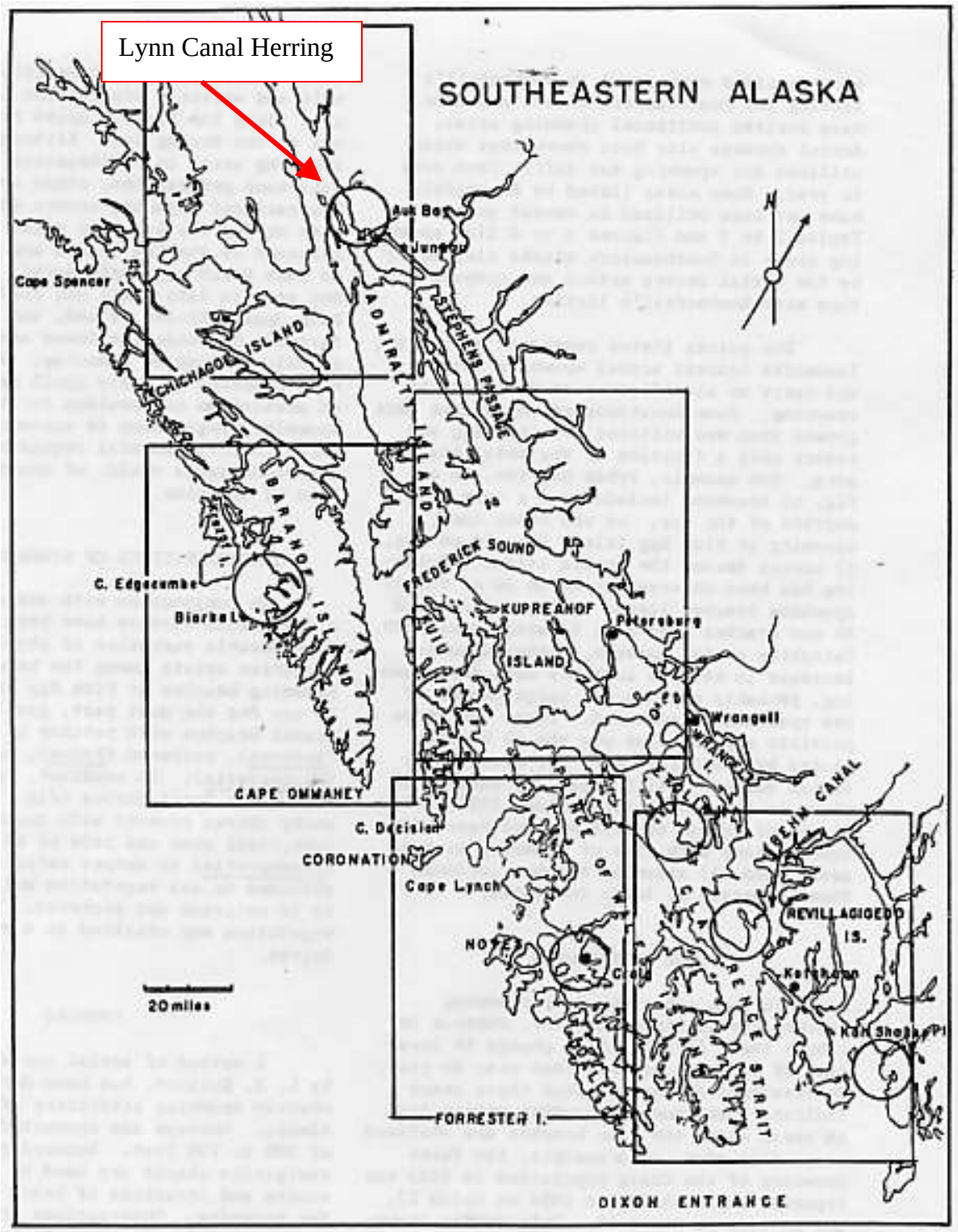

Figure 4: Major Pacific Herring populations in Southeast Alaska, showing the location of Lynn Canal Herring at the top (Figure from Skud 1959).

Carlson (1980) provides the most detailed account of the geographic distribution and habitat of Lynn Canal Herring. Calvin (1977) provides a description of inter-tidal habitats in

Berners Bay. The summary below is based on Carlson (1980) and a more recent review conducted by Williams et al. (2004).

Carlson (1980), Williams et al. (2004), and other authors use the following descriptors to refer to Lynn Canal Herring: Auke Bay, Lynn Canal, Berners Bay, Juneau area. All of these terms refer to the same population of Pacific Herring. This petition uses the name "Lynn Canal Herring." The Lynn Canal Herring historically inhabited all of Lynn Canal and adjacent bays, inlets and coves, including Auke Bay, Berners Bay and Icy Strait.

a) Summer Feeding Areas

Accounts of Lynn Canal Herring distribution as described by Rounsefell and Dahlgren (1935), Carlson (1980) indicate that the waters between Douglas Island and Admiralty Island in southern Lynn Canal and northern Stephens Passage were the most important summer feeding areas.

> Tagging studies have shown that Auke Bay stocks do not intermingle with other stocks in summer feeding areas (Dahlgren 1936 in Carlson 1980; Carlson 1977). From late may through September, scattered schools of adult herring were found over much of the nearshore waters of southern Lynn Canal and northern Stephens Passage, with consistent concentrations along the western shore of Douglas Island (Carlson 1980). Depth distribution ranged from the surface to near bottom, but mostly averaged between 5 m to 37 m. After mid-July, schools concentrated at 10- to 37- m depths.

(Williams et al. 2004).

b) Fall Migration

In the fall, Lynn Canal Herring move from summer feeding areas in more open waters to deeper, sheltered areas in coves and bays, primarily Auke Bay and Fritz Cove (Carlson 1980).

> Adult herring generally moved deeper in the fall (October) as water and air temperatures cooled. Carlson (1980) suggests that the breakup of the thermocline serves as a cue that stimulates movement of Pacific herring from feeding grounds to wintering areas. Herring movements, from open passages into more sheltered wintering areas in Auke Bay and Fritz Cove, were frequently tracked by larger predators such as humpback whales, Steller sea lions, and seabirds.

(Williams et al. 2004).

c) Wintering Areas

Wintering grounds for Lynn Canal Herring are located primarily in deeper, low-current areas from mid-Douglas Island to Benjamin Island near the eastern shoreline of Lynn Canal (Carlson 1980, Williams et al. 2004). Recent acoustic surveys indicate that Slate Creek Cove is also an important wintering area for Lynn Canal Herring (Harris et al. 2005).

> Herring schools concentrated at 52 m to 85 m, close to their yearly maximum depths. During daylight hours, adult herring remained deep and close to the bottom, and were generally not distinguishable on an echo sounder; at night they dispersed and rose in the water column. It is generally thought that in winter, herring are avoiding light levels sufficient for visual detection by predators, and that they use the bottom for cover and protection.
>
> More recent work involving acoustic surveys validated by midwater trawl suggests that mature Lynn Canal herring overwinter in low current areas near the shoreline from mid-Douglas Island to the backside of Benjamin Island.

(Williams et al. 2004).

d) Pre-spawning Aggregations and Spawning Locations

Historic spawning areas for Lynn Canal Herring extended from the northern reaches of Lynn Canal around Haines to the southern terminus of Lynn Canal and in the adjacent areas of Icy Strait in the 1950s according to Skud (1959) (See Figure 5 below). Since that time, spawning beaches have been reduced to Berners Bay, Point Bridget and Bridget Cove (ADFG 2006).

> From February to early March (when days neared 10 hours) herring moved from wintering grounds in Fritz Cove and Auke Bay to concentrate near the bottom off their traditional spawning beaches in Lynn Canal (Carlson 1980). Herring remained there at depths of 73 m to 110 m until late April or early May, when sea-surface temperatures increased to 5 C to 6 C and plankton blooms generally obscured surface visibility. Herring then moved into tidal shallows and commenced spawning, typically over a 2 to 3 week period between late April and early May (from 1973 to 1978), although spawning did extend until late May in some years. No feeding occurs before and during spawning; active feeding occurs thereafter. After spawning, herring returned to summer feeding areas.

(Williams et al. 2004).

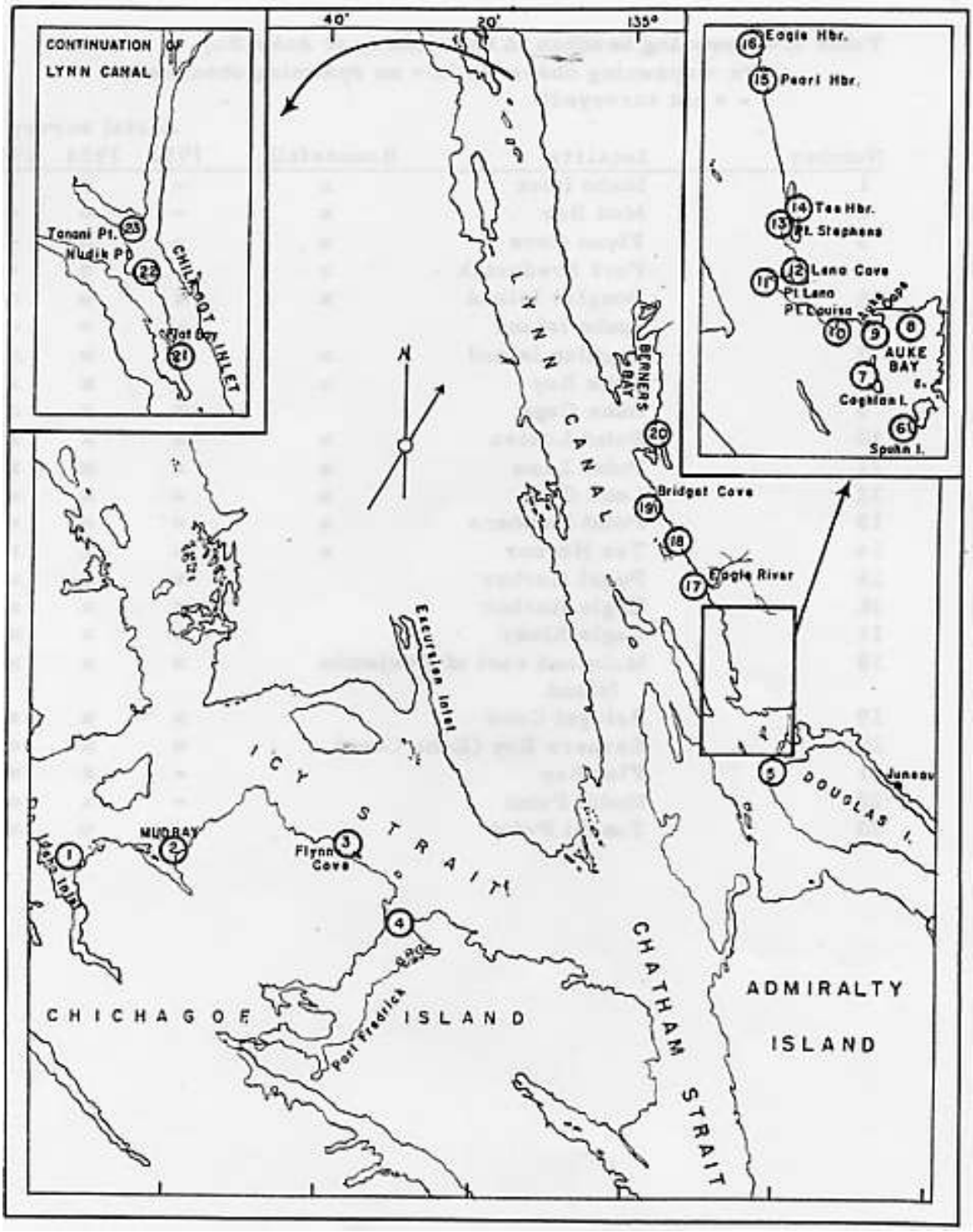

Figure 5: Pacific Herring spawning beaches documented in the 1950s (Figure from Skud 1959). Numbers correspond to the following localities: 1) Idaho Inlet, 2) Mud Bay, 3) Flynn Cove, 4) Port Frederick, 5) Douglas Island, 6) Spuhn Island, 7) Coglahn Island, 8) Auke Bay, 9) Auke Cape, 10) Point Louisa, 11) Point Lena, 12) Lena Cove, 13) Point Stephens, 14) Tee Harbor, 15) Pearl Harbor, 16) Eagle Harbor, 17) Eagle River, 18) Mainland near Benjamin Island, 19) Bridget Cove, 20) Echo Cove, Berners Bay, 21) Flat Bay, 22) Nudik Point, 23) Tanani Point.

e) Larval and Juvenile Rearing Habitat

The distribution of juvenile Lynn Canal Herring is not well known. The best available evidence suggests that juveniles do not stray far from their natal, shallow water habitats. Other populations of Pacific Herring may disperse to deeper offshore waters to mature (NMFS 2005c), but Lynn Canal Herring reside year-round in nearshore waters (Carlson 1980).

> Little specific information exists on the larval and juvenile distribution of herring in Lynn Canal, although Haldorson et al. (1990) noted the seasonal abundance of larval herring in Auke Bay is coincident with spring peaks in copepod abundance. It is generally thought that after hatching, herring larvae are locally retained in nearshore waters close to their natal spawning grounds, where they feed and grow in the protective cover of shallow water habitats. Larval metamorphosis occurs in late July through early September, with schools of juvenile herring observed in the head of Auke Bay in late August (Jones 1978 and Ziemann and Fulton-Bennett 1990). Juvenile herring 1 to 2 years of age are thought to be more dispersed in surface schools throughout Lynn Canal than are adult populations (personal communication, Mark Sigler, NMFS).

(Williams et al. 2004).

D. Life History of Pacific Herring

This section describes the life history of Pacific Herring species generally. Specific information about the Lynn Canal Herring population is provided where available. Lastly, information about Atlantic Herring (*Clupea harengus*) is included where comparison is appropriate.

1. Reproduction and Development

Adult Pacific Herring spawn in shallow sub-tidal and inter-tidal areas along shorelines (Lassuy, 1989, Hay and McCarter 1997). Eggs are deposited on kelp, eelgrass (*Zostera marina*) and other available structures. Pacific herring larvae drift in ocean currents after hatching and are abundant in shallow nearshore waters. After 2 to 3 months, larvae metamorphose into juveniles that form large schools and remain primarily in nearshore shallow-water areas during the first summer. The general life history of Pacific Herring is depicted in Figure 6 below.

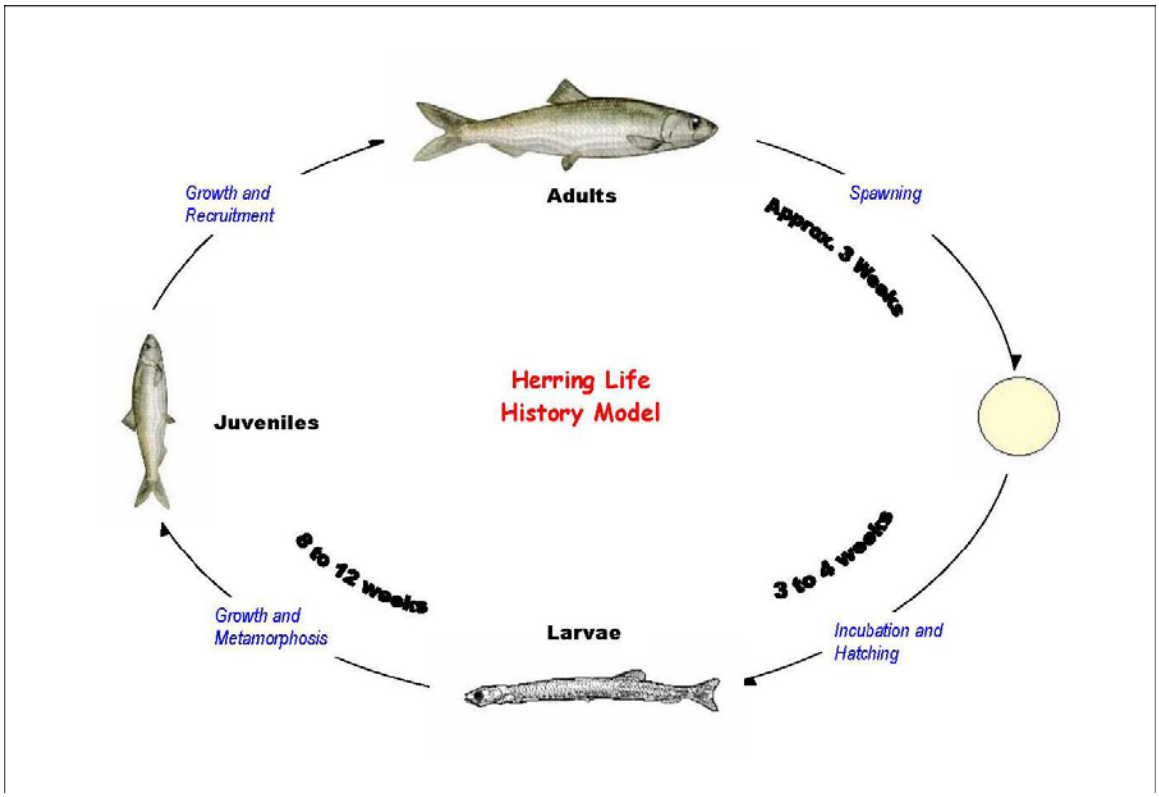

Figure 6: Alaska Pacific herring (*Clupea pallasi*) life history model (Figure from NMFS 2005a).

In particular, the egg stage is highly vulnerable to predation, pollution and other sources of mortality (Rooper et al. 1999). Similarly, juvenile fish are more susceptible to winter starvation than adults (Foy and Paul 1999).

> The demersal egg stage of the Pacific herring may be especially vulnerable to mortality because they incubate for long periods in shallow locations. Predators can feed for an extended period on eggs and may exhibit numerical response to the food source. Eggs can also be susceptible to harsh environmental conditions because they are unable to move from spawning beds.

(Rooper et al. 1999).

2. Feeding Behavior and Diet

Herring feed on phytoplankton and zooplankton in nutrient rich waters associated with oceanic upwelling. According to Carlson (1980), copepods are the primary food of Lynn Canal Herring during the summer, and are primarily composed of larger species that concentrate near the bottom. Once on the wintering grounds of Auke Bay and Fritz Cove, herring generally cease feeding (Carlson 1980).

For a comparison, Abookire et al. (2000) analyzed Pacific Herring in British Columbia for small scale distributions and feeding behavior. Abookire et al. (2000) determined that areas of less-saline, sediment laden waters attracted herring for feeding and to avoid predation.

> Pacific herring spawn in estuaries, and larvae remain in the estuarine nursery grounds through their juvenile stage (Hourston, 1958; Boehlert & Morgan, 1985, p. 162). Larval Pacific herring that hatch in Lamber Channel in the Strait of Georgia, British Columbia, quickly disperse into Baynes Sound, a stable area which is strongly stratified through freshwater input (Robinson, 1988). Our results indicate a similar distribution, as juvenile herring were higher in abundance, constituted a higher percentage of the fish community, and were more frequently captured in the more stratified Inner Bay. Juvenile herring may also be attracted to the Inner Bay by feeding opportunities. Because juvenile herring feed at a greater rate under moderate suspensions of fine grained sediment (Boehlert & Morgan, 1985, p. 161; St. John *et al*., 1992, p. 154), and much of the freshwater input in the Inner Bay contains sediment and glacial silt (Burbank, 1977), these suspensions may promote feeding aggregations by providing visual contrast of prey items while reducing predation (Boehlert & Morgan, 1985, p. 167).

(Abookire et al. 2000).

3. Homing, Straying and Site Fidelity

Although some mixing occurs, tagging studies show that Pacific Herring stick together, remaining in the same school for years. Hay and McKinnell (2002) tagged over 570,000 Pacific herring in British Columbia with external anchor tags during 429 tag release sessions between 1979 and 1992.

> Individually numbered tags were released in quantities of 1000–2000 at a time and recovered from commercial fisheries. Often several tags were recovered at the same time and place, and some recoveries occurred as “matches”, where two or more tags from a single release session were recovered together. We tested the hypothesis that the frequency of matching tag recoveries occurred by chance through random mixing of tagged herring before their recapture during fishing operations. The alternative is nonrandom, positive association among tagged individuals that persisted through time and during migrations. The results indicate nonrandom association of herring for periods of 6 months to several years and through migrations over considerable distances.

(Hay and McKinnell 2002).

Similarly, Hay et al. (2001a) discovered strong homing behavior, or high site fidelity, in certain Pacific Herring populations in British Columbia. Often associated with these areas are differences in spawning times, growth rates, and demographics and populations dynamics (Hay et al. 2001a). The fidelity rates depended on the geographical scale of a particular population, with a very large geographic area such as the entire B.C. Coast approaching 100% fidelity. Hay et al. (2001a) determined that fidelity rates of 80% are sufficient for population differentiation

and that about 80–100 linear kilometers, or 50-60 miles of spawning coastline would produce 80% fidelity.

The historic spawning coastline for Lynn Canal Herring extended outside of Lynn Canal into Icy Strait. This spawning area was likely at least 50 miles of coastline before historic overfishing reduced the population (Rounsefell 1931, Rounsefell and Dahlgren 1936, Skud 1959) (See Figure 5). In 1956-1957, Lynn Canal Herring spawned on 28.1 nautical miles (52 km) of coastline (ADFG 2004), but this was likely a reduced population. Thus, based Hay et al. (2001a) and evidence from Carlson (1980), Lynn Canal Herring do not intermingle with other herring stocks and exhibit strong site fidelity for Lynn Canal and the immediate vicinity.

II. ABUNDANCE AND TREND OF LYNN CANAL HERRING

Lynn Canal Herring are much reduced in total abundance and in the geographic area of observed spawning. For commercial fishery purposes, the Lynn Canal Herring "stock" collapsed in 1981 and has been closed since 1982 (Pritchett 2005). According to the Alaska Dept. of Fish and Game, the Lynn Canal Herring population's spawning biomass has declined by 90-99% since 1971 (See Figure 7) (NMFS 2005a). During this time, the extent of spawning beaches has also declined by at least 90%, from over 20 individual locations covering at least 30 miles of beach as described by Skud (1959) to less than 3 miles at 2-3 locations in recent years (See Figure 8 and Table 1) (ADFG 2006a).

Figure 4.1. Lynn Canal herring population biomass estimates and commercial harvest threshold.
Data provided by Mark Pritchett, Alaska Department of Fish and Game.

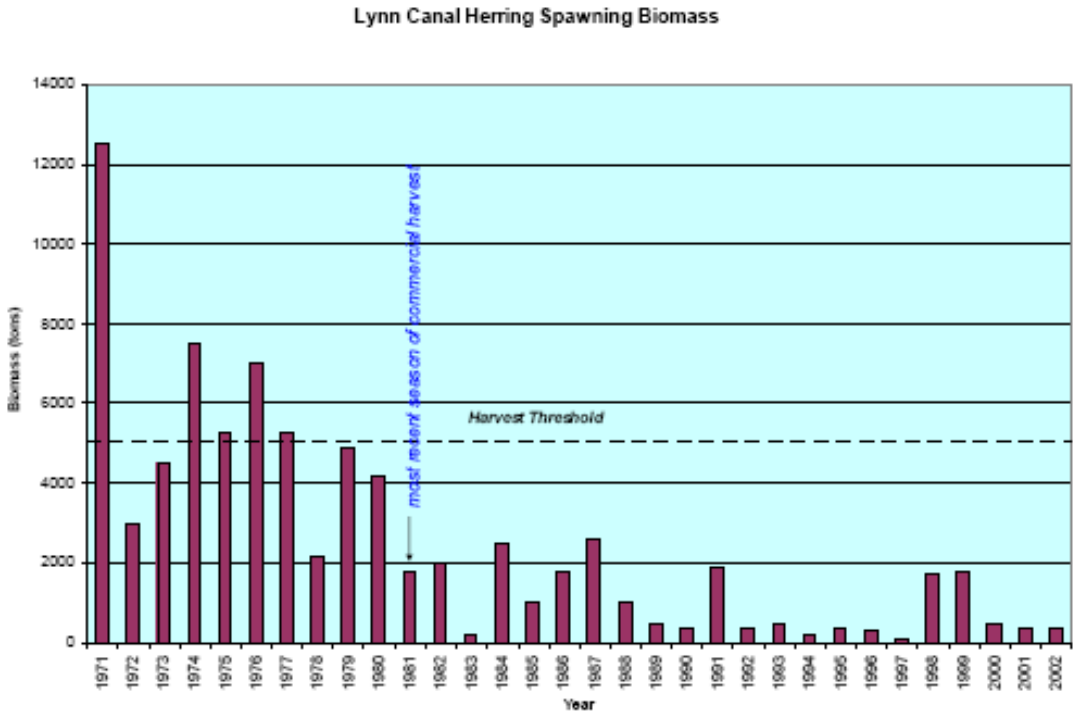

Figure 7: Lynn Canal Herring spawning biomass estimate. (Figure from NMFS 2005a)

According to the NMFS Alaska Regional Office:

> The Lynn Canal herring population has been depressed for the past 20 years. Data on spawning distribution have been collected by Alaska Department of Fish and Game since 1972, which show notable trends in the extent of spawning activity and herring biomass. During the winters of 1972 through 1979, biomass estimates for the Lynn Canal population exceeded 2.27 million kilograms, or approximately 2,500 tons (Carlson 1980). However, since 1981, spawning biomass estimates have been at or below 2,000 tons and

> the commercial fishery in Lynn Canal has been closed; for 2001-2003, the spawning biomass estimate was less than 1,000 tons and a more precise estimate for 2004 was 743 tons based on survey dives to measure egg density (M. Pritchett, pers comm). Along with declines in biomass estimates, the geographic extent of the population's spawning grounds has also declined. From 1972 to 1989, herring spawn was observed in Auke Bay in 14 out of the 18 years, or 78% of the time. However, 1989 was the last year that herring spawn was observed in Auke Bay, and no spawning activity has been observed south of Yankee Cove for the past 15 years (M. Pritchett, pers comm.). Based on the information available, it seems likely that abandonment of the Auke Bay spawning grounds was caused by a combination of factors, including increased shoreline development in the bay, declines in water quality, and low numbers of herring available to spawn and rebuild the stock (Wing, pers comm.,Koski, pers comm.). Continuing trends in small population size and the lack of steady population growth despite the fishery's closure suggest that a population bottleneck may have occurred.

(NMFS 2005: 59). Similarly, the Alaska Dept. of Fish and Game has summarized the status of the population in equally dire terms (ADFG 2004):

> Prior to 1983, the Lynn Canal herring stock was one of the larger stocks in Southeast Alaska supporting several commercial fisheries including a sac roe fishery, bait pound fishery, and a winter food and bait fishery. Lynn Canal herring traditionally spawned from Auke Bay to Point Sherman. This stock declined in 1982 and has since remained at low and variable levels as evidenced from estimates of linear measurements of shoreline that receive spawn. The reason for the decline is not clear, however, potential candidates are overfishing, habitat degradation and/or disturbance in Auke Bay, geographic shifting of spawning aggregations, population growth of major predators such as sea lions, or a combination of these. If the decline is attributable solely to overfishing, it is puzzling that there has been no apparent recovery or re-establishment of this stock during a 20-year absence of exploitation. In other areas in Southeast Alaska, such as West Behm Canal, herring stocks have grown from low levels to very high levels over a span of a few years.
>
> The documented spawn for the Lynn Canal herring stock from 1953 to 1981 ranged from 6 to 28 nautical miles averaging approximately 12 miles. Significant spawning occurred in the vicinity of Auke Bay. <u>In recent years however the entire Lynn Canal herring stock has centered its spawn activity between Pt. Bridget and the Berners Bay flats.</u> Since 1982 the documented spawn has ranged from 0.5 to 7 nautical miles averaging only 3.5 nautical miles. The established biomass threshold level for this stock is 5,000 tons of spawning biomass. This means that before a herring fishery may be considered for the Lynn Canal stock, a forecast spawning biomass must meet or exceed 5,000 tons. Based on shoreline miles of spawn, it is estimated that the stock biomass has varied between 100 and 2,500 tons over the last 20 years. Studies of herring over-wintering in the Juneau area have continued over the years in an attempt to reconcile acoustical observations of biomass with estimates of spawning biomass, and to monitor age composition of the stock.

> Cascade Point and adjacent areas of Berners Bay are within primary spawning grounds for the depressed Lynn Canal herring stock. Development of a marine facility here may have a negative impact on this herring resource. Vessel traffic, increased access, transient lighting, turbidity changes, the presence of hydrocarbons in the water and the potential for oil and/or gas spills are all concerns. Additionally, since spawning herring are believed to target inter tidal and sub tidal kelp to deposit eggs, reduced kelp abundance or variety would directly affect spawning success. Department records of the area since 1971 document herring spawn between Sawmill Cove and the Berners Bay flats in most years with few exceptions. The consistent herring spawn along this shoreline for the last 20 years is indicative of its importance to this stock. Continued encroachment on Lynn Canal shoreline that has historically been used for herring spawning may potentially have cumulative effect leading to the total collapse of the herring resource in this area. This could reduce forage for large predators such as salmon, sea lions, whales, and seals that inhabit Lynn Canal, with unknown ramifications.

(ADFG 2004). The decline in spawning habitat was predicted by USFWS and NMFS personnel at least as far back as 1980.

> A large portion of the coastline in the vicinity of the Cowee – Davis Management Area is herring spawning habitat. We believe that it is vitally necessary to protect such habitat in order to manage the herring resource. At this time, the best method we have for determining what is herring spawning habitat is by observing the frequency of spawning use. This indicates a preference for a particular are by the herring. Habitat alteration and man-induced disturbances in frequently used spawning areas can adversely impact future utilization. This appears to have occurred in Auke Bay where once herring used to spawn throughout the area (Figure 10) and now utilize just a very limited section near Auke Cape (Figure 11). Evidence does not exist to show that these displaced fish spawn in new areas. In addition, when spawning does take place on unsuitable artificial substrate such as boat hulls and petroleum saturated objects, significant egg mortality can result thus adversely affecting annual population recruitment.
>
> In the context of determining habitat value based upon frequency of utilization, <u>the Lynn Canal coastline from Auke Bay to Point St. Mary (Berners Bay) is the single most important stretch of spawning habitat to the Lynn Canal/Auke Bay herring stock</u>. This particular area receives the most concentrated herring spawning activity in Lynn Canal (Figure 11). To date, the spawning area locations charted by Skud in Figure 10 are still applicable, with the exception of Auke Bay as previously noted (D. Ingledue, ADF&G, pers. comm., 1980). <u>The Lynn Canal/Auke Bay herring stock is a discrete population distinguishable by their concentration for overwintering in Auke Bay and Fritz Cove (Carlson 1980)</u>. The location of this wintering are probably accounts, in part, for the geographic proximity of the observed major spawning grounds. We believe that the described spawning are will thus continue to be utilized as spawning habitat and that this will therefore require protection of certain coastal areas.

(USFWS-NMFS 1980: 6-7)(emphasis added).

While NMFS and FWS biologists identified the importance of the coastline north of Juneau to the Lynn Canal Herring population, subsequent construction of roads, dock facilities and other developments, took their toll on the spawning areas. By the mid-1990s, the herring had retreated to only a few pristine areas in and around Berners Bay.

In surveys conducted from 1953-1955, Skud (1959), documented major herring spawning areas throughout Southeast Alaska. Previous surveys in the Atlantic and North Sea indicated that patterns in distribution of herring schools could be extrapolated from spawning grounds. Skud (1959) explained:

> The prime objective of aerial surveys is to determine the mileage of beach used for spawning in a given area. The extent of spawn deposition is assumed to indicate size of spawning population. In addition comparison of annual changes in actual mileage, changes in areas used for spawning can be studied and may help to determine environmental requirements for spawning. Aerial surveys also afford a means of studying timing of spawning activities.

(Skud 1959: 1-2). From three years of flying around Southeast Alaska, Skud (1959) characterized the regional population structure of Pacific Herring and also documented a much greater area receiving herring spawn that has occurred in the last three decades. Skud (1959) compared his work with that of an earlier survey of Pacific Herring in Southeast Alaska conducted by Rounsefell (1930) for the U.S. Bureau of Fisheries.

> Spawning has been observed by air on 20 of the 57 spawning beaches listed by Rounsefell, and 82 new beaches have been located since 1953. Extensive aerial surveys, rather than an increase in beaches actually used for spawning, probably explain the large number of new spawning discovered.

(Skud 1959). Thus, the increase in recorded spawning beaches from 1930 to the 1950s was in fact attributable to the aerial survey methodology and extensive survey effort, not to an increase in actual spawning areas.

However, Skud (1959) did find that many of the beaches that were reported to receive herring spawn by Rounsefell (1930), no longer received any herring spawn in the 1954. For Lynn Canal Herring, Skud (1959) showed that spawning beaches at Idaho Inlet, Mud Bay, Flynn Cove and Port Frederick no longer received herring spawn (See Figure 5 and Table 1). These four areas are outside of Lynn Canal in an area known as Icy Strait (See Figure 5 and Table 1).

An aerial survey conducted by the ADFG on May 5, 2005 reported Pacific Herring only in a small cove south along the coastline outside of Berners Bay.

> *Lynn Canal:* Surveyed last on May 3. Herring were observed inside Bridgett Cove but no spawn or herring were seen in other areas of Lynn Canal including Berners Bay.

(ADFG 2005-Juneau Update #10). A survey from May, 16 2006 revealed that Lynn Canal Herring had failed to spawn in Berners Bay for the second consecutive year.

> Mondays survey revealed that the Lynn Canal herring spawn event was all but over. A couple of light spawns were documented at the southern entrance to Bridgett Cove and two spot spawns were documented on the southwest side of Mab Island. No other spawn was observed in the area. Many gulls and scoters are active in the areas of prior spawn, particularly the Point Bridgett area. No herring spawn was documented on Tuesdays survey although many schools of herring were observed in the Auke Bay boat harbor area and in Tee Harbor.
>
> Approximately 4 nautical miles of shoreline have received herring spawn in the Lynn Canal/Berners Bay area to date. For the second consecutive year, no herring spawn was documented on the eastern shoreline of Berners Bay north of Cascade Point.

(ADFG 2006-Juneau Herring Update 12).

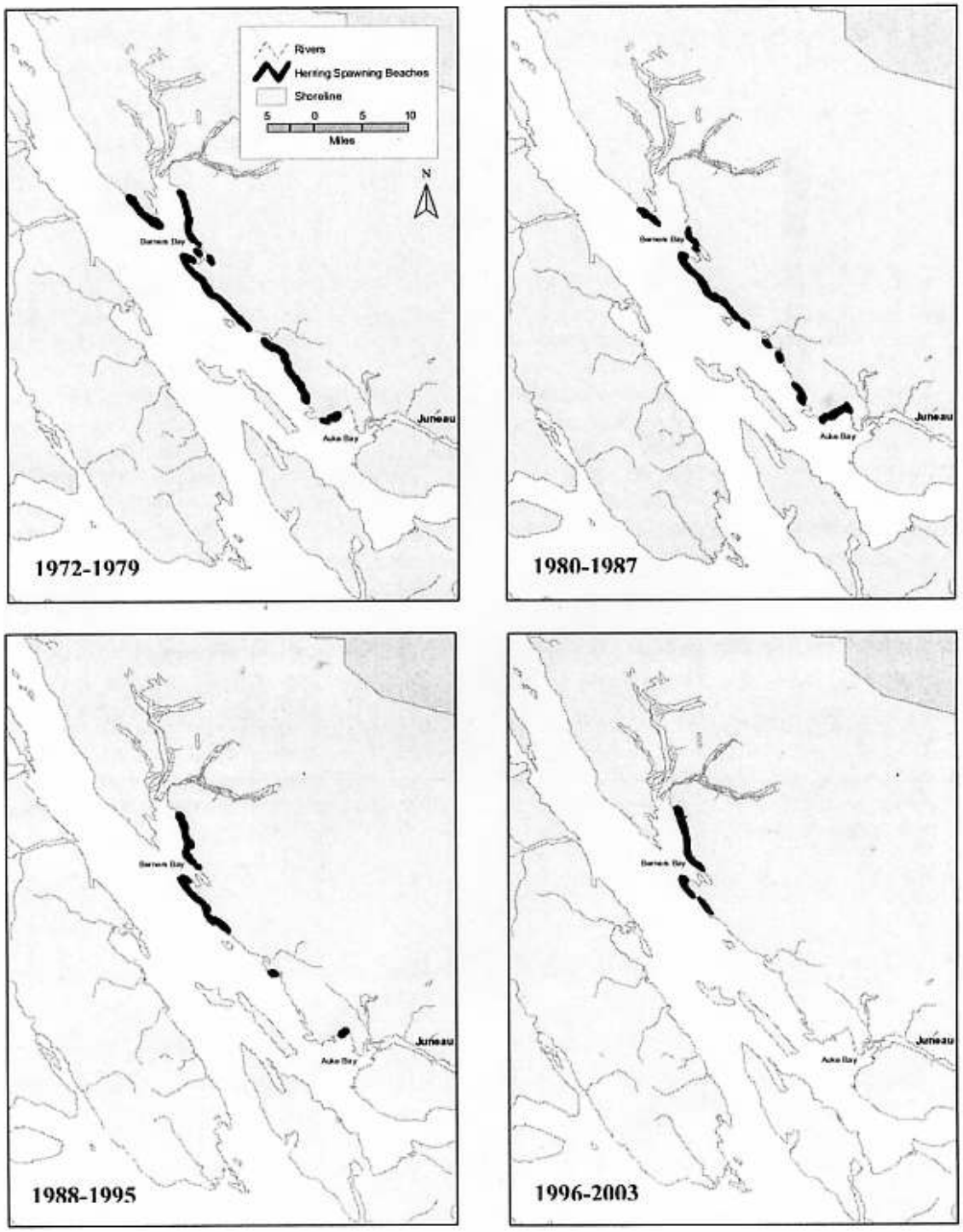

Figure 8: Documented spawning locations for Lynn Canal Pacific herring stocks over cumulative 8-year intervals: 1972-1979, 1980-1987, 1988-1995, 1996-2003 (Figure from NMFS 2005a).

Table 1: Spawning beaches in the vicinity of Lynn Canal; based on Skud (1959) and Alaska Department of Fish and Game aerial surveys 1972-2006 (ADFG 2006). S = Spawning observed; Blank = No spawning observed; N = not surveyed or no data available.

Skud (1959)	Locality	Rounsefell (1930)	Skud (1959)			Alaska Department of Fish and Game aerial surveys (ADFG 2006)																																				
			1953	1954	1955	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	Idaho Inlet	S	N		N																																					
2	Mud Bay	S	N		N																																					
3	Flynn Cove	S	N		N																																					
4	Port Frederick	S	N		N																																					
5	Douglas Island	S	S																																							
6	Spuhn Island	N	S																																							
7	Coghlan Island	S	S		S																																					
8	Auke Bay	S	S	S	S									S	S			S				S	S																			
9	Auke Cape	N	S	S	S	S		S	S	S	S		S	S	S																											
10	Point Louisa	S	S	S	S	S			S																																	
11	Point Lena	S	S	S	S																																					
12	Lena Cove	S		S	S																																					
13	Point Stephens	S			S	S			S	S				S																												
14	Tee Harbor	S	S	S	S	S	S		S	S		S	S	S	S				S																							
15	Pearl Harbor	N	S	S	S		S	S	S	S		S											S																			
16	Eagle Harbor	N	S	S	S	S		S	S	S		S											S																			
17	Eagle River	N		S	S	S	S	S	S	S		S		S																												
18	Mainland near Benjamin Island	N	S	S	S	S	S	S		S		S							S		S		S	S																		
19	Bridget Cove	N	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S		S	S		S	S			S								S	S	S
20	Echo Cove	N		S			S	S			S	S				S																										
21	Flat Bay	N	N	S	S																																					
22	Nudik Point	N	N	S	S																																					
23	Tanani Point	N	N		S																																					
	Point Bridget and Mab Island	N	N	N	N	S	S	S	S	S	S		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S			S	S						S	S	S
	Pt. Saint Mary	N	N	N	N						S		S		S																											
	Berners Bay East Shoreline						S				S		S			S			S			S				S	S	S	S	S	S	S	S	S	S	S	S	S			

III. QUALIFICATION OF LYNN CANAL HERRING AS A DISTINCT POPULATION SEGMENT UNDER THE ENDANGERED SPECIES ACT

The term "species" is defined broadly under the ESA to include "any subspecies of fish or wildlife or plants and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature." 16 U.S.C. § 1532 (16). The ESA does not define the meaning of term "distinct population segment."

A. The USFWS-NMFS Distinct Population Segment (DPS) Policy

NMFS and USFWS published a policy to define a "distinct population segment" for the purposes of listing, delisting, and reclassifying species under the ESA (USFWS-NMFS 1996). The DPS Policy identified two elements that must be considered when making DPS determinations:

1) The discreteness of the population segment in relation to the remainder of the species (or subspecies) to which it belongs; and

2) The significance of the population segment to the remainder of the species (or subspecies) to which it belongs.

(USFWS-NMFS 1996). To be considered a DPS, the population must be both "discrete" and "significant." Once a population has satisfied the DPS Policy, the population segment's conservation status in relation to the standards for listing a species under the ESA is then evaluated (USFWS-NMFS 1996). The following sections analyze the Lynn Canal Herring population under the DPS Policy. Section III evaluates the endangered status of the Lynn Canal Herring in the context of the five statutory listing factors.

1. Cherry Point Pacific Herring DPS Determination

NMFS analyzed the Puget Sound and Georgia Basin populations of Pacific Herring for ESA listing in 2001 and 2005 (Stout et al. 2001, NMFS 2005b). These analyses support the delineation of Lynn Canal Herring as a DPS because NMFS dismissed a larger, hypothetical DPS covering all of the eastern North Pacific. Rather than defining an expansive DPS, NMFS carved out the Georgia Basin DPS of Pacific Herring and therefore impliedly determined that several DPSs of Pacific Herring exist on the west coast of North America.

Specifically, in 2001, NMFS described the expansive, hypothetical Pacific Herring DPS as follows:

> A single DPS that includes the populations in the area from Baja California to Southeast Alaska, with the northern boundary being the border of the zoogeographic zone near Dixon Entrance, or a line between Helm Bay and Lynn Canal, Alaska. At this scale, the DPS is defined by the genetics investigations of Grant and Utter (1984), and by the zoogeographic boundary of Ekman (1953), Hedgpeth (1957), and Briggs (1974). This DPS exceeds any management area defined by DFO for Canadian populations.

(Stout et al. 2001). The 2001 Pacific Herring Biological Review Team (BRT) rejected this DPS configuration, and determined that the Strait of Georgia DPS is one of several Pacific Herring DPSs along the west coast of the United States and Canada (Stout et al. 2001).

In the 2005 Status Review, NMFS again proposed several expansive Pacific Herring DPS configurations to the BRT: reaching from San Diego, California to Sitka, Alaska. Again, the BRT refused to group Pacific Herring in southeast Alaska with populations to the south. Therefore, at the very least, NMFS has implicitly determined that at least one DPS exists in southeastern Alaska. The DPS analysis in this petition builds upon these two BRT conclusions to identify the Lynn Canal Herring DPS.

B. Application of the DPS Policy to Lynn Canal Herring

The following analysis of Lynn Canal Herring demonstrates that they qualify as a distinct population segment under the ESA. As shown above, NMFS prior conclusions on the Georgia Basin DPS of Pacific Herring supports a delineation of the Lynn Canal Herring DPS.

In an analysis of herring population structure in coastal British Columbia, Beacham et al. (2001, 2002) demonstrated that localized populations were the exception, with the vast majority of herring populations sharing high amounts of genetic information. However, in two instances Beacham et al. (2001, 2002) found significant level of genetic differentiation using microsatellite loci: 1) spawning time; and 2) isolated location.

In the case of Vancouver Island Pacific Herring populations, all observed genetic variability was due to the population being isolated by a constricted passage between islands and fiords. Lynn Canal Herring are similarly isolated from other SE Alaska herring to the south and west. In addition, Lynn Canal Herring are backed up into inlets and bays, rather than inhabiting a continuous stretch along a major Strait or Passage. Therefore the Lynn Canal Herring may have developed unique adaptations over generations to exist in this relatively isolated location.

The following sections analyses the Lynn Canal Herring population in the context of the DPS Policy. First the discreteness of the population is analyzed and then the significance of the population to the taxon is discussed.

C. Discreteness

Under the DPS Policy, a population segment is discrete if it satisfies either one of the following criteria:

1) It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. 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 Act.

(USFWS-NMFS 1996, DPS Policy, 61 Fed. Reg. at 4725). The policy further clarifies that a population need not have "absolute reproductive isolation" to be recognized as discrete.

Lynn Canal Herring are discrete based on the five factors listed as follows: 1) Genetics, 2) Physiology, 3) Morphology, 4) Spawning time and location, 5) Wintering and Summer Feeding Location and Migration.

1. Genetically Distinct

Herring stock structure and genetic differentiation is complex. Few specific genetic data are available for the Lynn Canal Herring population. One genetics study reported that Lynn Canal Herring are more closely related to Pacific Herring in the northern Gulf of Alaska than with herring to the south in Southeast Alaska and British Columbia (Grant and Utter 1984). Grant and Utter (1984) grouped Lynn Canal Herring more closely with herring from Yakutat Bay and Kodiak Island. Herring in Helm Bay and Queen Charlotte Island to the south were grouped separately from Lynn Canal Herring (Grant and Utter 1984). Based on this evidence, it is possible that future genetic data on Lynn Canal Herring will reveal greater differentiation.

Studies performed on Pacific Herring in Alaska, British Columbia, Washington and other parts of the North Pacific show that some individual herring populations are genetically distinct from others. Studies on Atlantic Herring reveal similar levels of genetic differentiation. A more detailed analysis of several genetic studies is provided in Appendix A of this petition.

2. Physiologically Distinct

Lynn Canal Herring are physiologically distinct from other Pacific Herring.

> Leon (1993) detected statistically significant differences in length-at-age and/or growth rates between three stocks of Pacific herring in Southeast Alaska, separated from one another by a minimum of 160 miles: 1) Sitka Sound, 2) Seymour Canal, and 3) Kah Shakes-Boca de Quadra. Comparison between two spawning sites separated by only 15-20 miles, Annette Island and Boca de Quadra, also indicated area-specific differences in growth characteristics (Leon 1993).

(Stout et al. 2001).

3. Morphologically Distinct

Lynn Canal Herring are morphologically distinct from other Pacific Herring. Rounsefell and Dahlgren (1935) delineated six populations in Southeast Alaska, and the Lynn Canal Herring were then described as the "Juneau - Icy Strait area" as recounted by Stout et al. (2001).

> Rounsefell and Dahlgren (1935) examined herring stock structure in Southeast Alaska, mainly through comparison of the mean number of vertebrae in different year-classes between 32 localities. Individual year-classes were studied, since a high negative correlation was found between temperature during development and the mean vertebral number in different year-classes. Rounsefell and Dahlgren (1935) identified six populations in Southeast Alaska that they considered independent of one another, based on a combination of differences in vertebral counts, growth rates, and year-class strength: 1) Juneau-Icy Strait area, 2) Sitka-Cape Ommaney-Chatham Strait area, 3) Noyes Island-west coast of Prince of Wales Island, 4) inner areas of Southeast Alaska, 5) vicinity of Petersburg, and 6) Todd-Peril Strait.

(Stout et al. 2001).

More recently, the Herring Stock ID Project (http://www.herringstockid.info/), a joint effort by ADFG and NMFS to delineate Pacific Herring populations using new techniques focused on the fatty acid levels in heart muscle, provides information that Lynn Canal Herring are morphologically distinct from other herring. The principal investigators of the Herring Stock ID Project recently published a paper detailing preliminary findings, Otis and Heintz (2003). They determined that herring populations in Southeast Alaska differ substantially from each other and from those found in the northern Gulf of Alaska and the Bering Sea.

Another important aspect of this work is that the authors reveal the limitations on relying on genetic evidence when it comes to herring. Otis and Heintz (2003) state that simply using genetic information to distinguish between stocks will not be sufficient.

> Reported Atlantic and Pacific herring homing rates range from 66-94 percent (Tester 1949; Cushing and Burd 1957; Hourston 1982; Wheeler and Winters

> 1984). The corresponding stray rates of 6-34% indicate there is more than sufficient gene flow between neighboring spawning areas to compromise the ability of allozyme markers to discriminate between putative stocks (Smith and Jamieson 1986; Bembo et al. 1996; Waples 1998). Waples (1998) warned, "because the amount of migration necessary to obscure most genetic evidence of stock structure (only a handful of individuals per generation) is generally inconsequential as a force for rebuilding depleted populations on a time scale of interest to humans, there is no guarantee that genetic methods alone will provide sufficient precision for key management decisions involving marine species".

(Otis and Heintz 2003).

4. Distinct Spawning Time and Location

The Lynn Canal Herring are separated from other populations of herring in Southeast Alaska by a distinct spawning time. Skud (1959) first described different spawning times as follows:

> Each year the initial spawning in Southeastern Alaska occurs in the vicinity of Craig during late March. Kah Shakes, Sitka, and Auke Bay spawnings follow and are usually completed in early May. Spawning times in Behm Canal, Etolin Island, and Frederick Sound are variable and have been reported in late April, May, and early June. Some areas do not conform to the northerly and westerly progression in spawning time described by Rounsefell (1930).

(Skud 1959: 16).

5. Distinct Wintering and Summer Feeding Location and Migration

The wintering grounds and summer feeding grounds for Lynn Canal Herring are entirely within the confines of Lynn Canal and adjacent waters. Whereas other Pacific Herring populations in Southeast Alaska venture further out into the open ocean for summer feeding (i.e. Sitka population) Lynn Canal Herring remain in Lynn Canal and do not undergo a large migration (Carlson 1980). In addition, the wintering grounds for Lynn Canal Herring near Auke Bay also isolate them from other herring populations in Southeast Alaska (Carlson 1980).

Based on Carlson (1980) NMFS has described the Lynn Canal Herring as a "discrete population" of the Pacific herring since at least 1980.

> The Lynn Canal/Auke Bay herring stock is a discrete population distinguishable by their concentration for overwintering in Auke Bay and Fritz Cove (Carlson 1980). The location of this wintering area probably accounts, in part, for the geographic proximity of the observed major spawning grounds.

(USFWS-NMFS 1980: 7). Carlson showed that Lynn Canal Herring do not intermingle with other herring populations, unlike populations in Sitka and Craig.

> In the early 1930's the Pacific herring at Sitka, Craig, and Auke Bay were identified as separate major stocks by spawning and feeding locales, vertebral counts, growth rates, and tagging work (Rounsefell and Dahlgren 1935). Later tagging studies showed that the Sitka and Craig spawning stocks migrate and intermingle in summer feeding areas (Skud 1963), and that the Auke Bay and Ketchikan stocks do not intermingle with others (Dahlgren 1936; Carlson 1977).
>
> The yearly distribution pattern of the Auke Bay stock of Pacific herring differs from that of the Sitka and Craig stocks, major stocks in southeastern Alaska, and major stocks in British Columbia that make extensive summer feeding migrations (Skud 1963; Outram and Humphreys 1974).
>
> We searched for the Pacific herring schools north of the Auke Bay study area in August, November, and January to determine whether we were working with a single, discrete group of herring that spawn in Lynn Canal. The cruises were for 5-7 days and thoroughly covered the entire length of Lynn Canal. We found only a few small, scattered traces of mostly juvenile herring. Within the study area, over 24 consecutive months, disappearance of schools from one locale always coincided with their appearance in another. From November to May we found no signs of schools over summer feeding grounds, and from June to October we found few signs of herring in the wintering area. Pacific herring that winter in Auke Bay and Fritz Cove apparently constitute most of the stock of fish that spawn in the Lynn Canal-Auke Bay are and are exploited in a spring roe fishery in lower Lynn Canal.

(Carlson 1980). Carlson (1980) concludes that Auke Bay Herring are distinct from other Southeast Alaska Pacific Herring in that they do not migrate like the other populations.

> The yearly distribution pattern of the Auke Bay stock of the Pacific herring differs from that of the Sitka and Craig stocks, major stocks in southeastern Alaska, and major stocks in British Columbia that make extensive summer feeding migrations (Skud 1963; Outram and Humphreys 1974). Like the Auke Bay herring, Ketchikan herring apparently do not migrate to intermingle with Sitka and Craig herring on common feeding grounds (Carlson 1977); therefore the yearly distribution of the Ketchikan stock may fit the pattern of the Auke Bay stock. Such a pattern – large stocks that do not make long migrations – may describe other stocks of Pacific herring when their year-round distribution is learned.

(Carlson 1980).

D. Significance

Under the DPS Policy, once a population has been determined to be discrete, the NMFS must then consider whether the population is significant to the taxon to which it belongs. The DPS policy states that a population may be considered significant based on, but not limited to, the following factors:

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.

   Because precise circumstances are likely to vary considerably from case to case, it is not possible to describe prospectively all the classes of information that might bear on the biological and ecological importance of a discrete population segment.

(USFWS-NMFS 1996).

Lynn Canal Herring are significant to the taxon based on seven factors detailed below: 1) Unique ecological setting, 2) Significant gap in range, 3) Marked differences in genetic characteristics, 4) Ecosystem significance, 5) Evolutionary potential, 6) Marginal populations, and 7) Cultural significance.

1. Unique Ecological Setting

The Lynn Canal Herring population occupies a unique ecological setting that may translate into adaptive potential for the Pacific Herring species. Overall salinity levels may be much lower in Lynn Canal than in other regions of Southeast Alaska because of the isolated nature of the inlets and bays, and the significant inputs of freshwater from glaciers and rivers. Salinity levels have been correlated with genetic differentiation in Atlantic Herring (Bekkevold et al. 2005).

> Baltic herring spawn in coastal low salinity habitats where larval retention is high due to limited large-scale hydrographical activity (Lehmann et al. 2002) and therefore developing larvae have high probability of experiencing a predictable environment. Across the North Sea–Baltic Sea transition zone spatially variable but locally predictable environmental conditions suggest that herring from different spawning locations experience stabilizing selection for different salinity

> tolerance optima. Locally differentiated selective pressures would consequently lead to selection against dispersal between spawning locations of differing salinity conditions, and may provide an adaptive explanation for the homing behavior reported in herring tagging studies (reviewed by McQuinn 1997).

(Bekkevold et al. 2005).

Furthermore, in contrast to other parts of the world, herring populations in the eastern Pacific, from California to the Bering Sea, consist of a relatively large number of small populations (Hay et al. 2001b). These individual populations are locally adapted to their spawning areas (Stokebury et al. 1999).

> The short term spatial variability in juvenile Pacific herring growth suggested that <u>each bay was a unique nursery area and that the juveniles within these bays were isolated</u>. This differs from other research on herring life history which suggests that there is a great deal of mixing both in the nursery areas and feeding grounds while segregation occurs only during the spawning and early larva stages (Iles 1971, Iles & Sinclair 1982, Sinclair et al. 1985). The physical and biological conditions within each bay appear to dictate the Pacific herring growth rate.

(Stokesbury et al. 1999)(emphasis added).

2. Significant Gap in Range

The Lynn Canal Pacific Herring historically inhabited all of Lynn Canal and the adjacent areas of Icy Strait and northern Stephens Passage (See Figures 4 and 5). This area constitutes a significant portion of the range of the taxon, whether the taxon is identified as the species *C. pallasi* or the subspecies *C. pallasi mirabilis*.

This petition considers the relevant taxon for this DPS significance factor to be a subspecies of the Pacific Herring and not the Pacific Herring species as a whole. As discussed earlier, Grant and Utter (1984) indicated: 1) an eastern North Pacific subspecies of Pacific Herring, *C. p. mirabilis*, is described for the area from the Bering Sea to California (See Figure 3), and 2) the Bering Sea herring are genetically distinguished from rest of the herring to the south in North America, possibly dividing *C. p. mirabilis* into at least two races or subspecies. Therefore, this petition concludes that the range of the taxon may include: 1) the area from the Bering Sea to California, or 2) the area from the Gulf of Alaska to California, or 3) a smaller area in thenorthern Gulf of Alaska.

There is no specific number or percentage required by the DPS Policy in determining what is a significant gap in a species' range. Based on the overall importance of herring to the ecosystem, the adaptive potential of each herring population, and the uncertain taxonomy of Pacific Herring, the area historically occupied by Lynn Canal Herring qualifies as a significant gap in the range of the taxon.

3. Marked Difference in Genetic Characteristics

The DPS Policy allows NMFS to use evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics to meet the "significance" prong of the DPS Policy (USFWS-NMFS 1996). However, the question of what constitutes a marked genetic difference is unique to each species. Past USFWS and NMFS final rules designating DPSs have utilized varying standards for "significance" in the context of genetic differentiation. One thing is certain, the DPS Policy does not require a population to be genetically "unique" in order to qualify as "significant" (USFWS-NMFS 1996).

As explained above in the discreteness section, the genetics of Pacific Herring are complicated. In addition, marine fish species generally have lower detectable levels of genetic differentiation than for terrestrial or anadromous species (Grant and Utter 1984, Bekkevold 2005). Therefore, just because the levels of detectable genetic variation are low does not mean that the observed genetic differentiation is insignificant. Even small amounts of genetic differentiation can be significant to the species. This is the conclusion of several authors studying herring genetics.

> Bentzen (1997) advocates that if even one of several loci yields a significant result, it may be biologically meaningful given the obstacles (huge population sizes, sampling biases) faced in detecting legitimate population differences in the marine environment.

(McPherson et al. 2001).

These conclusions run contrary to NMFS (2005c) assertions in the 12-month finding for Cherry Point Herring. In that finding, NMFS argued that the low levels of observed genetic differentiation in Cherry Point Herring, when compared to genetic differentiation observed in Pacific salmon species, is not "significant" (NMFS 2003c). However, according to herring researchers, even low levels of genetic differentiation can be significant.

a) Uncertainty in Genetic Evidence

The ESA requires NMFS to act in a precautionary manner when listing species. This precautionary approach is also mandated by the use of the best available science. NMFS implicitly applied the precautionary principle when it listed the Snake River Sockeye Salmon (*Oncorhynchus nerka*) as endangered under the ESA despite the fact that it was unclear whether the population at issue was actually distinct from other populations (NMFS 1991). NMFS listed the population solely based on preliminary evidence that the population was distinct from other salmon populations. Subsequent scientific research showed that the Snake River Sockeye Salmon was actually genetically distinct from other salmon populations. In the NMFS' 1991 status review of Snake River

Sockeye Salmon, Waples et al. (1991) explained the application of a precautionary approach in the context of the ESA.

> The Biological Review Team thus faced a difficult problem: a decision whether the sockeye salmon petition is warranted is required by law by April 1991, but there is insufficient information for a definitive determination of the first key question in the first key question in the process. After a lengthy discussion, the team reached a strong consensus that, because we cannot conclude with any certainty that the original sockeye salmon gene poll is extinct, as stewards of the resource we are obliged to make a conservative decision in this circumstance. The team was not unmindful of the implications of this decision, and we do not suggest that a lack of information should always result in a conservative decision in ESA evaluations. However, a factor that weighed heavily in these considerations was the irreversibility of the likely consequence of taking the alternative course. That is, if we were to assume that a recent anadromous *O. nerka* in Redfish Lake were derived from kokanee and this assumption proved wrong, the original sockeye salmon gene pool could easily become extinct before the mistake was realized.

(Waples et al. 1991: 13)(emphasis added). Therefore, any analysis of Lynn Canal Herring genetics should acknowledge the role of uncertainty and the precautionary principle.

Lastly, because the available genetic evidence is scant, any determination of local population structure using genetic data should be tempered by the limitations of molecular genetics techniques. As explained by Carvalho and Hauser (1994), failing to detect population separation using genetic data alone could mean that other methods are necessary to discern population structure.

> A lack of genetically detectable stock separation may arise from five sources: (i) sufficient gene flow to maintain panmixia; (ii) occasional 'sweepstake' events such as sporadic recruitment from distant, non-neighboring areas which could produce the appearance of panmixia; (iii) stabilizing selection arising from exposure to similar environments; (iv) recent genetic divergence of the compared populations; or (v) failure to detect genetic variants due either to the technique employed or to insufficient sample sizes. With the exception of (v), it may be impossible to distinguish between the various possibilities using molecular genetics alone and it becomes especially important to consider data from other methods.
>
> If the samples being compared are truly panmictic, then treating the fishery as a unit stock would have no consequences in terms of recruitment from overfished locales. If, however, some undetected reproductive isolation exists, the unit stock hypothesis may result in local overexploitation, diminishing the overall fishery yield. Furthermore, undetected stocks may become eliminated, with a corresponding reduction in inter-population genetic variance. Thus the lack of

> significant genetic heterogeneity should be interpreted with caution, and where feasible, additional sources of information shold be sought (e.g. Jennings and Beverton 1991), or conservative measures deployed (Leslie and Grant 1990).

(Carvalho and Hauser 1994).

4. Significant to the Ecosystem

Herring are important prey species for many species, including the ESA listed Steller Sea Lion and the Central North Pacific Humpback Whale. If Lynn Canal Herring were rendered extinct, or extirpated, the Steller sea lion and the Humpback Whales would lose a critical food resource. According to the NMFS Alaska Regional Office:

> Pacific herring (*Clupea pallasi*) play a "key role in subarctic Pacific pelagic ecosystems by being in an intermediary trophic position between plankton and consumers of herring such as other fishes, birds and mammals" (Kline 2001). Pacific herring are an important nutritional resource for several species of marine mammals, supporting the nutritional needs of Steller sea lions, humpback whales, and other species through direct consumption as well as secondary consumption, when the mammals feed on other fish species such as pollock and salmon, which also feed on herring. In dietary analyses of Steller sea lion populations foraging in Berners Bay and Lynn Canal, herring have been found as a component of 90% of the animals' diets (J. Vollenweider, pers. comm.). Herring are an important prey resource for marine mammals due to their high lipid concentrations and energy content, measured at around 4.5 to 8.1 kJ/g wet mass (Paul and Paul 1998, Anthony et al. 2000). During their different life stages, herring are also an important prey resource for several Steller sea lion prey species, including: pollock, salmon and Pacific cod.

(NMFS 2005a: 58).

In addition to being an important prey species for ESA-listed sea lions and whales, Pacific Herring share predation pressures with the Eulachon (*Thaleichthys pacificus*), which is also much reduced in Lynn Canal (NMFS 2005a). Predators commonly congregate at both herring and eulachon spawning runs (Wilson 2003). Bald Eagles by the hundreds and gulls (*Larus* spp.) numbering in the tens of thousands eagerly await the arrival of spawning fish. Eulachon occur only on the coast of northwestern North America, from northern California to Alaska (reviewed by Willson 2003). They are anadromous fish, spawning in freshwater streams, unlike herring which spawn in partially saline waters.

Pacific Herring and Eulachon rely upon each others sheer biomass to overwhelm predators during breeding in late spring. Eulachon are an essential prey for sturgeon, a species supporting a large commercial fishery (Willson 2003). Should Lynn Canal Herring go extinct, Eulachon would lose an important partner during the breeding season. With the loss of herring, Eulachon would be even more susceptible to extinction

themselves. Likewise, Lynn Canal Herring would be more susceptible to predation and extinction forces should Eulachon go extinct in Lynn Canal.

5. Significant to the Evolutionary Potential of Pacific Herring

The continued existence and evolutionary potential of the Pacific Herring species depends on each individual population. The Lynn Canal Herring contribute directly to this evolutionary potential. According to the NMFS Alaska Regional Office:

> . . . it is probable that the viability of the Lynn Canal subpopulation that spawns in and around Berners Bay will indirectly impact the viability of other southeast regional herring populations through recruitment, genetic diversity, and sharing of predation pressures from marine mammal populations in northern southeast Alaska waters.

(NMFS 2005a: 59).

6. Marginal Populations

Lynn Canal Herring are separated from other Pacific Herring and may inhabit a marginal marine ecosystem that is somewhat isolated from the Pacific Ocean overall by islands, peninsulas and glaciers. This geographic isolation means Lynn Canal Herring may constitute a marginal population as defined by Johannesson and Andre (2006), and Jorgenson et al. (2005).

As comparison, the marginal marine ecosystem in the Baltic Sea has produced several genetically distinct populations of Atlantic Herring (Johannesson and Andre 2006, Jorgenson et al. 2005). Similarly, the bays and inlets of the Lynn Canal areas may also create environmental and geographic conditions that promote genetic differentiation in Pacific Herring.

7. "Cultural" Significance

Culture and learning are normally attributes reserved for humans and a few advanced mammals or birds. However, herring may capable of learning and acquiring culture according to Corten (2002). Corten (2002) claims that individual herring populations depend on "culture", "tradition" and "conservatism" to successfully adapt to environmental changes. If this is the case, then Lynn Canal Herring are certainly capable of cultural significance based on their geographical setting and other factors.

> If a certain habit is advantageous for one year class, it will also be advantageous for subsequent year-classes. There is a benefit, therefore, for younger year-classes in copying feeding migrations from older generations, and turning the habit into a tradition. The schooling behavior of herring provides an opportunity for the

> transfer of habits between year-classes (McQuinn, 1997). Traditions occur widespread in the animal kingdom (Bonner, 1980; Mainardi 1980; Helfman and Schultz, 1984; Dodson, 1988). It is generally assumed that they serve to transfer newly acquired, adaptive behavior from one generation to the next. Mainardi (1980) and Bonner (1980) use the term "cultural evolution" for the transfer of new behavior by tradition instead of by genes. The advantage of the "cultural" transfer of new behavior is that it allows a more rapid and flexible adaptation to changes in environment than genetic evolution allows.

Corten (2002). More importantly, Corten (2002) points to "cultural differences" in herring populations that are not uncovered by traditional genetic studies.

> Conservatism, and in particularly tradition, will help to maintain a number of different spawning sites within the total herring stock. By doing so, it increases the chances that each year, somewhere within the total metapopulation, a batch of larvae will meet a suitable environmental window and grow up to become the next generation. Several authors (Hourston, 1982; Burd, 1985; Stephenson, 1998, 1999) have earlier advocated the protection of individual spawning populations because they assumed that these populations constituted irreplaceable, genetically unique stocks. If one denies the unique genetic constitution of individual spawning populations (as is done in this paper), it is tempting reject the need for management of individual spawning populations (Smith and Jamieson, 1986). However, the likely advantage of multiple spawning for the overall recruitment level of the metapopulation is a strong argument for maintaining a maximum number of separate spawning populations, even if the identity of these populations is based only on "cultural" differences instead of on genetic ones.

(Corten 2002). The Lynn Canal Herring most certainly exhibit such "cultural" differences as they are the only herring to remain in Lynn Canal year round. Future studies on herring population structure may uncover these differences.

E. The Importance of Populations to Species Preservation

In NMFS 12-month finding for the Cherry Point Herring population of the Puget Sound, the DPS determination was a very narrow interpretation of the ESA. By narrowly interpreting the goals and purposes of the ESA to only conserve the genetic diversity of a species, NMFS overlooked the goals and purposes of the ESA. In NMFS analysis of the Cherry Point Herring, NMFS asserts the following:

> There is no definition of the term "stock" that is generally accepted by fisheries biologists (Stout et al. 2001). The term stock has been used to refer to: (1) fish spawning in a particular place or time, separated to a substantial degree from fish spawning in a different place or time (Ricker, 1972); (2) a population sharing a common environment that is sufficiently discrete to warrant consideration as a self-perpetuating system that can be managed separately (Larkin, 1972); (3) a species group or population of fish that maintains and sustains itself over time in a

> definable area (Booke, 1981); and (4) an intraspecific group of randomly mating individuals with temporal or spatial integrity (Ihssen et al., 1981).
>
> None of these definitions imply that a fish stock is ecologically, biologically, or physiologically significant in relation to the biological species as a whole. Hence, information establishing a group of fish as a stock, such as the Cherry Point stock of Pacific herring, does not necessarily qualify it as a DPS. A DPS may be composed of a group of related stocks, or in some cases (if the evidence warrants) a single stock, that form(s) a discrete population and are (is) significant to the biological species as a whole.

(NMFS 2005c)(emphasis added). However, in this instance, NMFS has strayed from the specific language of the DPS Policy. Instead, NMFS required that the Cherry Point Herring not only be "significant to the taxon" as stated in the DPS Policy, but also that the population be "ecologically, biologically, or physiologically significant."

NMFS also dismissed the importance of local herring populations to the species as a whole when it discussed metapopulations in the Cherry Point Herring final rule.

> A "metapopulation" is an aggregation of subpopulations linked by migration, and subject to periodic extinction and recolonization events (Levins, 1968, 1970). Observations of herring population structure in the Atlantic and Pacific are consistent with this metapopulation concept (McQuinn, 1997; Ware et al., 2000; Ware and Schweigert, 2001 ,2002; Ware and Tovey, 2004): (1) local herring stocks are distributed across spatially fragmented spawning habitat; (2) local stocks exhibit partially independent demographics and dynamics; (3) there is appreciable straying and gene flow among local populations; and (4) there is evidence of disappearance and recolonization events.
>
> Consistent with the consideration of Pacific herring as a metapopulation, local spawning stocks of herring may demonstrate distinctive demographic patterns and reproductive isolation over relatively short temporal scales, yet over longer time periods regularly exchange low levels of individuals or experience periodic waves of dispersal during years of abundant recruitment.

(NMFS 2005c)(emphasis added). NMFS uses the metapopulation model in this instance to thwart species protection. Subsequent research in herring metapopulations not yet reviewed by NMFS is presented below. This new information shows that herring population structure is more complex than originally estimated. In the last decade, many herring populations that were once thought to be a single population have been divided into genetically distinct subpopulations.

NMFS reliance on McQuinn (1997) in the 2001 and 2005 status reviews for Cherry Point herring is misleading. NMFS used the metapopulation model to essentially preclude significance at the local population level by assuming that recolonization events would always restore some herring population.

To the contrary, recent research suggests that local adaptations can be significant despite gene flow and mixing. The significance of individual spawning areas to Atlantic Herring was analyzed by Stephenson et al. (2001) and the authors determined that the "maintenance of the full diversity of spawning groups should be the default approach in management." Bekkevold (2005) explains that in Atlantic Herring, that gene flow among populations does not necessarily rule out local adaptation. Such local population adaptations provide evolutionary potential and thus "significance" to the taxon.

> Based on estimates of dispersal between spawning locations, levels of gene flow have previously been considered to be substantial and to preclude local adaptation in herring (McQuinn 1997). <u>However, gene flow constrains, but need not preclude, adaptive evolution</u> (e.g., King and Lawson 1995; Calsbeek and Smith 2003; Saint-Laurent et al. 2003; Hendry et al. 2004). Moreover, rates of dispersal between populations cannot be directly translated into realized geneflow, because the reproductive success of dispersers and their offspring is influenced by local selective pressures. The relative fitness returns associated with dispersing versus philopatric behavior are at present unknown in herring, as in most other marine fishes. The present study suggests that salinity conditions on spawning locations affect the fitness associated with different dispersal behaviors.

(Bekkevold et al. 2005).

> <u>We have shown that genetic structure can be maintained in marine fish populations exhibiting substantial mixing during larval and adult life stages. Analyses incorporating genetic, spatial, and environmental parameters indicated that isolating mechanisms are associated with the specific salinity conditions on spawning locations. Our results do not imply a role for linkage between microsatellite DNA loci and traits under selection, but that populations experiencing dissimilar salinity conditions on spawning locations follow different evolutionary trajectories</u>. This shows that the North Sea–Baltic Sea transition zone offers an insightful opportunity for studying local adaptation in ''classical'' marine fishes with continuous distributions, such as herring, cod, and turbot. Little is yet known about selective patterns in species inhabiting the open sea, although it is evident that geographic separation and dispersal potential are poor predictors of the spatial scale of the potential for local adaptation in marine systems. Our approach of combining results from partial Mantel tests with the computational geometric approach offers a promising means of evaluating relationships between barriers to gene flow and environmental variance across marine fishes and ecosystems, as it can be applied both within and across species.

(Bekkevold et al. 2005)

Furthermore, Husebo et al. (2005) determined that at least for Norwegian spring spawning and autumn spawning Atlantic Herring, the McQuinn (1997) metapopulation concept does not hold.

> Based on the results of the present study, we conclude that the otolith microstructure of the mixed wintering aggregation indicate that the ripening Norwegian Spring Spawning (NSS) herring were hatched in spring, and that spent and resting-stage autumn spawners were hatched in autumn. In other words, the spring- and autumn-spawning herring presently are assessed as one NSS herring stock by ICES, but are really two distinct but co-occurring spawning populations that are not a result of year class twinning according to the metapopulation concept by McQuinn (1997a, 1997b).
>
> In cases where herring stray between spawning seasons (Graham 1962; Grant 1984; Aneer 1985; Smith and Jamieson 1986) one would expect a considerable gene flow between populations (McQuinn 1997b). However, we find evidence of distinctness between the two populations in their otolith characteristics.

(Husebo et al. 2005).

1. Pacific Herring and the "Metapopulation" Concept

A summary of the competing models of herring population structure is presented by McPherson et al. (2004).

> Iles and Sinclair (1982) predicted that the number of geographically stable larval ''retention areas'' determines the number of genetically distinct Atlantic herring stocks. Accordingly, each distinct gene pool is postulated to encompass all those spawning groups whose larval and postlarval stages come to share (and remain in) the same area of distribution. Such a model implies that natural selection will favor individuals that are ''well adapted'' (at early life history stages) to remain in population- specific nursery areas and to return to their natal sites for spawning so that progeny have access to these same nursery areas—all in spite of extensive feeding migrations far from the nursery grounds. Herring that do not complete such a life history are considered ''vagrants'' and do not contribute to the locally adapted gene pool or, importantly, to that of neighboring populations. As proposed by Sinclair (1988), such a process should result in reproductive isolation (and genetic structure) among herring populations.
>
> A more recent conceptual model of population structure for Atlantic herring in the Scotia–Fundy region was proposed by Stephenson (1999) and generalized in Smedbol and Stephenson (2001). The model reorganizes herring spawning groups into complexes that share larval retention areas. The additional layer of complexity (individual– population–complex) also appears in McQuinn (1997), who suggested that environmental instability prevents population isolation and local adaptation in herring and who proposed that the extent of temporal stability (population, habitat, or both) will determine the degree of genetic structuring. McQuinn's (1997) metapopulation (as defined by Hastings and Harrison 1994)

> model contends that herring persist as a collection of predominantly independent local populations that may be interconnected by migration and subject to extinction and recolonization processes. This population concept differs from that of Iles and Sinclair (1982) because McQuinn contends that the progeny from local populations do not necessarily recruit to their natal populations but may migrate to (and reproduce in) a nearby population.

(McPherson et al. 2004). Researchers have used genetics to determine population differentiation for herring and then compared the results with predictions of population models.

> In spite of the extensive mixing of individuals, herring population structure has been described largely from differences in morphology, growth, migration, and spawning behavior (Iles and Sinclair 1982). However, all of these traits are influenced by the physical and/or social environment that individuals experience early in life, and thus differences may be the result of phenotypic plasticity rather than of independent evolutionary trajectories. Molecular studies have provided some evidence for genetic differentiation among discrete spawning components (Shaw et al. 1999; Hauser et al. 2001; McPherson et al. 2001a; 2004; Jørstad et al. 2004; for a study employing protein markers, see also Ryman et al. 1984). In most cases levels of differentiation are estimated to be low and no study has reconciled patterns of differentiation with hypotheses about gene flow or with different selective pressures encountered locally.

(Bekkevold et al. 2005). In their study, Bekkevold et al. (2005) determined that much of the genetic differentiation in Atlantic Herring could be explained with environmental correlates.

> We identified temporally stable differentiation among spawning locations along an environmental gradient despite the fact that individuals migrate freely across it.
>
> Estimates of population differentiation are commonly almost an order of magnitude lower in marine fishes compared to estimates in freshwater fishes and terrestrial organisms.
>
> The levels of genetic differentiation detected in our study were higher than those reported for *C. harengus* populations across comparable geographical ranges in the northwestern Atlantic, where no relationship between geographic and genetic differentiation is evident (McPherson et al. 2004). A microsatellite study of autumn and winter spawning *C. harengus* populations spanning a 1000 km north-south transect in the western North Sea reported very low, albeit statistically significant differentiation (*F*ST 5 0.1%, *P* , 0.001) and lack of distinct geographical structure in this area (Mariani et al., in press). We found that northwestern Atlantic (Nova Scotia) and northeastern Atlantic (North Sea) spawning components did not differ genetically (Table 2). Lack of differentiation of neutral genetic markers across scales of several thousands of kilometers may

> reflect recent colonization histories coupled with large populations experiencing low levels of genetic drift (Grant and Bowen 1998) and need not invoke high gene flow per se. The large contrast detected in levels of differentiation among samples within the Atlantic and those between the Atlantic and the Baltic show that levels of gene flow can be expected to be highly variable over the distribution of the species.
>
> We found some indication for reproductive isolation between short-term temporally differentiated ‘‘spawning waves’’ at the Ru¨gen location. The early (March) sample was significantly differentiated from later samples (Table 2), but our samples did not allow tests of annual stability. Within year samples showed slightly differing age class distributions because older fish tended to spawn earlier than younger fish (Table 1), and tests for differentiation among short-term temporal samples using subsets of individuals belonging to the same age class revealed no evidence for structure (results not shown). Although we could not determine the biological significance of the short-term genetic differentiation at this location, our results emphasize the importance of sampling scheme (i.e., equal cohort representation and assuring that samples represent spawning individuals) in analyses of temporal stability. Failure to recognize local substructure would, for example, be critical to attempts at generating estimates of effective population size and could lead to severe underestimation of this evolutionarily important parameter.
>
> Nonetheless, the highly significant correlation between salinity and genetic differentiation when controlling for geographic distance showed that salinity parameters and/ or associated factors were correlated with gene flow among spawning locations, and suggested that salinity differences rather than distance per se affected levels of reproductive isolation among spawning components. In the North Sea–Baltic Sea transition zone salinity, or factors correlated with salinity, may act as cues for homing to spawning grounds. Factors associated with salinity parameters and the timing of juvenile and adult migratory behavior may also act to produce a strong signal of reproductive isolation being associated with salinity.

(Bekkevold et al. 2005). Based on the results, Bekkevold et al. (2005) concludes that even small genetic differentiation can have adaptive significance for herring.

> A number of studies have sought to use divergence in ecologically relevant habitat factors as a surrogate of divergent selection to examine associations with gene flow (e.g., Smith et al. 1997; Reusch et al. 2001; Ogden and Thorpe 2002). We identified correlations between population differentiation and environmental (salinity) parameters associated with the spawning, egg, and early larval phase that were of greater magnitude than correlations between geographical and genetic differentiation (Table 3). Whereas such observations do not demonstrate that genetic differentiation is maintained by selection, salinity parameters are expected to exert strong selective pressures in marine organisms. Fertilization and

> larval developmental success are, for example, reduced at both low and high salinity levels in Pacific herring, *C. pallasi*, and this species' optimal salinity range was found to be higher than that of Baltic herring (Griffin et al. 1998).

(Bekkevold et al. 2005). Griffin et al. (1998) determined that individual populations of Pacific Herring have differing tolerances salinity levels with regard to fertilization and reproduction.

> Although we do not believe that salinity is the only factor governing successful reproduction of Pacific herring, it does appear to be an important component of both fertilization and embryonic development. Furthermore, comparisons of fertilization in the San Francisco Bay population with that of a Baltic population of *C. h. membras* and with published reports of other Pacific herring populations suggest that salinity tolerance ranges may differ between populations. The effects of salinity pressure on development may be more subtle than those on fertilization, yet may have more impact on recruitment in the environment. Altered salinity not only reduces the number of normal, competent larvae that hatch, it also delays the hatching of those embryos. The costs of such delays, separations from larval schools, depleted energy reserves, and extended time in chorion (where embryos are subject to both predation and exposure) influence chance for survival.

(Griffin et al. 1998).

F. The "Best Available Science" concerning the DPS inquiry

While discussing what should make up "Designatable Units" of a species for conservation purposes, Green et al. (2005) emphasized that the geographical location is of paramount importance. While genetics are a useful tool, Green et al. (2005) stressed that an overemphasis on genetic distinctions should be avoided.

> [O]ccupation of differing biogeographic regions by a species reflects the probable existence of historical or genetic distinctions and adaptations in each of those regions even though the range may appear to be continuous.

(Green et al. 2005)(emphasis added). Green et al. (2005) further argues that:

> Designatable units based on the different biogeographic zones the species occupies are the most defensible and prudent means to adequately describe its overall conservation status (Schock 2001).
>
> Evolutionary patterns therefore are not the focus, and the methodology does not rely on *a priori* systematics. The use of [Designatable Units] might be criticized for recognizing "nonevolutionary" units or for not paying strict attention to the

> demonstration of monophyly, which are criticisms leveled at various versions of the [Evolutionary Significant Unit] as well. The discovery of real evolutionary and historical entities is the precinct of systematics, which clearly has a vital role to play in identifying those entities (Dimmick et al. 1999; Mace 2004).
>
> Contrarily, conservation status is determined based on ecological data, including information on habitat and population trends and threats, according to criteria grounded, for instance, in time-to-extinction models (Mace & Lande 1991; Gardenfors 2001). Employment of [Designatable Units] is a pragmatic approach to extinction risk assessment that seeks <u>to avoid serious conceptual and methodological pitfalls of approaches based too exclusively on taxonomic inference</u>.
>
> Scientists are rightfully prudent to avoid adding false information to the canon of knowledge. They therefore scrupulously avoid the possibility that they might accept a hypothesis that is actually false. If we as scientists are to be wrong, we consider it better to reject a hypothesis even though it may be true. In science this is a sensible and precautionary policy (Taylor & Dizon 1999). <u>But recognizing and listing endangered species is not science</u>. It is an aspect of environmental and conservation policy that is best guided by the results of science. The ultimate consequence of failing to safeguard a species that is actually endangered (i.e., the error of rejecting a hypothesis of endangerment even though it may be true) is dire and irreversible. In conservation practice, unlike the practice of science, we must avoid that sort of error and be careful not to lose potentially unrecognized species from the canon of life.

(Green et al. 2005). Under this view, genetic uniqueness is important in discerning what populations of a species should receive protection, but genetics is not the only consideration. Ultimately, the "occupation of differing biogeographic regions by a species" is most important when defining what populations are need of protection.

IV. ANALYSIS OF ENDANGERED SPECIES ACT LISTING FACTORS

Under the ESA, 16 U.S.C. § 1533(a)(1), NMFS is required to list a species for protection if it is in danger of extinction or threatened by possible extinction in all or a significant portion of its range. In making such a determination, NMFS must analyze the species' status in light of five statutory listing factors. They are as follows:

(A) the present or threatened destruction, modification, or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;
(C) disease or predation;
(D) the inadequacy of existing regulatory mechanisms;
(E) other natural or manmade factors affecting it continued existence.

16 U.S.C. § 1533(a)(1)(A)-(E);

A species is "endangered" if it is "in danger of extinction throughout all or a significant portion of its range" due to one or more of the five listing factors. 16 U.S.C. § 1531(6). A species is "threatened" if it is "likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." 16 U.S.C. 1531(20).

Under the ESA, a "species" includes any species, subspecies or "distinct population segment" of a vertebrate species. 16 U.S.C. § 1532(16). As explained in Section III, the Lynn Canal Herring population qualifies as a distinct population segment and is therefore a "species" under the ESA. The following analysis presents substantial information that

A. Present and Threatened Destruction, Modification or Curtailment of Habitat or Range

Herring require several distinct habitat types, and probably the most important is spawning habitat, which occurs in shallow inter-tidal and sub-tidal areas containing eelgrass, kelp and other structural components. Spawning grounds are incredibly fragile and easily affected by human activities. Once herring lose spawning grounds or fail to use historic spawning areas, they are virtually certain not to return.

As presented earlier in Section Three, Lynn Canal Herring have declined from most of their historic spawning areas throughout the Lynn Canal, Auke Bay, Berners Bay and Icy Strait areas. The past destruction of herring spawning grounds in Lynn Canal and adjacent areas has already been reduced from over 30 miles to around 3 miles. The

present and threatened destruction, modification and curtailment of spawning areas will further restrict the habitat and range for Lynn Canal Herring.

A species profile of Pacific Herring prepared by the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers, Lassuy (1989), concluded that herring do not re-colonize spawning beds once they are lost.

> One rather surprising generalization made by Cushing (1985) was that 'management of herring stocks based on a great expenditure of research has not been very successful.' In view of such management difficulties, the very basic concerns of others take on a special importance – especially with respect to coastal development policy. I refer to the statement by Trumble (1983) that 'there is no clear instance of a stock successfully moving its spawning area as a result of destruction or major alteration of their original spawning area.' A study of transplantation of eggs concluded that though eggs hatched, a new spawning population did not become established (Hay and Marliave 1988). Clearly, the maintenance of vegetation is a valid concern.
>
> Also pertinent to the maintenance of functional spawning grounds is the avoidance of activities (e.g. dredging) which would cause silting immediately before, during, and two to three months following the spawning season. The inhibition of spawning behavior, suffocation of eggs, and destruction of product quality were mentioned earlier. It also seems likely to me that a heavy loading of suspended sediment would be ingested of feeding inhibited during a period critical to the nutrition of both adult and newly hatched larvae. Boehlert and Morgan (1985) noted that sediment at 'low suspension levels' roughly equivalent to natural conditions actually enhanced larval feeding abilities. Higher loads, as might be expected in catastrophic events, inhibited feeding.

(Lassuy 1989). This sobering assessment implicate the destruction of spawning grounds as a major factor in herring declines.

In the case of Lynn Canal Herring, several researchers have noted that the destruction of spawning beds in Auke Bay is a major factor in the population's decline.

> Another factor widely cited by regional experts has been the progressive deterioration of shoreline habitats that were historically used by Lynn Canal herring as spawning areas. Auke Bay, which was once a major spawning area for the Lynn Canal stock, has been increasingly subjected to the cumulative effects of shoreline development and human use since the 1980s. These impacts include construction of a floating breakwater, docks and marinas for commercial and recreational vessels, fueling depots, sewage and waste treatment discharges, and ferry terminal expansion. In addition, current proposals include the development of a seafood processing plant. The historic extent of eelgrass (*Zostera marina*) beds once used by herring as spawning habitat have also declined in the bay over time (personal communication, Sue Walker, NMFS). Though direct evidence for

> linking the combined impacts of pollution, habitat loss, and other coastal human stresses to declines of the Lynn Canal spawning stock is, in part, circumstantial, similar declines have been noted elsewhere, particularly near coves, inlets, and estuaries. For example, the loss of historically important herring spawning habitat has been documented in Nanaimo, Pender and Ladysmith Harbors, British Columbia (DFO Canada 2004 website), as well as in Eagle Harbor, Puget Sound (Chapman et al. 1941). Relative to other areas where herring spawning continues, these bays have been substantially altered by human settlement, industrial development, log storage, and marine transport.

(Williams et al. 2004).

The following sections outline the many projects that are slated to occur in the range of Lynn Canal Herring in the very near future. Taken together, the developments in and around Berners Bay and eastern Lynn Canal will impact the remaining spawning areas.

1. Kensington Gold Mine Project

The Kensington Gold Mine Project will destroy habitat for virtually every species that lives in the Lynn Canal and Berners Bay region. Much of the environmental review for the project focused on ESA-listed Steller Sea Lion and Humpback Whale, which rely on Lynn Canal Herring and other forage fish (NMFS 2005a). The future of the Lynn Canal Herring population was one of the main concerns of NMFS, USFWS and the Environmental Protection Agency (EPA) in the reviewing the Kensington Mine (NMFS 2005a). NMFS Alaska Regional Office cited, among many impacts, the disturbance to herring spawning sites, which are permanently lost once destroyed.

> The proposed action considered in this biological opinion involves the activities of two federal agencies. The ACOE proposes to authorize Goldbelt Inc. to place dredged or fill materials into waters of the United States pursuant to section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act to construct a marine terminal at Cascade Point in Berners Bay, and the Coeur D'Alene Mines Corporation and Coeur Alaska's (Coeur) to construct a marine terminal at Slate Creek Cove in Berners Bay. The USFS proposes to approve an amendment to Couer's Plan of Operations for the Kensington Gold Project pursuant to the National Forest Management Act consistent with the 1997 Tongass Land Forest Management Plan.
>
> The proposed action, known as the Kensington Gold Project, involves the development of an underground gold mine located approximately 48 km north of Juneau, Alaska. The mine site is located in the Tongass National Forest adjacent to Berners Bay, a sheltered saltwater bay and estuary. The Kensington Gold Project involves the construction of two marine terminals, one at Slate Creek Cove on the north side of the bay and one at Cascade Point on the south side of the bay, and ferry transit across the bay multiple times daily to transport crew and

supplies to and from the mine. The straight-line distance between the marine terminals is approximately five nautical miles. In addition, barge traffic would enter and exit the bay to transport the mine's ore concentrate four times a week. After a two-year construction period, mining will occur for a projected period of ten years.

(NMFS 2005a).

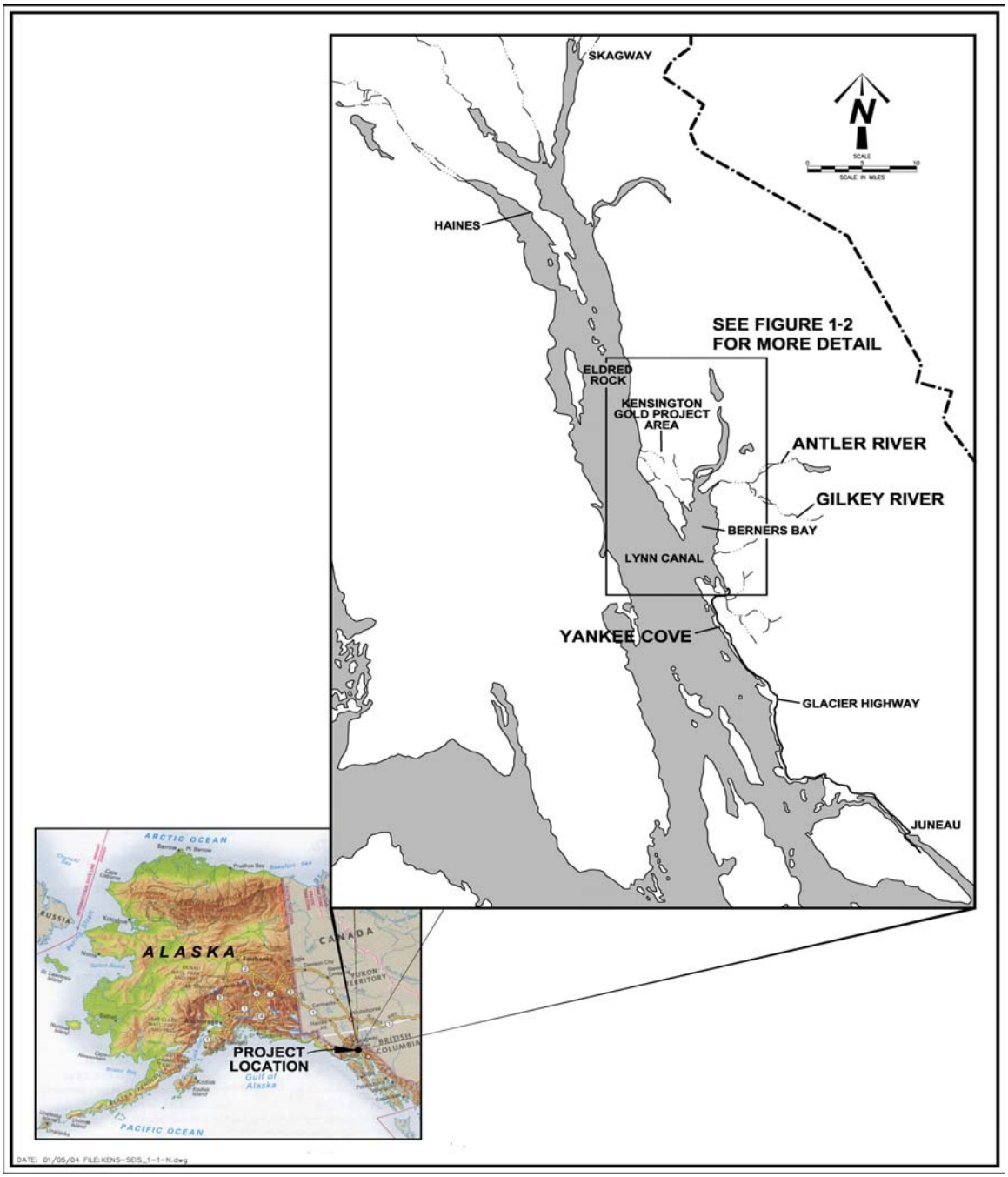

Figure 9: Location of the Kensington Gold Mine Project (Image from Kensington Final SEIS).

NMFS (2005a) concluded that Berners Bay is critically important to the continued existence of the Lynn Canal Herring population. Citing the negative impacts to herring and their habitat, particularly the direct loss of spawning habitat, NMFS required the action agencies, here the Federal Highway Administration (FHWA) and the U.S. Army Corps of Engineers (USACOE), to implement mandatory mitigation and to reassess portions of the project. Prior to the initiation of formal consultation, NMFS made recommendations that were not well received by FHWA.

> In the December 3, 2004 letter, and during informal consultation meetings with the action agencies and applicant, NMFS recommended several measures to limit adverse effects to listed marine mammals in Berners Bay and alleviate the need for formal section 7 consultation. Namely, these consisted of avoiding usage of Berners Bay altogether and proceeding with previously permitted helicopter transport; or, if transiting Berners Bay, using an alternate dock location to Cascade Point and suspending vessel operations during the spring eulachon/herring runs. <u>As the action agencies and applicant did not accept these recommendations</u>, formal consultation was initiated on November 17, 2004, pursuant to the request received on November 17, 2004.

(NMFS 2005: 5). In a NMFS summary attached to the formal consultation letter, the agency made it clear that the entire Berners Bay ecosystem would suffer damage from the mine developments, emphasizing the vulnerability and importance of the Pacific Herring.

> The following are NMFS concerns as expressed orally in meetings with the action agency and applicant during informal ESA consultation. In addition, NMFS outlines recommended measures here as acceptable alternatives to the proposed action. <u>The recommendations included here would be the necessary mitigation for NMFS to agree with the 'not likely to adversely affect' conclusion drawn by the action agency</u>. This discussion also responds to the mitigation measures proposed in the joint USFS and ACOE BA/BE, many of which are important in order to reduce impacts to marine mammals but would require further precautionary activities, time or area constraints, or additional complementary measures to adequately reduce risk.

(NMFS 2005a). Further impacts on herring will result from the daily operations and required travel of mine workers. NMFS noted this as an additional consequence of the mine:

> The proposed crew shuttle route across the bay, an almost straight line from Cascade Point to the Slate Creek Cove terminal site, will take the ferry directly through areas where large schools of eulachon and herring are known to aggregate prior to spawning in March and April. Individual adult herring and eulachon schools are likely to be exposed to vessel activities repeatedly throughout the spring months as the schools stage along the shoreline near Slate Creek Cove and Cascade Point in preparation for spawning.

(NMFS 2005: 107).

a) Contamination of Coastal Waters by Mine Tailings

The Kensington Mine will dump toxic mine tailings into Lower Slate Lake, which eventually drains into Slate Creek Cove and Berners Bay (NMFS 2005a). These pollutants are expected to eventually reach the waters inhabited by Lynn Canal Herring.

> With mining activity, the long-term, chronic disposal of tailings into Slate Lake may facilitate the transport of trace elements into the marine environment via Slate Creek, which could raise concentrations of such elements in the proximity of Slate Creek Cove.
>
> Elevated levels of heavy metals could have an impact on the fitness and survival of marine mammal prey resources, and consequently listed marine mammal species, if the concentrations exceed levels deemed safe for aquatic species. For example, high concentrations of copper, mercury and lead are of particular concern for larval and juvenile herring (Chapman 1978). Chronic exposure to copper concentrations above 7 ppb in the water column (Sorenson 1991), and 34 ppm in sediments (Johnson et al. 1999) have been shown to cause developmental abnormalities in laboratory research. If mine tailing runoff and associated discharges raise concentrations of these heavy metals in the estuary, there is the potential for these concentrations to exceed safe thresholds, which could reduce prey species fitness, abundance, and availability, thus potentially affecting marine mammals foraging on these resources.

(NMFS 2005a: 103-104).

b) Increased Vessel Traffic in Berners Bay Area

According to NMFS (2005a), marine vessel traffic within and around Berners Bay in the vicinity of spawning areas for Lynn Canal Herring will increase dramatically. The vessels themselves along with associated pollution will degrade spawning habitat and cause mortality to individuals.

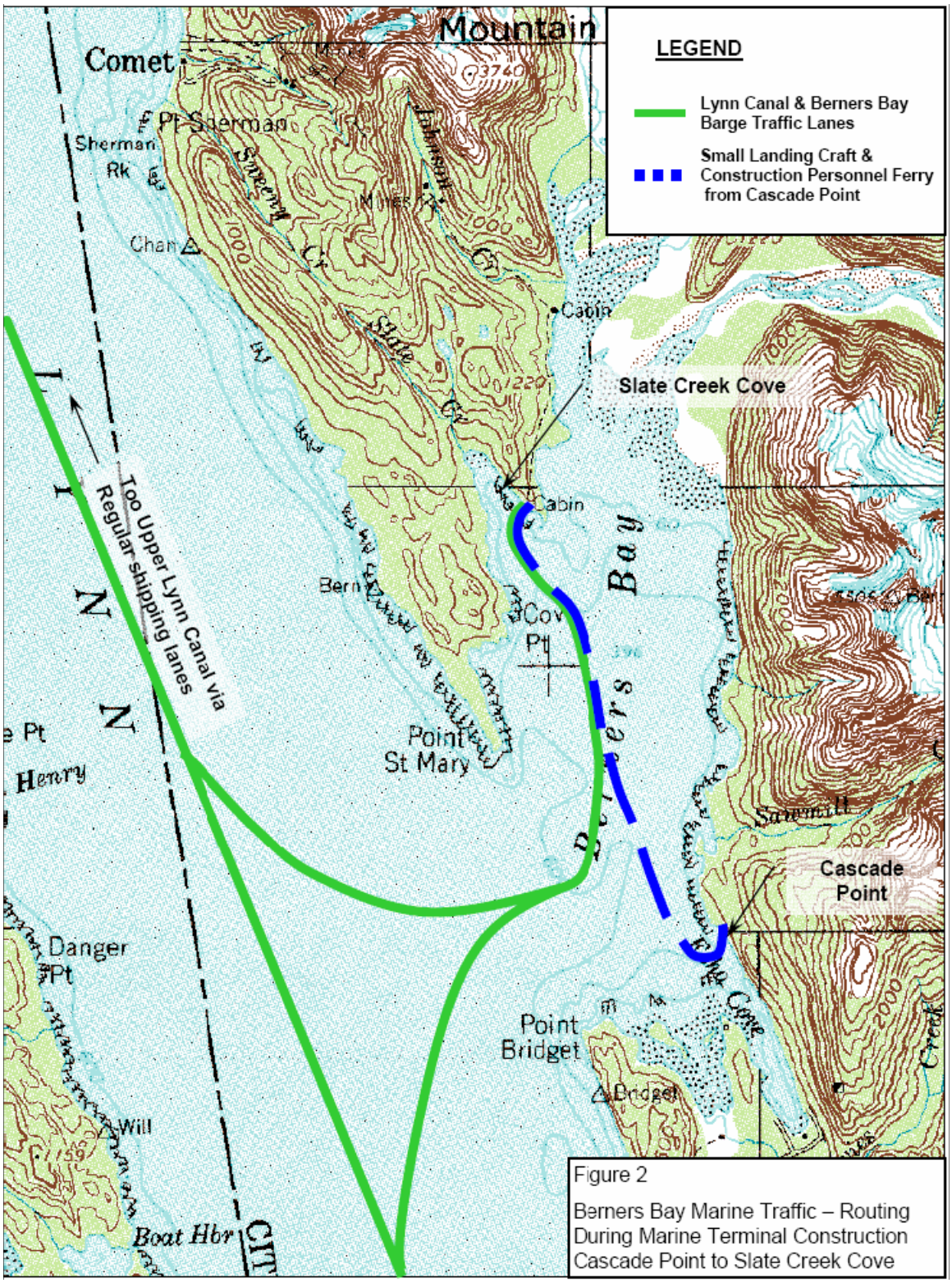

Figure 10: Proposed routes of marine vessels, including in the area of Cascade Point herring spawning habitat. (Figure from NMFS 2005a).

2. Juneau Access Improvement Project

The proposed construction of a major highway from Juneau to Skagway by the State of Alaska and the Federal Highway Administration threatens some of the last remaining spawning areas for Lynn Canal Herring. The Juneau Access Improvements Project (JAIP) is planned to cut along the coastline on the eastern shore of Berners Bay (FHWA 2006a, 2006b). Increased runoff and access will degrade the spawning beds. The Final Environmental Impact Statement (FEIS) for the Juneau Access Improvement Project indicates that Lynn Canal Pacific Herring are a primary concern and an "unresolved issue."

> NMFS, EPA, and OHMP have expressed concern that the cumulative marine traffic in Berners Bay associated with Alternatives 3, 4B, and 4D in conjunction with Kensington Mine and Goldbelt activities could have an adverse effect on the Lynn Canal herring stock. Both NMFS and OHMP believe special conservation measures, including no operations during the herring spawning period, would be necessary.

(FHWA 2006a: S-18)

The Record of Decision for the JAIP selects Alternative 2B (FHWA 2006b). This alternative will consist of a 50.8-mile long highway from the end of Glacier Highway at Echo Cove to a point north of the Katzehin River delta. A new ferry terminal will be constructed at the northern end of the new highway, with shuttle ferry service to both Skagway and Haines from the new terminal (FHWA 2006b). A total of approximately 36 acres of intertidal and subtidal marine habitat will be filled or dredged for construction of Alternative 2B (FHWA 2006b).

The impact of the road project on Lynn Canal Herring was analyzed in the FEIS, but highway and shoreline developments are cited as only one factor in the decline of the herring. Use this cumulative threats argument, the JAIP FEIS discounts the negative effects of the proposed highway.

> **Comment:** The highway would lead to herring die off in Berners Bay similar to what occurred with the Auke Bay herring fishery. This would result in a collapse to the food-web.
> **Response:** The EFH Assessment (Appendix N of the Final EIS) discusses the possible causes of the decline of the Auke Bay herring fishery in relation to the potential for similar impacts in Berners Bay from highway and/or ferry terminal construction and operation. While the cause of the Auke Bay herring decline is unknown, the most likely factors are loss of spawning habitat and overfishing. Alternative 2B would not involve any construction below the high tide line adjacent to herring habitat, and in these locations a vegetated upland buffer will be retained. Also, because most of the land adjacent to Berners Bay herring spawning habitat is under a USFS management plan that does not allow

> development, the highway is not likely to lead to habitat altering shoreside activities.

(FHWA 2006b: A-25).

3. Cascade Point Marine Facilities

Goldbelt, Inc., an Alaska Native corporation, owns approximately 1,400 acres along the east and west shores of Echo Cove, in Berners Bay. Goldbelt, Inc. is currently constructing and operating a moorage facility located at Cascade Point, at the north end of Echo Cove. The USACOE issued a permit for dredge and fill activities at Cascade Point on July 15, 2005. The authorized work includes placement of a pile-supported dock, dredging plus the discharge of dredged and fill materials into the waters of Echo Cove and Berners Bay. The permitted action includes the construction and use of a dock at Cascade Point to transfer workers to the Kensington Mine site.

A memorandum dated March 2, 1996 from an ADFG biologist expressed grave concerns about the proposed construction of marine facilities at Cascade Point. The ADFG biologist compared the observed effects of terminal expansion at Auke Nu Cove, another spawning area for Lynn Canal Herring, and determined that a Cascade Point marine terminal would permanently destroy herring spawning grounds.

> Continued encroachment on Lynn Canal shoreline that has historically been used for herring spawning may have a cumulative effect on the productivity of this stock. The Auke Nu Cove ferry terminal expansion is a good example; herring haven't spawned here in many years, but it used to be a very important spawning area. While it may not be realistic to stop the ferry terminal project for herring spawning concerns since the site hasn't been used recently, by developing it we have almost insured that herring will never use it again. The same may be case for Cascade Pt.

(McGregor 1996). Subsequent ADFG herring spawning surveys show that herring never returned to spawn at Auke Nu Cove after the ferry terminal expansion.

The USFWS also expressed grave concerns over the developments at Cascade Point. In an April 16, 1996 letter, the USFWS Alaska Field Supervisor, Nevin D. Holmberg, in Juneau stated:

> Project effects on Pacific herring habitat is a major concern to the Service. Pacific herring have historically spawned in the area scheduled for development at Cascade Point. With the depressed status of the Lynn Canal herring stock, maintaining herring spawning habitat in an unaltered state should be a top priority of resource managers.

(Holmberg 1996). The Field Supervisor further cautioned that "piecemeal destruction of Berners Bay" is sure to result from the menagerie of development projects proposed at that time. They included:

> By itself, construction of a road along the USDA Forest Service Right-of-Way to access private land at Cascade Point could have a significant on the area's fish and wildlife resources. However, construction of a road is just part of a total development plant that will affect lands and waters of the United States. The subject project includes land exchanges, timber sales, log transfer facilities, fish processing facilities, and development of a small community.

(Holmberg 1996).

In a July 29, 1998 letter from NMFS Alaska Regional Administrator Pennoyer, the impact of the Cascade Point facility on herring is described.

> The project would have removed an area representing at least 2 percent of available spawning habitat for a remnant population of herring in Berners Bay. In addition, the project may have had further reaching impacts to the recovery of this herring stock due to disruption of shoreline currents and tidal patterns, introductions of hydrocarbons from chronic boat spillage or leakage, and increased disturbance to spawning herring from vessel use of the marine facility from March 15 to June 1. While these activities are unlikely to adversely affect the current status of the humpback whale or Steller sea lion, they may have impeded their recovery by reducing the likelihood that the Berners Bay herring stock would recover fully and become a future food source for humpback whales and Steller sea lions.

(Pennoyer 1998).

The NMFS Biological Opinion for the Kensington Gold Project (NMFS 2005a) contains a substantial analysis of the effects of the Cascade Point Breakwater project. This project is likely the most damaging to Lynn Canal Herring because it will directly destroy spawning beds by dumping dredge and fill material on eelgrass and kelp.

> Overall, the combined changes in site hydrology, local water conditions and light availability are likely to change the structure and composition of the submerged vegetative community at Cascade Point. <u>Changes in the plant community may in turn affect the likelihood of utilization by spawning and rearing herring and other forage fish and adversely affect spawning success at and near the site</u>.
>
> <u>If the breakwater does not mitigate for the loss of Cascade Point intertidal habitat, the development of this site would result in a permanent loss of at least one acre of spawning habitat for Lynn Canal herring</u>. In addition, spawning habitats adjacent to Cascade Point will likely be impacted by habitat alteration and degradation. These losses of spawning habitat may impact spawning production

> and herring biomass in Berners Bay and Lynn Canal. Although it is possible that the herring would shift elsewhere to spawn, there is no documented instance where dislocated spawners have shifted to a new spawning location (Trumble 1983). Additionally, Pacific herring often exhibit homing behavior, with some herring returning to the same spawning grounds year after year, though some may change spawning areas between years (Hay et al. 2001). Therefore, herring that are dislocated from the Cascade Point spawning site might seek out suitable habitat elsewhere in the bay, or they may attempt to spawn on the breakwater or within the degraded Cascade Point terminal site. Without sufficient information on herring behavior and their ability to adjust to changes in spawning habitat, it is impossible to predict with certainty how their behavior will be modified. The extent to which the loss of current spawning habitat at Cascade Point might cause additional population-level declines in herring biomass is also unknown but the possibility of such impacts should not be discounted.

(NMFS 2005a: 111-113).

4. Cumulative Effects of Increased Industrial Developments in the Region

According to the NMFS (2005a), the Biological Opinion for the Kensington Mine, the cumulative effects of developments in the Berners Bay area is expected to transform a relatively pristine area into a heavily impacted industrial and commercial area..

> The proposed action is expected to alter the ecology and distribution of adult and juvenile forage fish in Berners Bay, which poses potential risks to Steller sea lions. The hydrology of the bay at Cascade Point will be permanently altered by the proposed action: wave action is likely to change along with tidal flushing, turbidity, and current flows; reduced sediment transport; and localized changes in temperature and salinity. The physical construction and operation of a Cascade Point marine facility is expected to alter the structure and composition of the vegetative community, temporarily or permanently, such that value of this area to herring and other forage fish will decline dramatically. Over the long term, the aggregate effects of habitat modifications and increased noise and vessel traffic may cause juvenile schooling fish to abandon shoreline rearing habitat within the action area. Without these shoreline habitats, these forage fish may not be able to use Berners Bay, reducing the prey base for Steller sea lions within the Bay and within Lynn Canal.

(NMFS 2005a: 123).

Figure 11: Cumulative impacts of developments in Berners Bay (Figure from NMFS 2005a).

In the rest of Lynn Canal, many large and small projects in the near future will collectively contribute to the overall net degradation of spawning habitat, water quality and increases in other sources of pollution (NMFS 2005a, Malecha and Stone 2003).

For example, a study conducted by the NMFS Alaska Regional Office recently reviewed three shoreline developments in the vicinity of Auke Bay (Malecha and Stone 2003). The developments included:

> Construction of a seafood processing facility has been proposed for Auke Bay near Auke Nu Cove. At the time of this study, the facility proposed to discharge approximately 68,000 kg of seafood waste per year at a depth of 24 m.
>
> A fisheries research facility has been proposed for Favorite Channel at Point Lena, which is estimated to discharge up to 8.5 million liters per day of seawater from flow-thru aquaria and 42,000 liters per day of tertiary-treated domestic wastewater at a depth of 60 m.
>
> A housing subdivision has been proposed south of Point Lena. The first phase of the proposed South Lena Subdivision consists of 47 residential lots. Individual sewage treatment systems would connect to a single marine outfall at a depth of 4.3 m and discharge between 114,000 and 303,000 liters of treated domestic wastewater per day.

(Malecha and Stone 2003). The NMFS study concluded that "[c]urrent data clearly indicate that Auke Nu Cove is a poor site for discharging seafood waste." The effect of these smaller developments is cumulative, but taken together they may cause herring to move away, reduce productivity or foul spawning areas with pollution.

B. Commercial, Recreational, Scientific, or Educational Overutilization

1. Historic Overfishing

Herring are heavily exploited by industrial fishing fleets around the world. Overall, Pacific Herring are much reduced in total abundance, and localized extinctions of populations, or extirpation, has occurred throughout their range (Pearson et al. 1999). Hourston (1978) describes the history of fisheries exploitation and population collapses in British Columbia.

Exploitation of Pacific Herring in Southeast Alaska began during the late 19th century and quickly decimated the populations throughout the region (Skud 1963). The reduction industry, which would catch and boil down millions of tons of Pacific Herring for oil, took a catastrophic toll on Pacific Herring. While government figures attempt to estimate the catch in tons from U.S. fishers, foreign fleets' catches mostly went unrecorded.

The reduction industry soon depleted Pacific Herring to the point that salmon fishermen in Alaska began to call for the protection of herring, which is a critical food source for salmon. Skud (1963) explained that the "contention of salmon trollers that local herring populations have been seriously depleted by the commercial reduction fishery" was a significant reason for the studies carried out on Pacific Herring by the U.S. Fish and Wildlife Service and the U.S. Bureau of Fisheries in the 1950s and 1960s.

A NMFS species profile for Pacific Herring describes the history of exploitation as follows:

> Pacific herring were a staple food and source of oil for preserving other food, lighting lamps, and fertilizing fields. The industrial fisheries arrived in the late 19th century and very nearly wiped them out in three decades. At one time, almost every bay and inlet in southeast Alaska contained a herring plant where the fish were rendered into oil, salted, pickled, and canned for a booming global market. The herring stocks crashed in the late 1920s, and they are no longer harvested commercially except for carefully controlled roe fisheries throughout their range.

(NMFS 2002).

Pearson et al (1999) reviewed literature on the causes of herring stock collapses throughout the world and reported that overfishing was the most frequent reason given (74% of 46 cases). Although overfishing was listed as the sole cause in 37% of the cases, many reported that environmental factors (e.g. density dependent responses, changes in food supply) acted in concert with overfishing (37% of the cases).

Worm et al. (2006) stated that "large purse-seine fisheries for herring and capelin developed in the NW Atlantic and NE Pacific in the 1960s and 1970s, partly replacing the role of whales as consumers of forage fishes. This pattern of serial depletion of predators and their prey has been documented as a general pathology of global fisheries."

2. Current and Future Fisheries Exploitation

The herring fishery in Lynn Canal and the Juneau area has been closed since 1982 (Pritchett 2005). In other parts of Southeast Alaska, other populations of Pacific Herring are currently harvested by purse-seine methods by the thousands of tons annually (Pritchett 2005). Fortunately, this level of exploitation is not currently perpetrated against Lynn Canal Herring. However, Lynn Canal Herring are still caught for personal use and exploited for a "spawn-on-kelp" fishery. A recent report prepared for the Alaska Board of Fisheries by scientists from the ADFG details the history and projections for the large "spawn-on-kelp' fishery currently practiced in southeastern Alaska and within Lynn Canal (Coonradt et al. 2006). While this small fishery is not a significant threat, it adds to the cumulative losses to the population.

C. Inadequacy of Existing Regulatory Mechanisms

The current regulatory mechanisms controlling development and resource exploitation in the vicinity of Lynn Canal, Alaska are inadequate to protect the Lynn Canal Herring from extinction.

1. Alaska State Law

a) Alaska Department of Game and Fish

The State of Alaska currently manages the herring fishery in Southeast Alaska (AAC 2006 – Herring Management Plan for Southeast Alaska). However, the fisheries laws currently in place in Alaska are insufficient to protect the Lynn Canal Herring from the threats of shoreline development and habitat loss. The State of Alaska's Board of Fisheries and the Alaska Department of Fish and Game have the authority to regulate the fisheries, but they have not been effective in preventing habitat destruction and degradation in coastal areas. The herring fishery in Lynn Canal has been closed since 1982 (Pritchett 2005). Harvest policies used for herring in Alaska set maximum exploitation rate at 20% of the exploitable or mature biomass, consistent with other herring fisheries on the west coast of North America (Hay et al. 2001b). Nearby, the Seymour Canal and Tenakee Inlet fisheries both remove thousands of tons of herring annually.

b) Alaska Coastal Management Program

The State of Alaska's Coastal Management Program as implemented pursuant to the federal Coastal Zone Management Act (CZMA) is failing to protect coastal habitat and contributes to the vulnerability of the Lynn Canal Herring.

For example, the Office of Project Management and Permitting for the State of Alaska determined that the Cascade Point developments are consistent with the Alaska Coastal Management Program. (Donohue 2005). Cascade Point developments include a large breakwater consisting of 29,000 cubic yards of fill being deposited in and around herring spawning beds, along with a marine ferry terminal and accompanying structures. NMFS (2005a) evaluated the Cascade Point project and determined that it threatens the continued existence of the herring spawning beds at Cascade Point and in the adjacent Echo Cove area of Berners Bay.

D. Disease and Predation

1. Disease

Disease has always been present in Pacific Herring populations (Marty et al. 2003). Disease becomes a major threat when other stressors, such as pollution or lack of food, cause herring to lose their immunity (Landis et al. 2004, Foy and Norcross 2001). The prevalence of viral hemorrhagic septicemia virus (VHSV) and ulcers in Pacific Herring was evaluated by Marty et al. (2003). The authors concluded that stressors that cause poor body condition in early spring make Pacific Herring more susceptible to disease.

> The unifying feature between two distinct epidemics in Pacific herring is that poor body condition in early spring may be the most significant risk factor, regardless of the underlying mechanisms of poor condition. In the first epidemic (early 1990s), population biomass was high, summer growth was poor, and fish entered the winter of 1992-1993 with inadequate energy stores (Pearson et al. 1999). By the time that second epidemic occurred (late 1990s), the population was low, summer growth was excellent, and fish entered the winter of 1997-1998 in good condition. However, water temperatures in Prince William Sound during the El Nino winter of 1997-1998 averaged 2 C greater than in the winter of 1996-1997 (Foy and Norcross 2001). Warmer water temperatures increased basal metabolism, food resources were no greater than normal during the winter of 1997-1998 (Foy and Norcross 2001), and fish were in poor condition by the spring of 1998. Poor body condition in the spring of 1994 and 1998 was associated with high prevalence of VHSV and ulcers. Food availability was good after the major winter-spring disease outbreaks of 1994 and 1998, and disease prevalence in 1995 and 199 was again low. Impacts of global warming are difficult to predict, but this study provides evidence that warmer winters increase the risk of disease outbreaks among fish populations in northern latitudes.

(Marty et al. 2003). \

Lynn Canal Herring are much reduced in total abundance and are therefore more vulnerable to disease outbreaks. In addition, much of their historic habitats are impacted by human developments and they encounter pollution from several sources. The combined effects of anthropogenic stressors and changing oceanic conditions makes the Lynn Canal Herring susceptible to a disease outbreak.

2. Predation

Herring populations around the world are subject to intense predation pressure, which healthy populations have evolved to sustain. While many species prey on herring, it is not possible to attribute the current decline observed in Lynn Canal Herring to predation. The herring's mass spawning behavior is a reproductive strategy that overwhelms predators such that sufficient cohorts survive despite high levels of mortality. However, this reproductive strategy is maladaptive when spawning levels are so reduced that predators can consume a large proportion of the population. Furthermore, such concentrations of a population make it inherently vulnerable to anthropogenic impacts such as spills or disturbance during the brief, but intense spawning period.

Pacific Herring deposit large quantities of eggs, and the eggs are subjected to intense predation.

> Herring egg loss is caused by several processes, including predation, physical displacement by wave action, anoxia, and desiccation (Palsson, 1984; Haegele

> and Schweigert, 1991; Rooper, 1996). Predators of herring spawn include birds, invertebrates, marine mammals, and fishes.
>
> While the rates of herring spawn consumption for the five avian predators are approximations, our model suggests that these predators are a significant component in the loss of herring spawn.
>
> At the same time, the high consumption by gulls, shorebirds, and surf scoters underscores the importance of herring spawn in the annual cycle of these species. Herring spawn contributes to meeting energy requirements for both breeding and migration.

(Bishop and Green 2001). Sea lions congregate in Berners Bay to exploit the Eulachon spawning runs in April and Mayof each year (Sigler et al. 2004). Sea lions also take herring during this time and throughout the year. Finally, Humpback Whales also prey upon herring (NMFS 2005a). However, the total predation pressures exerted on herring is not a new phenomenon. Indeed, two major predators, the Steller Sea Lion and Humpback Whale, are currently ESA-listed so the predation pressure on Lynn Canal Herring is probably less now than it was before these predators were depleted. In conclusion, while predation is a constant factor in herring population dynamics, the cause of the observed population collapse is primarily a result of overfishing and the destruction of spawning areas.

E. Other Natural and Manmade Factors Affecting Continued Existence

1. Changing Ocean Conditions

The warming of the oceans in recent decades is well documented (Behrenfeld et al. 2006). This warming threatens to reduce the amount of phytoplankton and zooplankton throughout the oceans. Lynn Canal Herring feed directly on plankton, so continued oceanic warming will reduce the available food. A recent article in the journal *Nature* analyzed the impact of warming ocean temperatures on phytoplankton abundance (Behrenfeld et al. 2006).

> Climate effects on ocean biology are documented here for nearly a decade of satellite ocean colour measurements. It is also clear from the current analysis that surface warming in the permanently stratified ocean regions is accompanied by reductions in productivity. The index used here (MEI) to relate climate variability to [net primary productivity] NPP trends does not distinguish natural from anthropogenic contributions, but observational and modelling efforts indicate that recent changes in [sea-surface temperature] SST are strongly influenced by anthropogenic forcing. These observations imply that the potential transition to permanent El Niño conditions in a warmer climate state would lead to lower and redistributed ocean carbon fixation relative to typical contemporary conditions. Such changes will inevitably alter the magnitude and distribution of global ocean

> net air-sea CO2 exchange, fishery yields, and dominant basin-scale biological regimes.

(Behrenfeld 2006: 754)(internal citations omitted). Oceanic food-web changes have already been documented in the North Pacific. These changes are implicated in the severe decline of many species of fish and marine mammals.

> The "ocean climate hypothesis" is an alternative explanation for the rapid changes that were observed to cross all trophic levels of the North Pacific (National Research Council 1996, Trites *et al.* in press). This bottom-up hypothesis is supported by a large and growing body of evidence (*e.g.*, Ware and Thomson 2005, Trites *et al.* in press). For the past 100 yr, 10–30-yr periods of stable physical conditions have been punctuated by rapid shifts to alternative stable physical oceanographic conditions (Ebbesmeyer *et al.* 1991, Graham 1994, Beamish *et al.* 2000, McKinnell *et al.* 2001, King 2005). These sudden and well-documented "regime shifts" significantly affect sea temperatures, currents, and ice coverage—and correspond in space and time with ecosystem changes noted in Alaska and in British Columbia (Hare and Mantua 2000, Benson and Trites 2002, King 2005).

(Trites et al. 2006). An ecological risk assessment performed on Cherry Point Herring by Landis et al. (2004) concluded that ocean conditions significantly affect Pacific Herring.

> An analysis of the Cherry Point Pacific herring age structure and population dynamics indicates that the loss of reproductive potential of the older age class fish was the population characteristic that led to the decline of the run. Exploitation, habitat alteration and climate change are the risk factors that contribute to the decline of the Cherry Point Pacific herring. The retrospective assessment identified the cyclic nature of climate change, as expressed by the warmer sea surface temperatures associated with a warm Pacific Decadal Oscillation (PDO), as the primary factor altering the dynamics of the Pacific herring.

(Landis et al. 2004).

Reduced phytoplankton productivity in the Lynn Canal area would have dire consequences for Pacific Herring. In particular, juvenile herring during the first winter are susceptible to environmental changes with little room for error to ensure survival. Marine perturbations that decrease food availability would inevitably cause greater winter mortality of juvenile herring, thereby depressing the future spawning generations. Cooney et al. (2001) found that juvenile herring were subject to substantial starvation losses during a winter period of plankton diminishment.

> [W]e determined that if a juvenile herring arrives at the beginning of oceanographic winter in late November or early December with an energy content of 5.0 kJ/g and burns energy without supplemental feeding at 23 J/g day–1, it will

> reach a critical energy level of 3.0 kJ/g in about 87 days. This lipid buffer provides a nominal 3-month bridge (December–February) to the beginning of the following year's production cycle but with little margin for error. The possibility that juveniles also supplement their energy stores by feeding opportunistically during the winter was examined by Foy and Paul (1999). They found that although there was evidence for limited feeding, the amounts ingested were apparently insufficient to account for winter metabolic demands. On the basis of these empirical observations, we concluded that the winter period of plankton diminishment imposes measurable bioenergetic constraints on the survival of juvenile herring and their eventual recruitment to the adult stock in PWS.

(Cooney et al. 2001).

In addition to the threat of starvation, changing ocean conditions may cause herring to grow too large for the ecosystem to support them. Studies in Alaska have shown that elevated temperatures associated with El Nino can accelerate growth rates to the point that the herring do not have sufficient energy to successfully over-winter and spawn, particularly if food is also in short supply due to elevated temperatures (Salazar and Salazar 2002).

The effects of warming ocean temperatures on the closely related Atlantic Herring is relevant to Lynn Canal Herring. For the Norwegian population of Atlantic Herring, Engelhard and Heino (2006) described the effects of climate and environmental variables on reproduction. The researchers determined that higher water temperatures and associated poor food availability caused herring to skip reproduction for that year (Engelhard and Heino 2006).

> The extent to which herring may skip reproduction was found to be not only related to fish size and condition but also to climatic factors.
>
> Notably, colder sea temperatures (possibly associated with a negative NAO index) favoured both adult survival and participation in the second spawning season (Table 3). Prey availability is a possible mechanism for this. The copepod *Calanus finmarchicus*, a key species in the Norwegian Sea ecosystem, is the most important prey species for adult herring during the summer feeding season (Dalpadado et al. 2000). There is an inverse relationship of *C. finmarchicus* abundance with the NAO and sea surface temperatures (Fromentin and Planque 1996).
>
> The possibility of contrasting climate effects on juvenile and adult herring has interesting population implications. Usually, variations in survival early in life far exceed those in adults, so that the relationship of overall stock abundance with temperature will still follow that of juveniles (in agreement with Toresen and Østvedt 2000). Despite this, the inverse temperature effect on adult herring survival and skipped reproduction remains relevant, as it is directly linked to the

> population's reproductive potential, and refers to the part of the stock relevant to commercial fisheries.

(Engelhard and Heino 2006).

2. Oil Pollution

Oil pollution kills adults and juvenile fish and is particularly harmful to egg and larval stage herring. A well documented example of the large scale oil pollution on Pacific Herring was the collapse of herring populations after the *Exxon Valdez* oil spill. The spill devastated Alaska's Prince William Sound ecosystem and Pacific Herring populations in Prince William Sound collapsed in 1993.

> The *Exxon Valdez* oil spill occurred on March 24, 1989, a few weeks before herring spawned in [Prince William Sound]. Because many herring were gathering in oiled waters to spawn, all herring fisheries were closed in 1989 to eliminate the risk of contaminated catches. About half of the egg biomass was deposited within the trajectory of the spilled oil, and an estimated 40% to 50% was exposed to oil during early development. An unknown portion of oil was dispersed throughout the water column to a depth of at least 25 m. Oil was in the water throughout the summer of 1989 and, to a lesser degree, in 1990, following beach cleaning operations.
>
> Adult herring also were exposed to spilled oil, but the effects of this exposure are not clear. Adults sampled immediately after the spill at oiled sites had liver lesions that were attributed to oil exposure. Recent laboratory studies have shown that exposure of wild herring to concentrations of crude oil similar to those that may have been encountered in PWS following EVOS depressed immune functions and allowed expression of a viral disease, viral hemorrhagic septicemia (VHSV), which also is associated with lesions. Thus, the lesions originally attributed solely to oil exposure in herring captured from PWS in 1989 may have been caused by disease, which, in turn, may have been triggered by oil exposure.
>
> Physical abnormalities and genetic effects caused by exposure of herring eggs to oil include increases in the incidence and severity of various morphological malformations and chromosomal aberrations.

(Brown and Carls 1998)(citations omitted). Carls et al. (1997) provide an exhaustive review and analysis of the effects of the *Exxon Valdez* oil spill on Pacific Herring. The ultimate conclusion from Carls et al. (1997) was that oil pollution caused reproductive impairment to adults, but more importantly oil caused mortality to eggs and larvae long after the spill was cleaned up.

> In 1993, the herring population in Prince William Sound collapsed, suggesting possible reproductive impairment. Reproductive condition of herring in Prince William Sound was assessed in 1995; adult herring and eggs were also

> experimentally exposed to oil. In laboratory tests, prespawn herring were negatively impacted by exposure to oil, principally by suppression of the immune system and increased expression of disease. Induction of aryl hydrocarbon hydroxylase, suppression of leukocytes, increased prevalence of viral hemorrhagic septicemia virus, and mortality were correlated with polynuclear aromatic hydrocarbon concentration. However, exposure of adult herring caused negligible damage in progeny at high concentrations (58 ppb aqueous polynuclear aromatic hydrocarbon). In contrast, exposure of incubating eggs to comparably weathered oil caused significant morphological defects at 9 ppb and effects of more weathered oil were significant at concentrations as low as 0.2 ppb polynuclear aromatic hydrocarbons; chromosomal aberrations were observed at 0.7 ppb. Most larvae with genetic defects would likely die due to concomitant morphological abnormalities.

(Carls et al. 1997). Large oil spills are not the only threat posed by hydrocarbon pollution.

Persistent, but minute amounts of hydrocarbons also have negative effects on Pacific Herring. Hershberger et al. (2005) analyzed the Pacific Herring at Cherry Point, WA to determine the observed declines in survival.

> Elevated prevalence of skeletal abnormalities at the southern extreme of the study range during the 1999 in situ egg exposures were likely caused by suboptimal environmental conditions along the spawning shoreline. It is possible that these conditions originated from industrial activities along the Cherry Point shoreline because the three southernmost stations were located on the south side of a petroleum off-loading pier and either side of a similar pier used for an aluminum smelting operation. Exposure of fertilized Pacific herring eggs to levels of petroleum hydrocarbons as low as 0.01 mg/L can cause low weight at hatch and DNA damage to developing Pacific herring embryos, while higher levels can result in physical defects and premature hatch to larvae (Kocan et al. 1996).

(Hershberger et al. 2005).

3. Anthropogenic Noise Pollution

The cumulative impact of increasing noise from ships, oil and gas exploration, and general human activity in marine environments is substantial. In the range of the Lynn Canal Herring, marine noise has steadily increased with the development of cities and ports in and around Juneau and Haines. The proposed mining, road building and commercial development of the region will significantly increase the amount of noise in the waters of Lynn Canal.

Pacific Herring use noise pulses to communicate and are sensitive to noises at low and high frequencies.

> Described sounds fall into three categories. Incidental noises include those associated with jaw movements while feeding, and hydrodynamic sounds from moving schools (Fish & Mowbray 1970). Tonal sounds, termed 'whistles', have been detected in the vicinity of herring at night (Schwarz & Greer 1984). Pulsed sounds vary from thumps to low-frequency pressure pulses (Fish & Mowbray 1970) and, in one study of Pacific herring, include bursts of broadband pulses (Schwarz & Greer 1984).
>
> The capacity of herring to respond to various underwater sounds is well documented (Schwarz & Greer 1984; Wilson & Dill 2002). Early studies of clupeoids indicated that their auditory range extended to 1 kHz, but more recent work has shown that they can detect sounds at higher, and in some instances considerably higher, frequencies (Mann *et al.* 2001).

(Wilson et al. 2003). Pacific Herring kept in captivity produced sound in way that implied that "sound production is socially mediated" (Wilson et al. 2003).

V. VULNERABILITY TO EXTINCTION

Marine organisms are perceived to be less vulnerable to extinction than terrestrial taxa for several reasons. However, Dulvy et al. (2003, 2004) dispels the myths associated with marine extinction.

> We find little evidence to suggest that marine taxa are less vulnerable than terrestrial taxa. While they may generally be more fecund, the high fecundity of broadcast spawners does not appear to result in higher maximum reproductive rates, which are similar to those of similar-sized terrestrial taxa. Additionally, fishes are no more variable in abundance from year-to-year than are mammals and butterflies, and demographic analyses indicate they may actually be even more vulnerable than birds and butterflies, all other factors being equal, e.g. severity of threat. A barrier to precautionary thinking has been the hope that economic extinction would pre-empt biological extinction. However, this is unlikely to hold for non-target species caught in multispecies fisheries and for those fisheries targeting species with value that increase with rarity.

(Dulvy et al. 2003). Like the Lynn Canal Herring, the disappearance of the Icelandic spring-spawning herring population was preceded by a steep decline as result of over-exploitation (Dulvy et al. 2004).

Other highly fecund marine fish are documented to near extinction. Sadovy and Cheung (2003) described the near extinction of the Chinese bahaba (*Bahaba taipingensis*), a highly fecund fish. Likewise, Hutchings (2001) concludes:

> Contemporary perceptions of the ability of marine fishes to recover from population decline do not have particularly strong theoretical or empirical

> support. Marine fishes appear to be no more likely to experience reductions in population size than nonmarine fishes.

(Hutchings 2001). However, Hutchings (2001) argues that reliance on such models and percentages is dangerous in that allowing very population declines before instituting protection will ultimately fail to recover a species.

> Recently proposed decline thresholds for marine fishes, ranging from 70 to 99% over the longer of 10 years or three generations (Musick 1999), may be akin to threading the extinction needle just a little too finely. In any event, the degree to which any criterion adequately reflects extinction probability cannot be known until substantial numbers of species have gone extinct, an obviously undesirable necessity and one that may require considerable amounts of time. So, rather than changing the risk criteria, one could change the names of the risk categories so that they better reflected the goals of conservation and preservation of biodiversity. For example, even if an 80% decline in a cod population does not significantly increase its probability of extinction, it certainly appears to affect its probability of recovery to former levels of abundance. So, irrespective of whether quantitative criteria adequately reflect extinction risk, they do appear to adequately reflect recovery potentials, something of clear importance to resource managers, harvesters, ecologists, and conservation biologists.

(Hutchings 2001). In the context of the ESA, the real goal of listing a species is to eventually recover the population(s). Thus, evaluating extinction risk for listing purposes should be tied to the recovery goal of the ESA, rather than an uncertain model.

> Clupeids, which include herrings and sardines, appear to be more likely to recover from collapse than other species. This apparent increased resilience may be attributable to an earlier age at maturity, to reduced vulnerability to incidental exploitation or bycatch, and possibly, given the clupeid's pelagic life cycle, to reduced probability of habitat destruction by fishing gear (Hutchings 2000, 2001b). However, notwithstanding their greater ability to recover as a group, clupeids have been eliminated from parts of their range in the past century (Dulvy et al. 2003).
>
> The perception that collapsed marine fishes are not at imminent risk of extinction seems pervasive among fisheries managers, who do not seem to appreciate the dramatic influence that relatively small catches can have on the recovery of depleted populations. Further compounding this perception is the near absence of discussion of the effects that declining population size can have on genetic variability, a metric of considerable importance to population persistence.

(Hutchings and Reynolds 2004).

VI. BEST AVAILABLE SCIENCE

The ESA requires the NMFS to use the "best available science" in determining the status of the Lynn Canal Pacific Herring. The American Fisheries Society recently published a summary, critique, and recommendation on the use of the "best science."

> Because government agencies act both as representatives of the public interest and as scientific bodies, conflicts can arise as to how information is collected and utilized and how it is communicated. Agencies should acknowledge potential conflicts and move to ameliorate them whenever possible. Providing forums for public observation of the scientific process and public participation in scientific debates is one means of accomplishing this. Administrative separation of agency divisions tasked to conduct science and develop policy may also be an effective way to avoid clouding issues and to reduce conflicts of interest. However, policy and science groups should communicate closely to ensure that management decisions are informed by the best available science.
>
> Resolution of many of today's environmental issues, such as the influence of human activities on ecosystems, is hampered not only by rudimentary scientific understanding but also by a weakly developed scientific process. Collectively, scientists have been reluctant to go beyond the safety zone of traditional scientific approaches—hypothesis testing and statistical interpretation of results—although counter-examples do exist (see Vitousek et al. 1986, Rinne et al. 2005, Brown et al. 2005, and Hughes et al. 2006). Because management decisions continue to be made with whatever information is available, scientists need to become more involved in assessing information quality and providing guidance on how the available information might best be used. <u>Such guidance would also help safeguard against science being subverted for political ends</u>.

(Sullivan et al. 2006)(emphasis added).

VII. CRITICAL HABITAT

Petitioners request that the Service designate critical habitat for the Lynn Canal Herring concurrent with any listing. Any critical habitat designation should focus on the importance of protecting the remaining spawning grounds and restoring historic spawning areas. A critical habitat designation should include areas above mean high tide line because spawning grounds are easily degraded by land-based disturbance.

VIII. CONCLUSION

Based on the population declines, threats to habitat and inadequacy of existing regulatory mechanisms, NMFS should act in accordance with its duties under the ESA to list the Lynn Canal Herring as either threatened or endangered and designate critical habitat. Any delay will compromise the ability of the species to recover and undermine the entire marine ecosystem in Lynn Canal.

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APPENDIX A: HERRING GENETICS

This appendix contains information reported from genetic studies performed on Pacific Herring and Atlantic Herring. Only one study, Grant and Utter (1984), contains specific genetic data on Lynn Canal Herring. Based on Grant and Utter (1984) and subsequent studies in Alaska, British Columbia, Washington and the Atlantic Ocean, this petition concludes that Lynn Canal Herring are a genetically discrete and significant population of Pacific Herring.

Grant and Utter (1984) and O'Connell et al. (1998) showed that Pacific Herring populations from the Bering Sea are genetically distinct and the Gulf of Alaska. Microsatellite analysis also suggests that some genetic structuring may also exist within the Gulf of Alaska (O'Connell et al. 1998).

> Grant expanded upon Utter's initial work, and surveyed 40 allozyme loci in Pacific herring (Grant 1979, 1981; Grant and Utter 1984). Grant and Utter (1984) found 26 polymorphic loci in 21 samples collected from five areas throughout the range of Pacific herring -- Asia, the northeastern Bering Sea, the southeastern Bering Sea, the Gulf of Alaska, and the eastern North Pacific Ocean (including samples from the Strait of Georgia and Hale Passage in Puget Sound) (Fig. 15). Their analyses revealed two main genetic stocks: Asian-Bering Sea herring and eastern North Pacific herring, separated by a Nei's genetic distance (D) (Nei 1972) of 0.039 (Fig. 16). The authors postulated that these two distinct stocks arose because of restricted gene flow between them, due to repeated Pleistocene glaciation on the southern coast of Alaska. Genetic differentiation was also detected among all five areas. However, only the Bering Sea and the Gulf of Alaska showed any significant genetic differentiation within an area. The samples from the eastern North Pacific Ocean, which include the two Puget Sound samples, were not genetically distinct from each other, even though the collection sites ranged from California to southeast Alaska. The average D value between pairs of samples within the eastern North Pacific Ocean was not significantly different from zero. A gene diversity analysis revealed that only 0.5% of the observed variation was due to differences among populations within an area. The authors also reported a north to south cline in allele frequencies of the locus GAPDH-1* for eastern North Pacific Ocean samples. The reason for this is uncertain, but because no other loci showed a similar cline, one possible explanation is that selection is occurring at this locus.

(Stout et al. 2001).

> Several genetic studies of Alaska Pacific herring have also been conducted. Burkey (1986) analyzed 16 samples collected from seven locations by commercial herring fisheries within Prince William Sound, Alaska. He analyzed 14 polymorphic allozyme loci but did not find any significant differences among samples, among locations, or between years within a location. A gene diversity

analysis showed that over 99% of the total variability was due to variability within samples.

Seven populations of Alaskan Pacific herring were sampled in two different years and examined for microsatellite variation (Wright et al. 1996, Wright and Dillon 1997, O'Connell et al. 1998a, 1998b) and mtDNA variation (Bentzen et al. 1998). The results of these studies were summarized by Seeb et al. (1999). Differences in microsatellite allele frequencies were significant among all samples, whereas the mtDNA haplotype frequency variation was not significant among samples collected in 1995, but were significant among 1996 Prince William Sound samples. Similar to previous studies, the greatest amount of genetic divergence was between samples from the Bering Sea and the Gulf of Alaska. Analogous to what was found by Schweigert and Withler (1990), samples collected from the same location in different years showed a high degree of genetic differentiation. The authors state that "the magnitude of genetic variation among sampling years within locations was equal to or greater than the magnitude of variation among locations within sea basins." They concluded "the DNA data provide no evidence of stable differentiation among populations within sea basins on spatial scales of up to ~700 km. Rather, the DNA data suggest that temporal variation among spawning aggregations dominates genetic variability on these spatial scales."

Two main conclusions about genetic differentiation among Pacific herring populations can be drawn from these studies. First, Pacific herring show considerable temporal variation in allele frequencies. Bentzen et al. (1998), Wright and Dillon (1997) and Schweigert and Withler (1990) all found significant temporal variation in the samples they analyzed. A high degree of temporal variation has the potential to confound genetic population studies. Ideally, all samples for a study should be sampled in the same year. Such was the case for the majority of the studies reviewed here. Additionally, sampling all locations in multiple years as Wright and Dillon (1997) and Bentzen et al. (1998) did, will provide valuable information regarding the nature of any observed genetic variation.

Second, Pacific herring have comparatively low levels of genetic differentiation among populations. According to Hartl (1980), gene diversity values of 0.05 - 0.15 indicate moderate differentiation among populations. Reported gene diversity values for Pacific herring of 0.005 (Grant and Utter 1984), 0.004 (Burkey 1986), 0.003 (Schweigert and Withler 1990), 0.013 (mtDNA) and 0.030 (microsatellites) (Seeb 1999) for comparisons among samples within a predefined area, are all below this range. While some genetic differentiation was evident in Alaskan samples, neither Utter et al. (1974), Grant and Utter (1984), or Kobayashi (1993) found any evidence of significant genetic differentiation between Puget Sound herring populations and California, Oregon, British Columbia, or southeast Alaska herring populations. Grant and Utter (1984) determined that "very little migration is required to maintain genetic homogeneity at the very large population sizes that are characteristic of herring." Significant migration among

> Pacific herring populations would result in a high degree of gene flow, and thus little to no genetic differentiation among populations.

(Stout et al. 2001).

In the Kensington Gold Project Biological Opinion, NMFS biologists concluded that Lynn Canal Herring population is probably distinct from other Pacific Herring in Southeast Alaska.

> Herring populations, or stocks, are scattered across the region from Lynn Canal to Prince of Wales Island, with the main spawning concentrations occurring in the vicinities of Ketchikan, Craig, Frederick Sound, Sitka, and Auke/Berners Bays (Skud 1959). Population research conducted in southeast Alaska and Prince William Sound suggests that regional herring stocks are comprised of multiple, distinct subpopulations, or races, which are part of a larger regional metapopulation, with potential recruitment occurring between subregions (Rounsefell and Dahlgren 1935, Skud 1959, Brown and Norcross 2001).
>
> Recent genetic analysis of satellite mitochondrial DNA loci from 65 Pacific herring sampling locations in British Columbia, southeast Alaska and Washington state found herring spawning in Southeast Alaska to be distinct from those spawning further south in the Queen Charlotte Islands (Beacham et al. 2001). There was little evidence of genetic substructure among the herring stocks examined, but for locations where genetically distinct populations were identified, differences in timing of spawning was the main isolating mechanism and geographic isolation of the spawning population was thought to have an effect in maintaining genetic distinctiveness of the spawning population.
>
> Applying the metapopulation model (Levins 1970) to southeast Alaska herring stocks, it is probable that the viability of the Lynn Canal subpopulation that spawns in and around Berners Bay will indirectly impact the viability of other southeast regional herring populations through recruitment, genetic diversity, and sharing of predation pressures from marine mammal populations in northern southeast Alaska waters.

(NMFS 2005a: 58-59)(emphasis added).

A. Comparison with Pacific Herring Populations in the Gulf of Alaska and Bering Sea; Grant and Utter (1984), O'Connell et al. (1998).

Grant and Utter (1984) determined that Pacific Herring in the Bering Sea are a distinct "race" separated from all herring to south along North America's west coast.

> One important result of this study is the discovery of two genetically distinct geographic races of Pacific herring. Although several races or varieties of Pacific herring have previously been described on the basis of morphological differences, none of the geographic ranges of these varieties coincides with the geographic distributions of the two genetics races described in the present study.
>
> A rare Asian freshwater form has been described from Kamchatka, Sakhalin, and Hokkaido, among other locations, which penetrates into rivers or freshwater lakes to spawn and overwinter (Berg 1948, Shmidt 1950, Svetovidov 1952). This form has not yet been examined genetically nor has it been given taxonomic standing.
>
> The remaining forms of Pacific Herring are spring spawning and strictly marine. Populations of herring along the west coast of North America from the Bering Sea to California were described as a separate variety (*C. p. mirabilis* Girard), which was thought to consist of an uninterrupted series of transitional forms (Shmidt 1950, Svetovidov 1952, Andriyashev 1954).
>
> Two geographically isolated groups of Pacific herring have been described from the European section of the Arctic Ocean. *Clupea p. maris-albi* Berg occurs in the White Sea and *C. p. suworowi* Rabinerson occurs toward the Kara Sea. These fish are often sympatric with migratory populations of Atlantic herring from the coast of Norway but are morphologically and biochemically distinguishable from them. Truveller (1979, cited in Altukhov and Salmenkova 1981) compared White Sea herring with Pacific and Atlantic herring using disc-gel electrophoresis of several proteins and confirmed that they were more closely related to Pacific herring than Atlantic herring.

(Grant and Utter 1984).

O'Connell et al. (1998) determined that significant genetic differences exist between and among Pacific Herring populations in Prince William Sound, Kodiak Island and the Bering Sea. This is in agreement with earlier work by Grant and Utter (1984). In addition, O'Connell et al. (1998) found significant genetic variation that showed population structuring within Prince William Sound.

> A comparison of pairwise Θ values revealed that the populations from outside the Gulf of Alaska (Togiak Bay and Norton Sound) were approximately three times more distinct from populations within Prince William Sound than the Prince William Sound populations were from each other. The Θ values also revealed the Kodiak Island and Port Chalmers samples to be relatively distinct from the remaining Prince William Sound samples (Table IV).
>
> The R_{ST} coefficient confirmed the high degree of genetic isolation between populations from the Gulf of Alaska and the Bering Sea and also confirmed the relative distinctness of the Point Chambers and Kodiak Island samples from the other Prince William Sound and Bering Sea samples.

(O'Connell et al. 1998: 155)

B. Comparison with Pacific Herring Populations in British Columbia; Beacham et al. (2002).

Beacham et al. (2001, 2002) analyzed the population structure of Pacific Herring in British Columbia using microsatellite loci and found genetically distinct populations of herring in two circumstances: 1) timing of spawning, and 2) geographic isolation.

> In order for local population differentiation to occur, herring spawning in a particular area must home and be isolated from other spawning herring through differences in timing of spawning, or the location of spawning must be isolated from other spawning areas, or both may occur.

(Beacham et al. 2002).

First, differences in timing of spawning by specific herring populations is thought to provide reproductive isolation and in turn produce genetic differentiation.

> Differences in timing of spawning may have led to some genetically discrete local populations of herring. Herring spawning in Skidegate Inlet spawn later than in other locations sampled in British Columbia and southeast Alaska (samples collected April 15-18, 1998; May 7, 1999), and this later timing of spawning has provided enough reproductive isolation for genetic differentiation to occur. Herring spawning at Secret Cove in the Strait of Georgia tend to spawn somewhat earlier than in other locations in the Strait (sample collected March 2, 1999), perhaps enough of an isolating mechanism to allow for genetic differentiation. Herring spawning at Cherry Point, Washington were sampled May 2, 2000, approximately two months after spawning typically begins in the Strait of Georgia. This difference in timing of spawning has likely led to the observed genetic differentiation between Strait of Georgia herring and those from Cherry Point.

(Beacham et al. 2002). Second, geographic isolation is thought to produce reproductive isolation and in turn genetic differentiation.

> Geographic isolation may also have led to differentiation of local populations. Herring spawning in Esquimault Harbour at the extreme southern end of Vancouver Island move in to Portage Inlet (where samples were collected) prior to and just after spawning. As there is a restricted distribution of spawning herring in this area, geographic isolation of the spawning population may have led to differentiation of a local population.

(Beacham et al. 2002). Lastly, geographic isolation and spawning time are thought to work together on some herring populations to produce genetic differentiation.

> Esquimault Harbour / Portage Inlet herring also spawn in late March, later than herring in most other locations in the Strait of Georgia, and thus both geographic isolation and differences in timing of spawning may be isolating mechanisms to maintain the distinctiveness of these populations.

Beacham et al. (2002). Thus, in Lynn Canal Herring either one or both of these mechanisms may be operating to make the population genetically distinct from others.

C. Comparison with Puget Sound Herring; Small et al. (2005).

Small et al. (2005) determined that the Squaxin Pass herring population is isolated from other herring in the Puget Sound, and that this isolation separates this population even though they spawn at the same time as others.

> The winter spawn timing of Squaxin Pass herring overlaps with other [Puget Sound] herring spawn timings, but Squaxin Pass is the most physically isolated of the [Puget Sound] populations in the study. In addition to threading their way down to the southern reaches of [Puget Sound], Squaxin Pass herring must negotiate a glacial sill at the Tacoma Narrows approximately 30 km northeast of the spawning area. Herring from north of the Tacoma Narrows may be unmotivated to explore into the region if aggregation sizes are small (Ware and Schweigert 2001) and if spawning habitat is available at their natal sites. The isolation of Squaxin Pass may be similar to Esquimalt Harbor on the Southern Coast of Vancouver Island (Beacham et al. 2002) or Bras d'Or Lake along Nova Scotia (McPherson et al. 2004), where geographic isolation promoted genetic divergence.

(Small et al. 2005).

In addition, Small et al. (2004) hypothesizes that Pacific Herring may show undifferentiated genetics between populations simply by chance.

> The most puzzling result from this study is our failure to detect differentiation between herring from the Bering Sea and Prince William Sound in Alaska. Allozyme analysis (Grant and Utter 1984), microsatellites (O'Connell *et al.* 1998) and mitochondrial analysis (Bentzen *et al.* 1998) report significant genetic differences between herring collected from these locations. By increasing the number of microsatellite loci, we expected to increase the resolution of their genetic relationship. The high stray rate reported for BC herring (Ware and Schweigert 2001) is unlikely between Norton Sound and Prince William Sound, a minimum distance of around 3000 kilometers. Ware *et al.* (2000) found that of the herring that strayed, less than 8% dispersed 800 or more kilometers. This lack of observed differentiation between spawners from Norton Sound and Prince

> William Sound may indicate that the populations are so large that same-sized alleles arise in the populations by different evolutionary pathways, making the collections appear undifferentiated. The extreme haplotype diversity in these herring (Paul Bentzen, preliminary summary to WDFW, March 13, 2004) would support a hypothesis of large effective population sizes. Alternatively, or in addition, interannual variability may be so high in AK herring stocks that at times they are genetically undifferentiated simply by chance. In another puzzling comparison, the AK stocks were undifferentiated from Port Gamble and Northumberland herring. This may have been a result of poor genetic characterization of the 02Port Gamble stock, but this fails to account for relationships with 99Port Gamble and 99Northumberland. Pairwise genotypic tests are highly sensitive and detect even subtle differences among subpopulations (Balloux and Lugon-Moulin 2002). Thus, the lack of differentiation is puzzling.

(Small et al. 2004).

D. Comparison with Atlantic Herring

McPherson et al. (2004) determined that population structure in Atlantic Herring exists at the basin, shelf, and bank scales, and demonstrated interannual stability, as reflected by allele frequency homogeneity and analyses of molecular variance.

> In summary, we have provided evidence for genetic differentiation among spawning groups of Atlantic herring at a number of spatial scales. Replicate samples and year-class analyses, when used to test for the annual temporal stability of allele frequencies at four locations, show stability in the majority of cases. When these results are interpreted within the context of the retention and metapopulation models proposed for herring, we find that neither model is fully consistent with our observations.

(McPherson et al. 2004).

Similarly, Jorgensen et al. (2005) determined that Atlantic Herring within the Baltic Sea are separated into several genetically distinct populations that correlate mainly with environmental variables.

> Based on our results we clearly reject the hypothesis that herring in the Baltic Sea constitutes one panmictic unit. Previous studies employing allozyme and mitochondrial DNA markers have found significant differentiation among herring populations inhabiting relatively closed marine areas such as fjords (e.g. Jörstad *et al*. 1991; Turan *et al*. 1998), whereas no significant genetic differentiation was found between herring populations from open sea areas, including the Baltic Sea (e.g. Ryman *et al*. 1984; Turan *et al*. 1998). More recently, studies employing microsatellite DNA markers have revealed statistically significant albeit low differentiation among spawning groups from open marine areas (e.g. Shaw *et al*. 1999; McPherson *et al*. 2004), and our results are in accordance with these

> studies. However, beyond the general finding that genetic differentiation is present among Baltic Sea herring spawning groups, interpretation of the results is complicated. First, temporal genetic differentiation was observed at some locations. Second, genetic differentiation was not correlated with geographical distance between populations. On the other hand, genetic differentiation was significantly correlated with differences in salinity and water temperature, but this correlation primarily reflected the genetic divergence of Rügen (RU) samples in the southwestern Baltic Sea, where salinity and temperature gradients were steepest. Third, we identified two geographical zones that appeared to act as barriers to gene flow, and these zones corresponded to the transition zone in the southwestern Baltic and the separation of the central and northern parts of the Baltic Sea into separate basins.

(Jorgensen et al. 2005).

Jorstad (2004) determined that herring in the Barents Sea were genetically differentiated from herring in the Northeast Atlantic, an area where the two populations are considered to be and managed as one population.

> The data presented clearly demonstrate that two highly genetically differentiated groups of herring exist in the eastern Barents Sea in the northeast Atlantic. The groups are fixed or nearly fixed for alternative alleles at several allozymes, and the highest genetic distance observed (Nei 1972)was approximately 1.5. One group was dominated by juveniles and belongs to the NSS stock as seen by comparing the observed allele frequencies with values reported earlier (Jørstad et al. 1991, 1994). The other group of herring possibly belong to one of the 'low vertebrae' herring groups found in Russian seas including the White Sea and the north-western coastal areas. According to Svetovidov (1963) the herring populations in this region are considered as a subspecies of Pacific herring, *C. pallasi*. The taxonomy of the herring group in this region is controversial, and for a recent discussion of the problems see Novikov et al. (2001).

(Jorstad 2004).

Ruzzante et al. (2006) concludes that the individual variation among Atlantic Herring populations, no matter how small, is critically important to preserving the complexity of the species and its adaptive potential.

> Most importantly, [our results] provide strong evidence for the persistence of genetic differences associated with life-history differences (spawning season, which is linked to spawning location, inferred from otolith central microstructure, migration pattern), among herring from three regions despite intermingling freely in large nursery, feeding and overwintering aggregations. The fact that such a complex pattern of intraspecific differentiation persists despite mixing supports the view of strong natal homing behaviour in herring (Iles & Sinclair 1982), at least at the broad geographic scale of our analysis.

> We argue that sustainability (Hilborn et al. 2003), resistance to disturbance (e.g. Hughes & Stachowicz 2004), and perhaps even the ability to recover from low abundance following environmental change or climatic extremes (e.g. Reusch et al. 2005), are all likely to be compromised if this genetic diversity is reduced through generalized management or misdirected area closures that can disproportionately impact smaller or less-productive populations. Loss of, or reduction in such biocomplexity is likely to have ecological implications by affecting the dispersal patterns that sustain major fisheries and evolutionary implications by removing adaptive genetic variation. We stress that detailed spatial and seasonal information is required for assessing the impact of spatially explicit conservation measures (e.g. marine protected areas, FSBI 2001), even for widely abundant and highly migratory species with low levels of genetic differentiation. Overlooking population differences in spatial use throughout their life cycles will affect the viability of populations, their ability to recover from low abundance and their evolutionary potential.

(Ruzzante et al. 2006).