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### KEY INFORMATION

**Area of Concern**  
Puget Sound.

**Year Identified as “Species of Concern”**  
1999

**Factors for Decline**

- Overfishing
- Decline in age- and size-at-maturity

**Conservation Designations**  
IUCN: Not Evaluated  
American Fisheries Society: Vulnerable

### Brief Species Description:

Pacific hake, *Merluccius productus* (Ayres, 1855), also known as Pacific whiting, is a gadiform (cod group) groundfish that is currently the most abundant commercial fish species on the U.S. West Coast (Methot and Dorn 1995). There are three recognized **stocks** of Pacific hake: a highly migratory offshore (or coastal) stock that ranges from southern California to Queen Charlotte Sound, a central-south Puget Sound stock, and a Strait of Georgia (SOG) stock. The Georgia Basin DPS includes both the Puget Sound and Strait of Georgia stocks (Figure 1). Pacific hake are silvery on the back grading to whitish ventrally and can reach up to 36 inches (91 cm) in length and 15 years of age. Pacific hake have two dorsal fins and a truncate caudal fin. Their pectoral fin tips usually reach to or beyond the origin of anal fin. The caudal fin is always concave. Pacific hake are nocturnal feeders that undergo diel vertical migrations off the bottom in order to feed on a variety of fishes and invertebrates. They are an important prey item for sea lions, small cetaceans, and dogfish sharks. Pacific hake are common in moderate depths and occur to depths of 3000 ft (910 m).

The offshore Pacific hake stock spawned off south-central California to Baja California in the winter months of January and February during the 1960s, 1970s and 1980s (Methot and Dorn 1995, McFarlane et al. 2000). In spring and summer adults migrated northward to feed

to as far as central Vancouver Island (and as far as Queen Charlotte Sound in some years). In the fall, adults migrated southward toward spawning grounds. Since the early 1990s a percentage of the offshore stock has remained off the west coast of Canada year round and some Pacific hake have been observed spawning off the west coast of Vancouver Island (McFarlane et al. 2000). Recent research shows a link between Pacific hake distribution and the California Current System (Agostini et al. 2006).

Resident Pacific hake in Puget Sound spawn in Port Susan (Pedersen 1985) and Dabob Bay (Bailey and Yen 1983) from February through April, although Dabob Bay has never supported a fishery. The SOG resident stock aggregates to spawn in the deep basins of the south-central Strait of Georgia where peak spawning occurs from March to May (Shaw et al. 1990).

Pacific hake may spawn more than once per season, so absolute fecundity is difficult to determine. Historically, inshore female Pacific hake matured at 15 inches (37 cm) and 4 to 5 years of age. Currently, length at 50% maturity for females in the Port Susan Pacific hake population is



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approximately 8.5 inches (21.5 cm), compared to 11.7 inches (29.8 cm) in the 1980s. Females of the offshore stock mature at 3 to 4 years of age and 13.4 to 15.75 inches (34-40 cm) and nearly all males are mature by age 3 and as small as 11 inches (28 cm). By age 3, most offshore Pacific hake become available to the mid-water trawl fishery, although Pacific hake between ages 6 and 11 are most commonly caught.

### Rationale for “Species of Concern” Listing:

#### ***Demographic and Genetic Diversity Concerns:***

The biomass of Pacific hake in Port Susan during the spawning period has declined by 85% over the past 15 years, yet numbers have fluctuated around 30 million fish until dropping to less than 11 million in 2000. Over the same period, size composition and size-at-maturity for females have also decreased substantially. In contrast, significant declines in biomass, fish size, or maturity for Pacific hake populations in the Canadian portion of the SOG were not evident (Gustafson et al. 2000). Recently, however, the population biomass in the SOG has begun to decline, apparently a result of declining size-at-age of age 3+ hake, although population numbers of hake appear to be stable. Although Puget Sound Pacific hake are severely depressed, Strait of Georgia Pacific hake are estimated to be ten times as abundant, and are not believed to be at risk of extinction.

At the time of the 2000 status review that was convened in response to an ESA listing petition, the Biological Review Team (BRT) identified several areas of uncertainty regarding the relationship among stocks and effects of potential risk factors. The extent of any mixing of spawning products or spawners among stocks within the Georgia Basin is unknown. A majority of the BRT felt that significant population structuring may exist within this region and that up-to-date studies of the genetic analyses of spawning aggregations would be necessary to adequately define this structure. Information about population structure is also considered crucial to the BRT's decision concerning extinction risk for Pacific hake because its abundance in the SOG has not declined markedly over the past 15 years. Recent work by Iwamoto et al. (2004) confirms the genetic discreteness of these three stocks.

#### ***Factors for Decline:***

**Overfishing**. Historically, spawning Pacific hake in Port Susan were likely **overfished**. Risk factors are also poorly known and for the most part, the BRT could only speculate on potential factors and their effects. A subsequent effort to age Pacific hake collected in 1986 and 1999 from otolith (ear bone) samples showed a much reduced abundance of older hake in the 1999 sample compared to 1986 and a large reduction in length-at-age for both males and females from 1986 to 1999. Mean age decreased from six years in 1986 to three years in 1999 and the length of five to seven year old hake decreased from 15.4 inches (39 cm) in 1986 to 11.4 inches (29 cm) in 1999. These data are consistent with reduced growth and the known decline in age-at-maturity (Gustafson et al. 2000). These demographic changes appear to be due to some basin-scale environmental stressor. The reduction in length at age may make hake more vulnerable to predation if larger hake are better able to avoid predation.



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## Status Reviews/Research Underway:

NMFS conducted a status review (Gustafson et al. 2000) and determined that the species did not warrant listing (65 FR 70514, November 24, 2000). However, concerns and uncertainties still remain, and therefore, NMFS retained this species on the species of concern list.

NMFS is presently examining population structure among geographically discrete and temporally persistent spawning aggregations of Pacific hake in Puget Sound, the Strait of Georgia, and off southern California (Figure 1) using allozyme electrophoresis (Iwamoto et al. 2004), and microsatellite DNA markers. Spawning Pacific hake were sampled from Port Susan in Puget Sound in 2000, 2001, and 2002; the Canadian portion of the Strait of Georgia in 2000 and 2002; and off southern California in 2001. Unfortunately, because of budget concerns WDFW no longer conducts annual spawning abundance surveys of the Port Susan population and more recent samples have not been available. Results of allozyme studies (Iwamoto et al. 2004) indicate that within-population temporal samples are not significantly different from one another, but statistically significant differences were detected at 15 of 29 polymorphic loci ( $p < 0.05$ ) among the three populations. In addition, the two Georgia Basin populations (Port Susan and Strait of Georgia) were significantly different at six loci. Results of the allozyme analysis suggest a high degree of demographic isolation among all three populations (Figure 2).

To date, the above Pacific hake samples (Figure 1) have been screened at six polymorphic microsatellite loci developed specifically for Pacific hake. The number of alleles per locus ranges from 30 to 63 for these six loci. Analysis of microsatellite DNA data is ongoing.

Figure 1. Known or suspected spawning locations (shaded) and collection locations (numbers) for Pacific hake in Puget Sound and Strait of Georgia. Color coded sample numbers correspond to allozyme data illustrated in Figure 2. The solid line encompasses the approximate boundaries of the 'Georgia Basin Pacific hake Distinct Population Segment'.

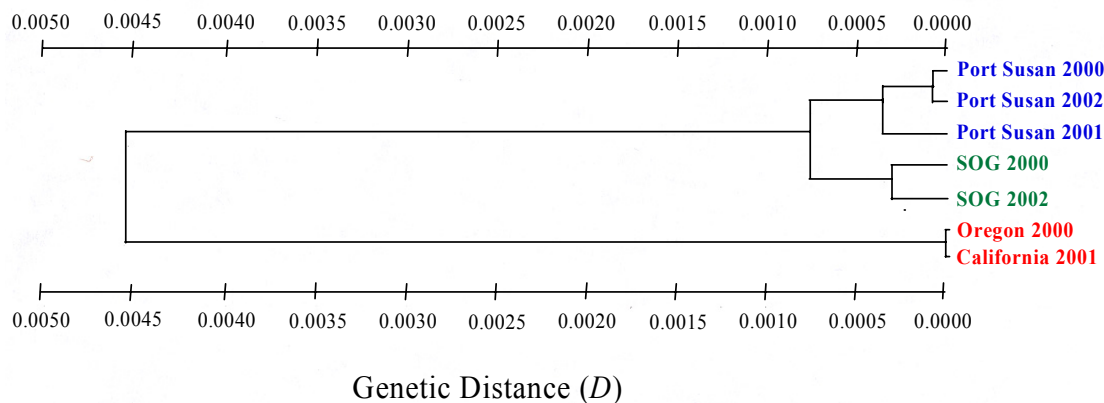
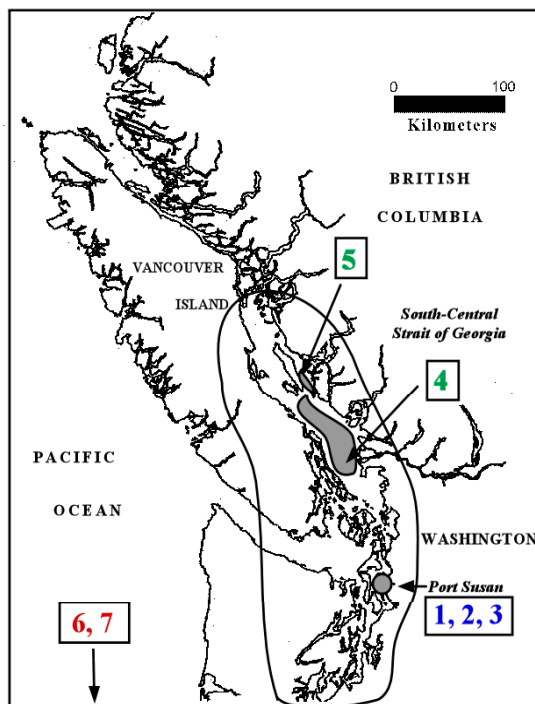


Figure 2. UPGMA tree of relationships among Pacific hake allozyme samples, based on Nei's (1978) genetic distances ( $D$ ).



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NMFs scientist Rick Zabel and collaborators are using otolith microchemistry and growth rings to examine population structure and growth issues between Puget Sound and Strait of Georgia areas.

### Data Deficiencies:

### Existing Protections and Conservation Actions:

Pacific hake from Central Puget Sound are a Washington State Candidate Species. The recreational fishery for Puget Sound Pacific hake is closed and there has been no directed commercial fishery on Puget Sound Pacific hake since 1991.

### References:

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### Point(s) of contact for questions or further information:

For further information on this Species of Concern, or on the Species of Concern Program in general, please contact NMFS, Office of Protected Resources, 1315 East West Highway, Silver Spring, MD 20910, (301) 713-1401, [soc.list@noaa.gov](mailto:soc.list@noaa.gov); <http://www.nmfs.noaa.gov/pr/species/concern/>, or Dr. Rick Gustafson, NMFS, Northwest Fisheries Science Center, 2725 Montlake Blvd. East, Seattle, WA 98112-2097, (206) 860-3372, [Rick.Gustafson@noaa.gov](mailto:Rick.Gustafson@noaa.gov); or Dr. Scott Rumsey, NMFS, Northwest Region, Protected Resources Division, 1201 NE Lloyd Blvd, #1100, Portland, OR 97232, (503) 872-2791, [Scott.Rumsey@noaa.gov](mailto:Scott.Rumsey@noaa.gov).