What is the PCFG? A review of available information

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ABSTRACT

The majority of Eastern North Pacific gray whales migrate north in the spring to feeding grounds in the Bering, Chukchi, and Beaufort seas. However, each year some smaller portion of the population spends part (or all) of the feeding season farther south, between California and the Alaskan Peninsula. A number of whales which have been catalogued in these areas have shown inter-annual fidelity to foraging grounds between 41N and 52N in the summer and fall. These animals have come to be known collectively as the Pacific Coast Feeding Group (PCFG). The current estimate of abundance for the PCFG -- based on mark-recapture analyses of available photo-ID data -- is approximately 200 individuals. Here we summarize knowledge on the range, behaviors, food habits, and known history of PCFG whales. The objective of this paper is to summarize and offer interpretations of the current state of knowledge of the PCFG; much of this information is available in SC/62/BRG32 (Calambokidis *et al.* 2010). We also summarize past studies on genetic structure and respond to conclusions of Frasier *et al.* (2010) and Lang *et al.* (2011). While mtDNA results show statistically significant differences between the PCFG and various reference gray whale populations, there are caveats to interpretation such as high genetic diversity of the PCFG, haplotypes of the PCFG being in other sampling areas, questionable reference populations for comparison, and photographic evidence of annual immigration from outside the PCFG. We conclude by encouraging caution in the interpretation of the genetics, range, abundance, and recruitment of this feeding aggregation and how it impacts the proposed Makah hunt.

KEYWORDS: GRAY WHALE; PACIFIC COAST FEEDING GROUP; FEEDING GROUNDS; ABUNDANCE ESTIMATE; GENETICS; MOVEMENTS

INTRODUCTION

During the current Implementation Review for eastern North Pacific gray whales, the Scientific Committee is responsible for assessing the Makah Tribe's proposed hunt off northern Washington, USA (see MTC 2011(AWMP6) for details of the proposed hunt). The hunt has been designed with the goal of protecting animals which are known to preferentially spend the feeding season in an area which has been roughly defined as between northern California and British Columbia/SE Alaska. These animals have come to be known as the Pacific Coast Feeding Group (PCFG; IWC 2010). While the proposed hunt has management measures to protect PCFG whales (e.g., no whaling during the summer feeding season), it is recognized that some takes may still occur (MTC 2011).

A central question in the assessment of the proposed Makah hunt is, "What is the PCFG?" We provide a review here of available information pertinent to this question. This review will include basic information such as the past and current definitions of the PCFG, the range of the PCFG, food habits of whales in the PCFG, behaviors of the

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PCFG, population dynamics and the known, or speculated, history of the PCFG. We will also present a review of genetic studies with a focus on Lang *et al.* (2011) in context of the summarized information on the PCFG.

DEFINITION AND RANGE

Definition of the PCFG

US domestic policy defines the PCFG as gray whales observed between 1 June and 30 November from Northern California through Northern British Columbia (recognized as the Pacific Coast Feeding Aggregation by the US). The IWC has refined this definition to a new working definition: PCFG whales are gray whales observed between 1 June and 30 November from 41°N to 52°N in two or more years.

Range

The definition of range for the PCFG has changed through time. Darling (1984) studied gray whales around Vancouver Island, British Columbia and hypothesized that whales of Vancouver Island were a unique group but whales showing low fidelity to the area might belong to a larger northwest coast population. Based on expanded field effort from California to Southeast Alaska, Calambokidis *et al.* (2002) defined the range of the PCFG as at least Northern California through Southeast Alaska. In 2004 the range was reported as Oregon to Northern British Columbia (Calambokidis *et al.* 2004) based on low survey effort and low observed rates of interchange for Southern and Central California and for Southeast Alaska with the "core range" of Northern Washington and Southern Vancouver Island. During the IWC intercessional meeting, data on the interchange of gray whales from the Makah Usual and Accustomed fishing grounds (U&A; see Scordino *et al.* 2011) and Southern Vancouver Island and survey areas to the north and south was assessed to create a definition of the range of the PCFG as 41°N to 52°N (Calambokidis *et al.* 2010; IWC 2011). Whales within this range not included as PCFG whales are whales observed in the spring and early summer in Puget Sound due to their low rate of interchange with the rest of the PCFG.

Gray whales have typically been recorded in nearshore environments in waters less than 20 meters during summer and fall feeding within the range of the PCFG (Darling *et al.* 1998; Calambokidis *et al.* 2008). Survey efforts are focused to this environment due to this documented distribution. In 2007, gray whales were observed and photographed 19 kilometers offshore Central Washington during surveys for the US Navy (Calambokidis *et al.* 2008). The offshore sightings represented one third of all individual gray whales seen in the PCFG during 2007 (Calambokidis *et al.* 2008). Shifts in distribution from the nearshore environment to offshore have also been documented in Western gray whales (Vladimirov *et al*. 2008). Because annual survey effort has traditionally been low or non-existent offshore, it is unknown how often PCFG whales forage offshore and where offshore foraging occurs.

Therefore, it may be that the PCFG utilizes a wider range than that defined by current survey effort. Analysis of gray whale data collected from Northern California to Northern British Columbia using open population models demonstrates lack of geographic and demographic closure (Calambokidis *et al.* 2004). Likewise, gray whales are known to feed in Southern and Central California to the south of the defined range

(Calambokidis *et al.* 2004) and in Southeast Alaska through the Alaska Peninsula to the north of the IWC defined PCFG range during summer and fall months (Calambokidis *et al.* 2004; Gosho *et al.* 2011).

To date there has been much less effort and data collection (e.g. photographs) on the periphery of the IWC defined PCFG range than within the putative range. Survey effort over a wider area will be needed to better understand the full extent of the feeding areas utilized by PCFG whales. Indeed, available evidence suggests that this range is probably larger than currently defined. For example, Gosho *et al.* (2011) found that 17.5% of gray whales photographed during surveys at Kodiak Island matched to whales in the Cascadia Research Collective catalogue of whales in the PCFG. Further, if Kodiak Island was included as part of the PCFG range it could significantly increase population estimates of the PCFG; Moore *et al.* (2007) estimated 350-400 gray whales utilize the Kodiak Island feeding area although recent estimates have fluctuated annually and are closer to 100-200 gray whales (Witteveen personal communication).

BEHAVIOUR AND MOVEMENT

Food Habits

Food habits of PCFG gray whales are best described and documented around Vancouver Island, Canada. PCFG gray whales in this area have been observed to shift between feeding on benthic, epi-benthic, and pelagic prey within and between years (Darling *et al.* 1998; Dunham and Duffus, 2001; 2002). These food habits are in contrast to the generally accepted pattern of targeting benthic prey (believed to be primarily ampelecid amphipods) in the Bering, Chukchi, and Beaufort seas (Nerini, 1984; Moore *et al.* 2007). Published food habits of PCFG whales are listed in Table 1.

Population behaviors

Both photo-identification work and satellite telemetry show that PCFG whales exhibit high variability in the location of areas visited and number of areas frequented (Mate *et al.* 2010; Calambokidis *et al.* 2010). Calambokidis *et al.* (2010) used the 75% inter quantile of gray whale sighting locations (for whales seen greater than six times) to describe the primary range of individuals. They found the length of the inter quantile exceeded 60 nautical miles (111 km) for 40% of individuals and exceeded 180 nautical miles (333 km) for 15% of individuals (Calambokidis *et al.* 2010). This result is supported by satellite telemetry findings which showed that some individuals remained in the area they were tagged throughout the feeding season, or until tags fell off, while others used feeding areas from California through Vancouver Island in a single feeding season (Mate *et al.* 2010). Additionally, one individual fed in Southeast Alaska (north of the defined PCFG range) in the spring following tagging (Mate personal communication), while one satellite tagged whale did not migrate south to Baja and continued to feed through the winter at Pt. Saint George, CA (Mate *et al.* 2010). Figure 7 from Calambokidis *et al.* (2010) shows the spatial distribution of the primary range of individual PCFG whales latitudinally (Figure 7 is included in Tables and Figures).

Satellite tagged gray whales showed interesting patterns of locating and accessing food resources. Some whales were observed to transit past known feeding areas at speeds similar to migration before stopping to feed (Mate *et al.* 2010). This finding suggests that gray whales may have knowledge/memory of feeding areas. The other pattern of interest was the observation of satellite tagged whales which congregated in Northern California in an area of dense forage. Nine of ten satellite tagged whales were seen foraging off Pt. Saint George, California (Mate *et al.* 2010). It is not known how all of the satellite tagged whales found the same feeding area but it is noteworthy because dense feeding aggregations of gray whales are often found in discrete times and areas (Calambokidis *et al.* 2008; Scordino *et al.* 2011).

Behaviorally there are two categories of whales seen in the PCFG survey area. Many of the whales return with some level of fidelity and are recognized as part of the PCFG whereas others appear to be "stragglers" from the main migration and are only seen in the PCFG survey area during a single year (Calambokidis *et al.* 2004; Calambokidis *et al.* 2010). However, some "stragglers" appear to recruit into the PCFG; the probability of a whale recruiting into the PCFG increases with the number of days the whale is seen in the PCFG during its first year seen (Calambokidis *et al.* 2010). It may be that a "straggler" that is successful during its initial foraging exploration of an area is more likely to return and forage in subsequent years. Roughly half of new whales seen in a given year are seen in subsequent years both throughout the PCFG range (IWC 2011) and on finer spatial scales (Calambokidis *et al.* 2010; Scordino *et al.* 2011).

POPULATION DYNAMICS AND HISTORY

Population Dynamics

The earliest estimate we could find for PCFG abundance was from Darling (1984) who estimated approximately 100 whales in Oregon-Washington-British Columbia. This estimate was based on aerial and boat surveys in British Columbia and Washington, combined with an estimate of population size from Bruce Mate in Oregon. The earliest mark-recapture analysis used Lincoln-Peterson estimators and estimated an abundance of 181 and 179 when 1998 was compared to 1996 and 1997 (Calambokidis *et al.* 2002). More recently, Calambokidis *et al.* (2010) computed a time series (1998-2008) of abundance estimates for the PCFG using both closed and open population estimators. Time series from both open and closed population estimators had relatively constant abundance estimates of around 200 whales (Calambokidis *et al.* 2010).

Each year new whales are observed in the PCFG. Open population models in Calambokidis *et al.* (2010) documented high annual survival and an average of 10.1 new whales per year in a subarea of the PCFG range (the Makah U&A and Southern Vancouver Island). Further examination showed an average of 17 new gray whales per year in the PCFG range which were seen again in subsequent years (Annex E; IWC 2011).

Noting the apparent inconsistency of high survival rates, relatively high rates of discovery of new animals yet stable abundance estimates, Jeff Laake recently revisited the analysis and reported new population estimates available as Annex E of the IWC AWMP intercessional meeting report (IWC 2011). The open population estimate approach taken by Calambokidis *et al.* (2010) models the minimum tenure in the first year a whale is observed to inform first year survival rates. This approach allows “stragglers” which have not been observed in subsequent years to count towards the estimated abundance of the PCFG. The revised time series of abundance estimates removes stragglers altogether, including the year they were first observed, and thus assumes that only those whales that are seen in multiple years are part of the PCFG.

Population estimates in Calambokidis *et al.* (2010 included a large number of whales seen in only one year during 1999-2000. By re-defining the abundance estimates to include only whales seen in more than one year, the time series of abundance estimates consistent with the recruitment of new whales that returned during later years. In practice, the two series of abundance estimates measure different quantities. The series in Calambokidis *et al*. (2010) is an estimate of whales "using" the area in each year and the sequence in Annex E measures the whales that use the area in at least 2 years. Neither really truly matches perfectly the dynamic nature of the whale’s usage nor the assumptions for the estimation model.

This new time series indicates that the population of PCFG whales seen in multiple years increased drastically between 1998 and 2002. After 2002, the time series is similar to that of Calambokidis *et al.* (2010) and has remained constant at around 200 (Figure 1). If the latest time series is accurate (the increasing abundance is inconsistent with results from past estimation methodologies), it would indicate an average annual recruitment of 25.8 new whales into the PCFG between 1999 and 2002. This rate of increase is very unlikely to come from calf production alone given the estimated abundance of the PCFG and the very low observed calving rates for eastern gray whales during those years (Perryman *et al*., 2011). Indeed, during preliminary attempts at conditioning the trials, it was found that a standard density dependent population dynamics model could not mimic the trends in the more recent time series of PCFG abundance estimates. Part of the observed dynamics may be due to the “discovery” of new whales in the PCFG which were already members of the PCFG. Or it might have also been associated with a relatively large pulse of immigration associated with the mortality event during 1999-2000.

The recent estimation approach assumes that all PCFG whales were sighted if they are in the PCFG range from 1 June to 30 November. However, given the limitations on survey effort mentioned above (i.e., less effort in offshore or more remote areas) this assumption deserves further consideration. If it is not met because PCFG whales are feeding in areas that are either poorly or not sampled, the abundance estimates for PCFG whales seen in greater than one year would be biased low.

History

Gray whales have been documented feeding along the Pacific Ocean coastline during the months between June and November throughout the 20th and 21st centuries. Pike (1962) was the first researcher to document the occurrence of PCFG whales in a publication when he described whales feeding in British Columbia. Gray whales were also noted feeding in the summer and fall in the 1970s in California (Sullivan *et al*. 1983), Oregon (Herzig and Mate, 1984; Sumich, 1984), Washington (Rice and Wolman, 1971), and British Columbia (Hatler and Darling 1978; Darling, 1984). In 1926 a gray whale was landed at the Trinidad, California whaling station. This whale was observed to have eaten "shrimp" and was likely a PCFG whale (Clapham *et al.* 1997).

Whether or not this feeding group existed prior to the 20th century is harder to determine. In studying the Makah Tribe, Swan (1870) noted that "December is called the se-whow-put-hl, or moon in which the se-whow, or chet-a-pook, the California gray whale makes its appearance". Curtis (1911) described the Makah's ceremonial traditions of whaling lasting "from October through the end of the whaling season… about the end of June". Ancient gray whale bones from Makah and Quileute middens found Nitrogen 15 and Carbon 13 were not statistically different than gray whale bones collected at the Richmond, California whaling station in the 1960s suggesting that gray whales collected locally in Washington in the past had similar feeding ecology to present day migrating whales (Alter 2008). Based on this finding Alter (2008) concluded that there was not a unique feeding group around the Olympic Peninsula in the past. Together these citations support the hypothesis that the PCFG is a recently founded group.

However, Swan (1870) noted that Makah whalers are more successful whaling in some seasons than others. His statement leaves open the possibility that the Makah were harvesting in the summer and fall feeding season. Commercial whaling practices were shown to change the distribution of humpback whales further offshore (Clapham *et al.* 1997); commercial whaling may have likewise impacted the distribution and abundance of the PCFG by the mid-19th century making Swan's observations of traditional Makah whaling practices misleading for summer and fall months. The stable isotope finding from Alter (2008) may be in error, based on data in table 4.5 a t-test does show that Carbon-13 is significantly larger for samples from ancient whaling than from samples from the California whaling station (-12.156 and -12.938 respectively; two tailed $p = 0.00372$) which may suggest that the Makah and Quileute were harvesting locally feeding whales. Nitrogen-15 values did not have statistically significant differences. Nevertheless, the sample size in Alter (2008) is small (16 ancient samples and 11 from California whaling station) and any conclusion should be viewed conservatively. Last we need to note that genetic uniqueness of a population takes many years to develop, especially when immigration is occurring from a larger population, and small, but statistically significant differences in mtDNA haplotypes were observed between the PCFG and representative samples of the larger population (Frasier *et al.* 2010; Lang *et al.* 2011).

GENETICS

Darling (1984) hypothesized that gray whales feeding in the waters off of Vancouver Island were a unique population due to observations of strong fidelity to the region. Interest in the population structure of PCFG gray whales increased drastically in 1994 when the US delisted the gray whale from the Endangered Species Act and the Makah Tribe announced its intention to resume traditional whaling practices on the recovered population.

In 1995 and 1996 biopsy samples were collected around Vancouver Island with the intention of testing if PCFG whales are a separate stock from the greater Eastern North Pacific population (Steeves *et al.* 1998). Fourteen samples collected from Vancouver Island were compared to 41 samples collected from whales either migrating in California or feeding in the Bering Sea (Steeves *et al.* 1998). The study failed to reject the null hypothesis of panmixia (p>0.51) (Steeves *et al.* 1998). This result could have been influenced by small sample size or because the reference population contained PCFG whales (Calambokidis *et al.* (2010) found around 20% of whales photographed in migration off Washington are PCFG whales).

In 2001, simulations were conducted to determine if mitochondrial DNA (mtDNA) could be used to determine the population history of PCFG whales (Ramakrishnan and Taylor, 2001). Ramakrishnan and Taylor (2001) noted that there are three possible population histories of PCFG whales, either 1) they are panmictic with the rest of the ENP, 2) they are a separate stock with significantly different mtDNA haplotype frequencies, or 3) there is limited immigration occurring to the PCFG from the larger ENP. The simulations only tested the first two possibilities. The simulations show that a single founding event (or re-colonization) in the last century would result in genetic differentiation 97.8% of the time between the northern feeding areas and the PCFG.

Ramakrishnan *et al.* (2001) used the results of the simulation of Ramakrishnan and Taylor (2001) to test if if the level of mtDNA diversity in 45 samples from the PCFG was consistent with single founding event scenario. They concluded the PCFG is not from a single founding event. In discussion, Ramakrishnan *et al.* (2001) left open the possibility that immigration into the PCFG is occurring from northern feeding grounds and suggested future studies to assess internal versus external recruitment.

Frasier *et al.* (2010) presented to the IWC a comparison of mtDNA frequencies of 53 whales sampled around Vancouver Island and 83 samples of gray whales at the breeding lagoons which were sequenced by Goerlitz *et al.* (2003). Frasier *et al.* (2010) found small but statistically significant differences in haplotype frequencies (Fst=0.0189, p=0.00090; Φst=0.01688, p=0.0030). The analysis had potential shortcomings of statistical evaluation error, a small sampling area in comparison with the range of the PCFG, possibly an inappropriate reference population, and lack of microsatellite evaluation to determine if double sampling occurred.

The study was reanalyzed using 40 samples from Vancouver Island (some samples were removed because they sampled outside the IWC defined PCFG season and others due to duplication based on analysis of photographs) compared to 120 samples from whales who died during the 1999/2000 mortality event, from subsistence take whales, and from some live biopsy sampling (LeDuc *et al.* 2002). Frasier *et al.* (*in press*) again found small but statistically significant differences in haplotype frequencies (Fst = 0.0616, P < 0.001; Φst = 0.0423, P = 0.00587). The authors addressed most of the concerns raised by the IWC but did not conduct microsatellite analysis and could not change the sampling regime from which their samples were collected.

In 2010, a new genetics study was conducted on PCFG gray whales to determine if the results of Frasier *et al.* (2010) could be duplicated with a larger sample size collected from a larger portion of the range of the PCFG compared to samples collected from whales foraging in northern feeding grounds. This study analyzed mtDNA as well as eight microsatellites to ensure no duplicate samples were included in the analysis and to test for potential reproductive isolation (Lang *et al.* 2011). The study was designed to test certain stock structure hypotheses specifically related to whether or not a pattern of genetic differentiation was present to indicate the PCFG is a demographically independent unit. This would qualify as a stock under the definition of the National Marine Fisheries Service and thus qualify for protection under the US Marine Mammal Protection Act.

The results of Lang *et al.* (2011) are consistent with the previous findings of mtDNA differentiation of the PCFG (Frasier *et al.* 2010). Slight but statistically significant mtDNA differentiation was found when PCFG whales were compared to whales taken from northern feeding areas, as well as when they were compared to a subset of northern whales taken in the native harvest at Chukotka. Also of importance is the observation that high levels of haplotype and nucleotide diversity are present in all areas sampled. However, no statistically significant differences were observed in any comparisons using the biparentally inherited microsatellites.

Notwithstanding the conclusion of Lang *et al.* (2011) that the PCFG is demographically independent (and hence a recognizable stock), there are important gaps in our understanding of gray whale biology that prevent a clear understanding of the status of this group of whales. Chief among these is uncertainty as to the overall pattern of mtDNA subdivision in Eastern Pacific gray whales. It is clear from the genetic studies that haplotype diversity is high in this species, and that nearly every population comparison yet made has yielded statistically different haplotype frequencies. For example, comparisons of both the northern feeding group and the southern feeding group from Lang *et al.* (2011) to the lagoons reported by Goerlitz *et al.* (2003) both yielded significant haplotype frequency differences (data not shown), as did a comparison of the lagoons to the PCFG whales reported by Frasier *et al.* (2010) (data not shown). The problem stems from having a genetically diverse and very large population and making comparisons among selected groups with small sample sizes. The degree to which small samples, such as those taken from the lagoons by Goerlitz *et al.* (2003), or the northern feeding group by Lang *et al.* (2011), or the samples from LeDuc *et al.* (2002) which were mostly migratory whales, are representative of the very large population of the northern feeding area or the overall eastern Pacific gray whale population is questionable. Until we have adequate samples from the very large range of this population questions will remain as to the meaning of the patterns we have observed.

Lang *et al.* (2011) conclude "The low level of differentiation identified, as well as the high diversity found in the PCFG strata, may indicate relatively recent colonization of the PCFG but is also consistent with a scenario in which some low‐level external recruitment into the PCFG may occur." It is important to emphasize that the PCFG is not a genetically defined population, rather an assemblage of individuals with a learned behavior passed down from mother to offspring. The only relationship to genetics is the fortuitous one of mtDNA having strict maternal inheritance and thus tracking the learned behavior. One possible explanation for the observed evidence of genetic subdivision of mtDNA is that the founding females did not represent a random draw of the overall population (or at least of the reference samples that have been used in the genetic studies). Another possibility is that genetic drift has played a role in subsequent differentiation of the small PCFG. A third possibility is that the original founding females were a random draw from the population, but the continued return of their offspring increased the frequencies of those haplotypes, resulting in the accrual of differences from the larger population. The phylogenetic analyses of the mtDNA haplotypes by Frasier *et al.* (2010, *in press*) and Lang *et al.* (2011) clearly show that the PCFG is not made up of a monophyletic maternal lineage. In fact, most of the PCFG haplotypes are also known from other feeding areas. Thus, another key issue to determine the conservation status of the PCFG is the degree to which recruitment is internal or external. If recruitment is mostly internal, then the PCFG does indeed represent a demographically independent assemblage of potentially high conservation significance. Clapham *et al.* (1998) have discussed the importance of conserving such cultural diversity and its implications for the possible lack of recovery of some whale populations from over-hunting.

CONCLUSION

The PCFG has been researched rather thoroughly over the last 30 years; this summary of the PCFG would not be possible without the great work of scientists throughout the years. Despite this thorough research we are still learning about the PCFG and our definitions and understanding of PCFG population dynamics, behaviors, and genetic structure of the group have recently changed (Calambokidis *et al.* 2010; Mate *et al.* 2010; Frasier *et al.* 2010, *in press*; Lang *et al.* 2011; IWC 2011). We recognize that it is plausiblethat the PCFG is demographically distinct and thus a separate stock from the overall Eastern North Pacific population of gray whales. However, we encourage the Scientific Committee to recognize that more studies are needed to resolve the inconsistencies observed in photo-documentation of recruitment into the PCFG and the observed statistical differences in haplotype frequencies of mtDNA for the PCFG and sample sets thought to be representative of the ENP population. We conclude by encouraging caution in the interpretation of the genetics, range, abundance, and recruitment of this feeding aggregation and how it impacts the proposed Makah hunt.

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Table 1: Published food habits of gray whales of the PCFG. This is not an exhaustive list but rather a summary of available publications.

Prey Item	Area	Study
Mysids	Vancouver Island, Oregon	Oliver *et al*. 1984; Murison *et al.* 1984; Kim and Oliver, 1988; Darling *et al*. 1998; Dunham and Duffus, 2001; Newell, 2005
Ampeliscid amphipods	Vancouver Island	Oliver *et al*. 1984; Darling *et al*. 1998; Dunham and Duffus, 2001
Porcelain crab larvae	Vancouver Island	Dunham and Duffus, 2001
Herring eggs and larvae	Vancouver Island	Darling *et al*. 1998
Ghost shrimp	Puget Sound, Vancouver Island	Weitcamp *et al*. 1992; Duffus, 1996; Darling *et al*. 1998; Dunham and Duffus, 2001
Crab larvae (multiple spp.)	Vancouver Island, N. California	Duffus, 1996, Darling *et al*. 1998, Jenkinson, 2001
Cumacean (shrimp)	N. California, Kodiak Island	Jenkinson, 2001; Moore *et al.* 2007; Gosho *et al.* 2011
Mobile amphipods (*Atylus spp.)*	Vancouver Island, N. CA	Darling *et al*. 1998; Jenkinson, 2001
Bait Fish (herring, anchovy, sardine, sandlance)	Vancouver Island	Darling *et al.* 1998*
Polychaete worm	Vancouver Island, Puget Sound	Oliver *et al.* 1984; Weitkamp *et al.* 1992
Tube-dwelling amphipod	Northern California	Avery and Hawkinson, 1992
Euphausiid	Northern California	Howell and Huey, 1930; Jenkinson, 2001

* - Darling *et al.* noted highly suggestive but unconfirmed evidence of sandlance or needlefish predation by gray whales. There is also suggestive visual evidence of baitfish predation in Washington (Scordino unpublished data).

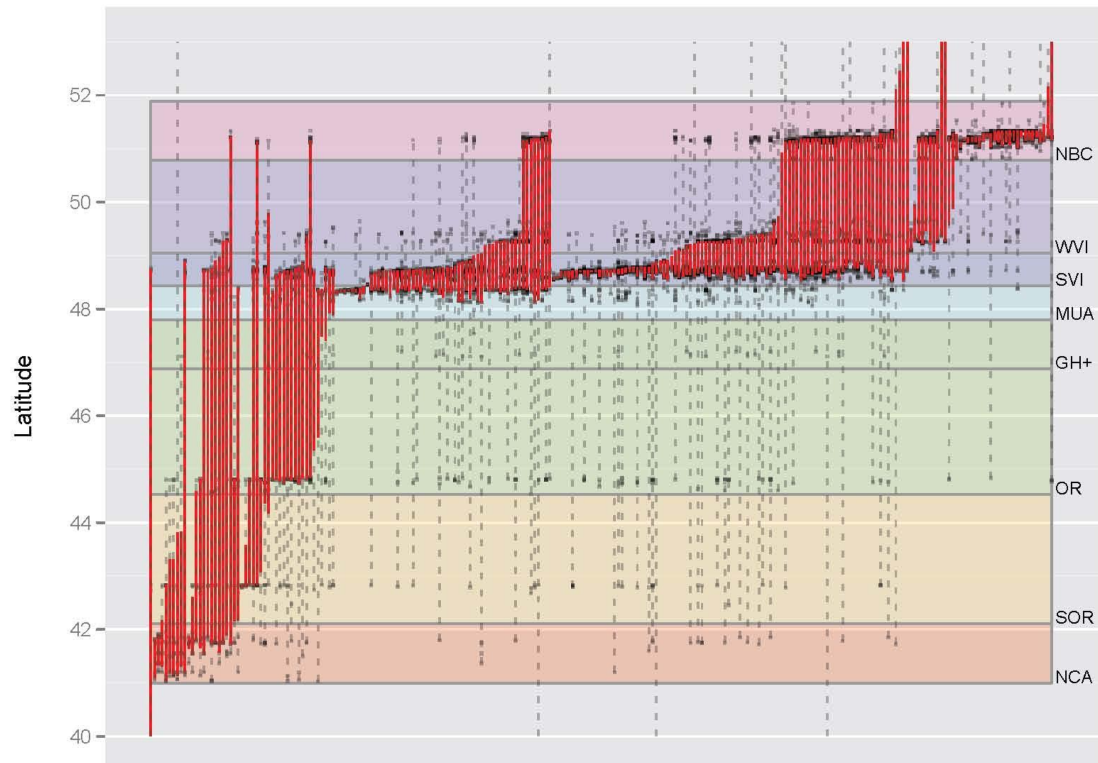

Figure 7: Distribution of latitudes of sightings (points) for whales with 6 or more sightings after 1 June from 1998-2008, the 75% inner quantile (solid thick line), and full range (light dashed line). Each position on the x axis represents an individual whale. Whales have been arranged on the plot by sorting first on the lower bound of the inner quantile (to a half-degree) and then the upper bound of the quantile. This has the effect of sorting from south to north and clusters whales with smaller quantile ranges followed by whales with larger ranges.

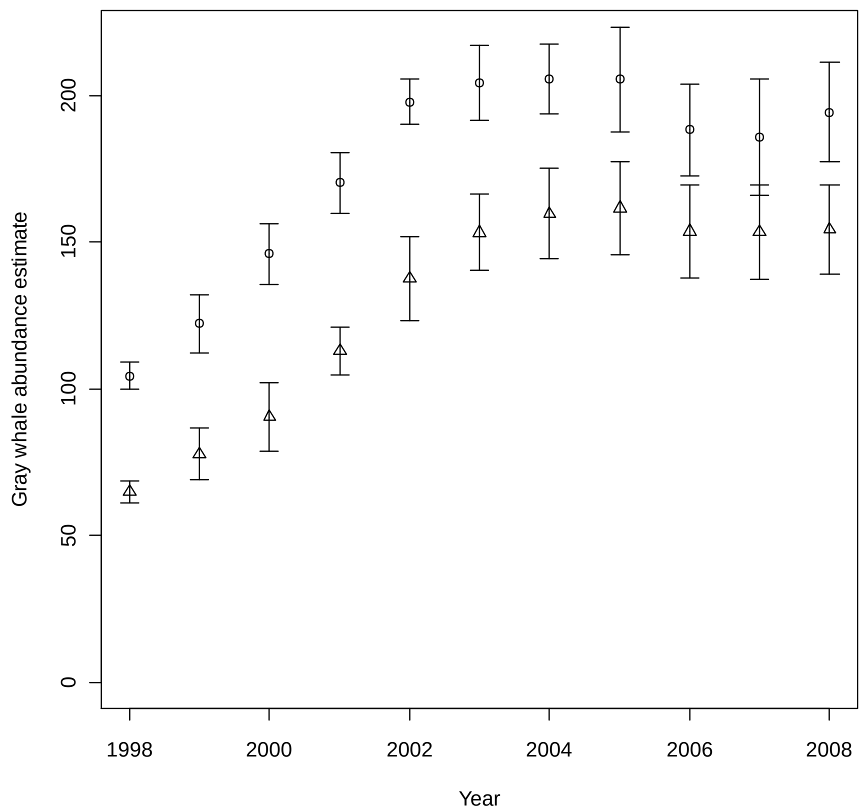

Figure 1 (Annex E; IWC 2011). Plot of PCFG (41-52N) (circle) and OR-SVI (42-49N) (triangle) abundance estimates from 1998-2008 with +/- 1 standard error bars.