Cetacean strandings in Oregon and Washington between 1930 and 2002

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ABSTRACT

The Northwest Region (NWR) Marine Mammal Stranding Network was created in the early 1980s to provide a consistent framework in which to collect and compile data about marine mammal strandings in Oregon and Washington. The NWR includes the nearshore waters and 4,243km (2,632 n.miles) of coastline. For the years 1930-2002, there were 904 stranding events, representing 951 individual animals and 23 species: 4 species of balaenopterids, 1 eschrichtiid, 2 physeterids, 4 ziphiids, 10 delphinids and 2 phocoenids. Gender was determined for 343 males and 266 females. Only one mass stranding was recorded (sperm whales: 1979). A few species comprised the majority (71%) of stranding events in the NWR: harbour porpoise (34%), gray whales (23%), Dall's porpoise (12%) and Pacific white-sided dolphins (4%). There was a steep increase (511%) in the number of stranding reports beginning in the 1980s with over 86% of all records occurring during the last two decades (1980s and 1990s). The general trend of increased reported strandings during the last two decades corresponds to the formation of a formal stranding network and a heightened interest and dedication by the public and government agencies in reporting and documenting strandings. For all events combined, the primary stranding peak was April-July. Since stranding recoveries depend heavily on reports from the general public, most stranding records were in summer when more people are present along the coastline. Individual species or species groups showed varying levels of conformity to this overall seasonal trend. The value and limitations of the use of strandings data in a management context are discussed.

KEYWORDS: CETACEANS; STRANDINGS; DISTRIBUTION; OCEANOGRAPHY; GRAY WHALE; HARBOUR PORPOISE; DALL'S PORPOISE; WHITE-SIDED DOLPHIN; TRENDS; HABITAT; NORTH PACIFIC; SPERM WHALE; NORTH AMERICA

INTRODUCTION

A systematic effort to collect and compile data on marine mammal strandings in Oregon and Washington began with the formation of the Northwest Region (NWR) Marine Mammal Stranding Network in the early 1980s (1980-1981). The network is composed of volunteers based at academic institutions, state and federal wildlife and fisheries agencies, veterinary clinics, enforcement agencies and by individuals who respond to or provide professional advice on handling stranding events (Scordino, 1991). Stranding Network activities are coordinated by the National Marine Fisheries Service (NMFS), Marine Mammal Health and Stranding Response Program (MMHSRP)/Regional Coordinator based in Seattle, Washington, USA. Each stranding event is handled on a case-by-case basis because response capability varies between areas depending on available resources, personnel and logistics.

The NWR Stranding Network coverage area includes the nearshore waters and shoreline of Oregon and Washington north of 42°0'N and south of 49°0'N (the US/Canada border), including the inland waters of Washington State (Fig. 1). There are 3,767km (2,337 n.miles) of marine shoreline in Washington State and 476km (295 n.miles) of shoreline in Oregon.

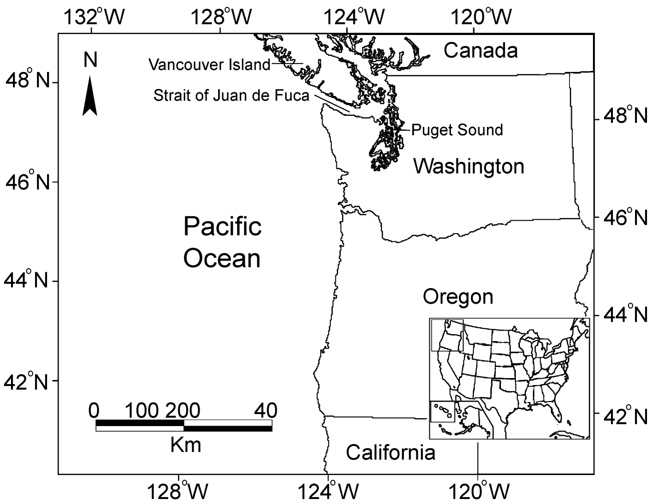

Fig. 1. Geographic area covered by the Northwest Region marine mammal stranding network.

The data collected from stranded cetaceans provide information on distribution, mortality and seasonal movements (e.g. Scheffer and Slipp, 1948; Fiscus and

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Niggol, 1965; Balcomb, 1980; Rice *et al*., 1986; Osborne and Ransom, 1988; Osborne *et al*., 1988; Ferrero and Tsunoda, 1989; Scordino, 1991; Ferrero *et al*., 1994). The entire cetacean stranding record for the NWR is summarised here, covering the years 1930 to 2002. Trends in stranding reports are analysed in relation to species composition and abundance, geographic and seasonal distribution, group size of stranded animals and gender. No attempts have been made to explain the cause of strandings except in general terms.

OCEANOGRAPHY OF THE NORTHWEST REGION

The influence of wind on carcass movement varies depending on carcass height above the water line, winds and water currents. In the NWR, winds are typically from the west/northwest during the summer and from the east/southeast during the winter. Wind transitions usually occur during April-May and October-November (Hickey, 1979). Cetacean carcass distribution can be influenced by these current and wind conditions, along with upwelling and downwelling. Coastal upwelling occurs most frequently in summer and fall when it is promoted by northerly and northwesterly winds. The upwelling season runs from April to October, with maximum intensity in July and August (Bakun, 1973), its effects extending to slope and offshore waters. Upwelling intensity is usually greatest along the southern Oregon coast and diminishes northward, although it can occur anywhere along the Oregon-Washington coast under favorable wind conditions. The Columbia River defines the coastal boundary between Oregon and Washington. Its effluent contributes to approximately 60% of the freshwater entering the Pacific Ocean between San Francisco and the Strait of Juan de Fuca in the winter, and up to greater than 90% in the remainder of the year, heavily influencing the oceanography of the area (Barnes *et al*., 1972).

The continental shelf (waters typically <200m deep) is less than 80km wide along the coast of Oregon and Washington. The continental slope (200-2,000m) is wider off Washington than Oregon (National Oceanic and Atmospheric Administration, 1988). There are a series of submarine canyons that transect the shelf and slope along the Washington coast but are absent off Oregon. Several rocky submarine banks occur off Oregon. The shelf between Washington and Vancouver Island is interrupted by the Strait of Juan de Fuca (National Oceanic and Atmospheric Administration, 1988).

McGowan (1974) describes the biogeography of the NWR as part of a transition zone, which includes the North Pacific and California currents where annual primary productivity is moderate, peaking in the late spring to early summer. Sea surface temperatures range from 13°-20°C in summer to 8°-17°C in winter (National Oceanic and Atmospheric Administration, 1988).

The oceanic current system in the NWR is comprised of the California Current, Davidson Current and California Undercurrent, and can vary interannually (Hickey, 1979). The California Current flows southerly beyond the continental shelf throughout the year, but is typically strongest during the summer (Hickey, 1979). In winter, this current moves offshore and is replaced by the northward flowing Davidson Current.

El Niño-Southern Oscillation (ENSO) events can influence sea surface temperature and current patterns in the NWR. Warm events of the equatorial Pacific Ocean generate significant sea surface temperature anomalies in North America (Aceituno, 1992; Bunkers *et al*., 1996; Hoerling and Kumar, 1997), which may lead to unusual distributions of cetacean species during years of abnormally warm water temperatures in the North Pacific (Osborne and Ransom, 1988; Ferrero and Tsunoda, 1989; Ferrero *et al*., 1994).

MATERIALS AND METHODS

Source of records and reporting effort

Records of cetaceans stranded alive or dead on the beach prior to 1989 were collected on an opportunistic basis and were not maintained in a computerised database. Records dating from 1989 have been maintained in a web-based database system at the National Marine Fisheries Service Marine Mammal Health and Stranding Response Program. Sources of records included unpublished reports provided by university and aquarium personnel, the general public, state and federal agencies and published reports. Reports prior to 1980 were accepted into this study only if the information provided allowed verification of species identification. Network volunteers responded to most ($n = 715$; 79%) of the total reported cetacean stranding events ($n = 904$) between 1930 and 2002.

The NWR stranding network often receives reports from the general public or US Coast Guard stating that a dolphin, porpoise or whale has been found stranded on the beach. A stranding network member may not have been able to respond to a report, but as much descriptive information as possible is obtained from the caller in an attempt to more specifically identify the animal. If the network member was not able to examine the animal at a later date, it was recorded as an ‘unknown’ odontocete, mysticete or cetacean.

Records of stranded cetaceans after 1980 came mostly from members of the NWR stranding network. Data included species, stranding date, location, length, body condition and gender. When species identification could be verified from non-network sources, it was included in this review. In instances when species could not be determined, regardless of source, the reports were tallied in one of several ‘Unknown’ categories based on the amount of information received. In this report, a stranding event is defined as one or more animals present on the beach at the same time and includes calves, but not foetuses. The last stranding included in this report took place on 5 November 2002. All data in this review are maintained at the NMFS Northwest Regional Office in Seattle. For all cetaceans that are physically examined, the only morphometric measurement requirement indicated on the NMFS stranding form is total straight length, which is measured from the tip of the snout to the fluke notch (if present) or centre of the trailing edge of the flukes (Norris, 1961). Individual responders do have established protocols for detailed measurements, as well as for tissue and skeletal sampling and archiving. However, these data and samples have been considered proprietary and to this point have been maintained by each individual responder. Contact information is available upon request through the NMFS Northwest Regional Office in Seattle.

RESULTS AND DISCUSSION

Factors affecting stranding frequency and distribution (other than the abundance and distribution of the animals themselves)

A number of authors have considered the possibilities and limitations of strandings information (e.g. Klinowska, 1985; IWC, 1986). It is possible that the proportions of species in the stranding record reflect the relative abundance of live animals of the species in the respective region (Sergeant, 1979; Woodhouse, 1991). For instance, most species that are relatively rare in the NWR are represented by a small number of strandings. However, strandings may also reflect nothing more than a general region of occurrence and may not be related to a specific habitat preference.

Strandings are highly dependent on physical oceanographic features that bring the carcass to shore. Currents and wind affect when and where (and if) an animal strands. Other environmental factors might influence carcass distribution: water temperature affecting decomposition rate, degree of buoyancy (e.g. some cetaceans might sink soon after death while others float) and biodegration/scavenging of the carcass before it reaches the shore. Animals may strand hundreds of kilometres from their normal range. The species that occur in the NWR frequently are either primarily cosmopolitan, or associated with the temperate/sub-Arctic, or mixed-water oceanographic regions (Rice, 1998). In the NWR, unusual distributions of cetacean species may be observed during years of abnormal influxes of warm water. This is most likely related to incursion of warm waters into this region, related to El Niño/El Niño-Southern Oscillation (ENSO) events, allowing some species to move temporarily into more northerly latitudes.

When an animal is found stranded, it must be determined whether it is a live (at least one animal alive when first observed) or dead (all animal(s) dead when first observed) stranding. It is important to try and determine if the animal arrived at the stranding location under its own power or if it died at sea and washed ashore with tides or currents (Klinowska, 1985). The vast majority of strandings in the NWR were dead strandings. Only 68 of 951 individuals were live-stranded and subsequently either died (n = 59) or were returned to the water (n = 9). In general, we conclude that the stranding of a cetacean in a certain area at a particular time does not necessarily mean that it is representative of live animal distribution or relative abundance.

Table 1

Species and occurrence of cetaceans stranded in Oregon (OR) and Washington (WA) from 1930-2002.

	Stranding events			Individuals stranded		
Species	Total	OR	WA	Male	Female	Unknown
Balaenopterid						
Blue whale	1	0	1	0	1	0
Fin whake	8	2	6	3	5	0
Humpback whale	6	4	2	2	1	3
Minke whale	21	7	14	8	8	5
Eschrichtiidae						
Gray whale	200	54	146	85	63	52
Physeteridae						
Sperm whale	18	7	11	21	33	4
Pygmy sperm whale	8	4	4	6	1	1
Ziphiidae						
Baird's beaked whale	4	0	4	0	2	2
Cuvier's beaked whale	17	13	4	9	2	6
Stejneger's beaked whale	13	7	6	5	4	4
Hubbs' beaked whale	2	1	1	0	1	1
Delphinidae						
Killer whale	16	9	7	8	5	6
False killer whale	3	1	2	2	0	1
Short-finned pilot whale	7	1	6	3	1	3
Risso's dolphin	9	4	5	5	1	3
Pacific white-sided dolphin	34	20	14	18	10	6
Bottlenose dolphin	1	0	1	1	0	0
Common dolphin	5	4	1	3	1	1
Rough-toothed dolphin	3	1	2	2	2	0
Striped dolphin	12	10	2	8	4	0
Northern right whale dolphin	8	4	4	2	3	3
Phocoenidae						
Harbour porpoise	303	162	141	105	93	108
Dall's porposise	107	14	93	44	25	38
Unknown species						
Unknown ziphiid spp.	5	5	0	3	0	2
Unknown odontocete	44	26	18	0	0	45
Unknown mysticete	1	1	0	0	0	1
Unknown cetacean	48	32	16	0	0	49
Total	**904**	**393**	**511**	**343**	**266**	**342**

Species

The total number of stranding events recorded for the NWR during 1930-2002 was 904, representing 23 species and 951 individuals (Table 1). In 7 events, more than 1 animal was involved. Although most were adequately identified, 97 animals could not be identified to species level. Four species of balaenopterids, 1 eschrichtiid, 2 physeterids, 4 ziphiids, 10 delphinids and 2 phocoenids stranded in the NWR. Four species comprised the majority (71%) of stranding events in the NWR: harbour porpoise, *Phocoena phocoena* (34% −Table 1; Fig. 2); gray whale, *Eschrichtius robustus* (23% −Table 1; Fig. 3); Dall's porpoise, *Phocoenoides dalli* (12% −Table 1; Fig. 4); and Pacific white-sided dolphin, *Lagenorhynchus obliquidens* (4% − Table 1; Fig. 5). Stranding events involving multiple animals occurred in four species: harbour porpoise, killer whale (*Orcinus orca*), rough-toothed dolphin and sperm whale (*Physeter macrocephalus*). Only the sperm whale had a mass stranding (47 individuals), whereas the remainder of the multiple strandings were of just two individuals.

Specific protocols for examinations and necropsies differ from examiner to examiner depending on the nature of the investigative inquiry, the experience of the examiner(s), the ultimate analysis envisioned for the samples collected, and the size or species involved. Measurements for total body length were recorded for 748 (79%) stranded individuals, however, 120 (16%) of these values were estimated lengths.

The most common balaenopterid stranding was of minke whales, *Balaenoptera acutorostrata* (Table 1; Fig. 6). Four humpback whales (*Megaptera novaeangliae)* stranded in Oregon, and two stranded in Washington. All of these strandings occurred on the outer coast, and in Oregon the strandings occurred in the mid-to southern half of the state. On the other hand, 3 of the 8 fin whales (*Balaenoptera physalus*) strandings in Washington occurred inside Puget Sound. These three fin whales had been struck by ships and were presumably carried into the Sound. Only one blue whale (*Balaenoptera musculus*) has stranded in the NWR. The death of this animal may also have been caused by a ship strike, as it was draped around the bow of a freighter. The strike was theorised to have occurred off California along the freighter's route. The animal was a 16.2m female and based on lengths at sexual and physical maturity of females (22.5m and 24.8m, respectively, for the North Pacific; Omura, 1955; Ohsumi, 1979), this animal was probably a subadult.

Killer whales (*Orcinus orca*) are widely distributed in the NWR in small numbers (Leatherwood and Dahlheim, 1978) and stranded infrequently. Populations in the NWR are divided into 2 distinct 'forms' called *resident* and *transient* (Baird and Stacey, 1988; Baird *et al*., 1992; Hoelzel *et al*., 1998; Ford *et al*., 2000). The residents can be further divided into 3 geographically-based communities: northern and southern residents and offshore whales, the latter two of which are found most commonly in NWR waters (Bigg *et*

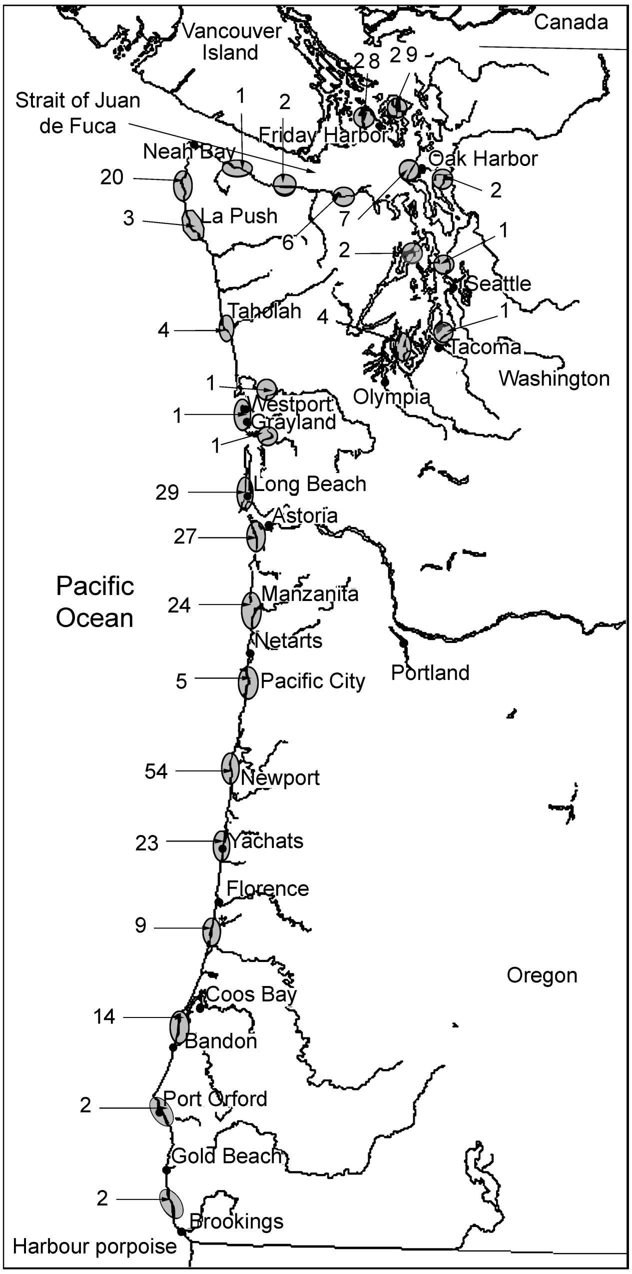

Fig. 2. Spatial distribution of stranded harbour porpoises in Oregon and Washington (1930-2002).

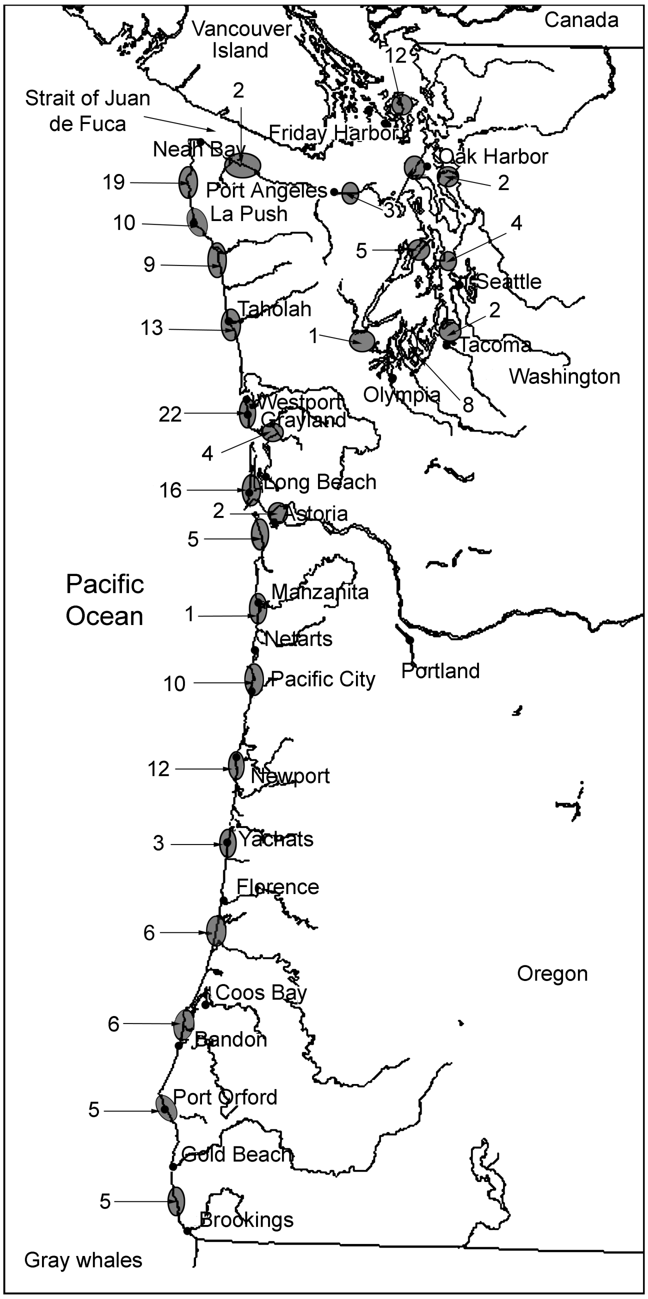

Fig. 3. Spatial distribution of stranded gray whales in Oregon and Washington (1930-2002).

al., 1987; Baird, 2001). Six of the 17 (35%) individual stranded killer whales were confirmed as southern residents (Osborne, 1999). Two of the individual stranded killer whales in Oregon were confirmed as transient (Stevens *et al*., 1989).

Five of the species that stranded in the NWR are considered rare inhabitants due to their normal preference for warm temperate and tropical waters: short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus* spp) and rough-toothed dolphin (*Steno bredanensis*). Most of their strandings events ($n = 13$) occurred during or within a year of an El Niño year(s) (Table 2). Their presence is thus considered extralimital rather than an extension of their range. Examples of unusual extralimital strandings in the NWR are bottlenose dolphins, common dolphins and rough-toothed dolphins (Osborne and Ransom, 1988; Ferrero and Tsunoda, 1989; Ferrero *et al*., 1994).

Reporting efficiency

There are strong geographical and seasonal biases in stranding reporting efficiency and effort. Whether cetacean strandings are recorded depends upon many factors including human activity and awareness, the physical environment and climate, and seasonal animal movements. Seasonal movements of animals into the NWR do account for the rise in strandings of some species as do an increased number of visitors to coastlines during these same months, leading to more frequent reporting. Strandings in the NWR were recorded most frequently in regions with high human population or activities, particularly near towns or areas popular with vacationers, such as the San Juan Islands in northern Puget Sound and along the Oregon coastline. The general trend of increased reported strandings during the last two decades (Table 3) corresponds to the formation of a formal stranding network and a heightened interest and dedication by the public and government agencies in reporting and documenting strandings.

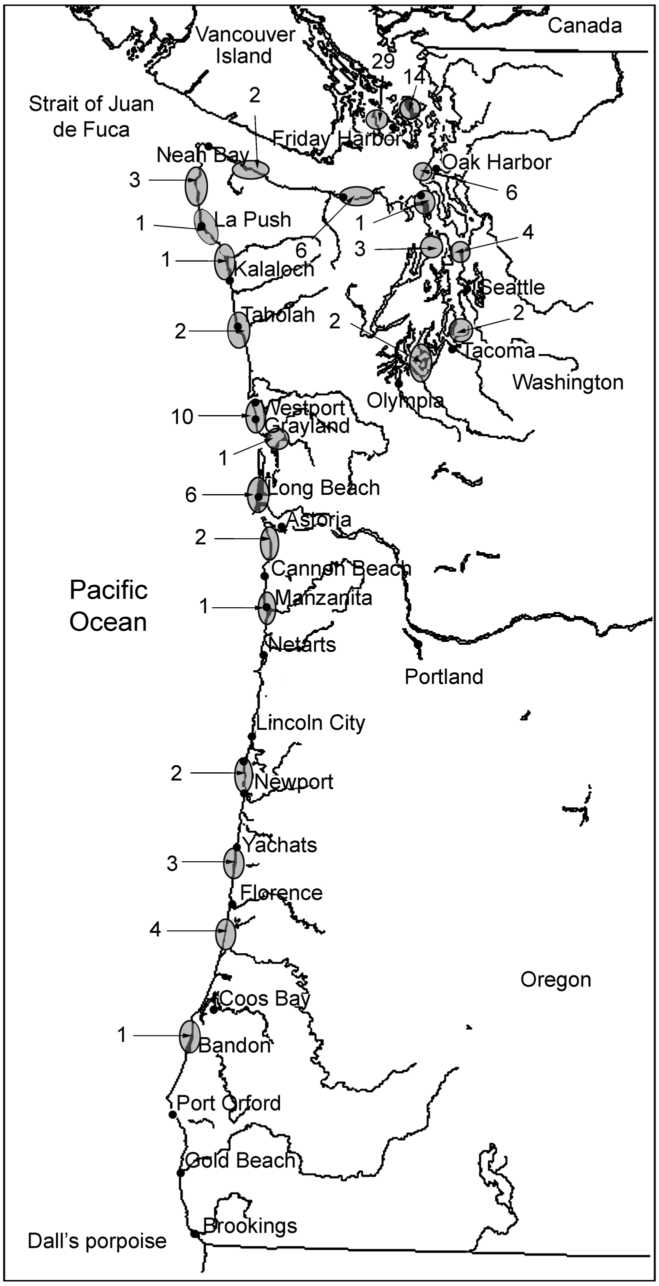

Fig. 4. Spatial distribution of stranded Dall's porpoises in Oregon and Washington (1930-2002).

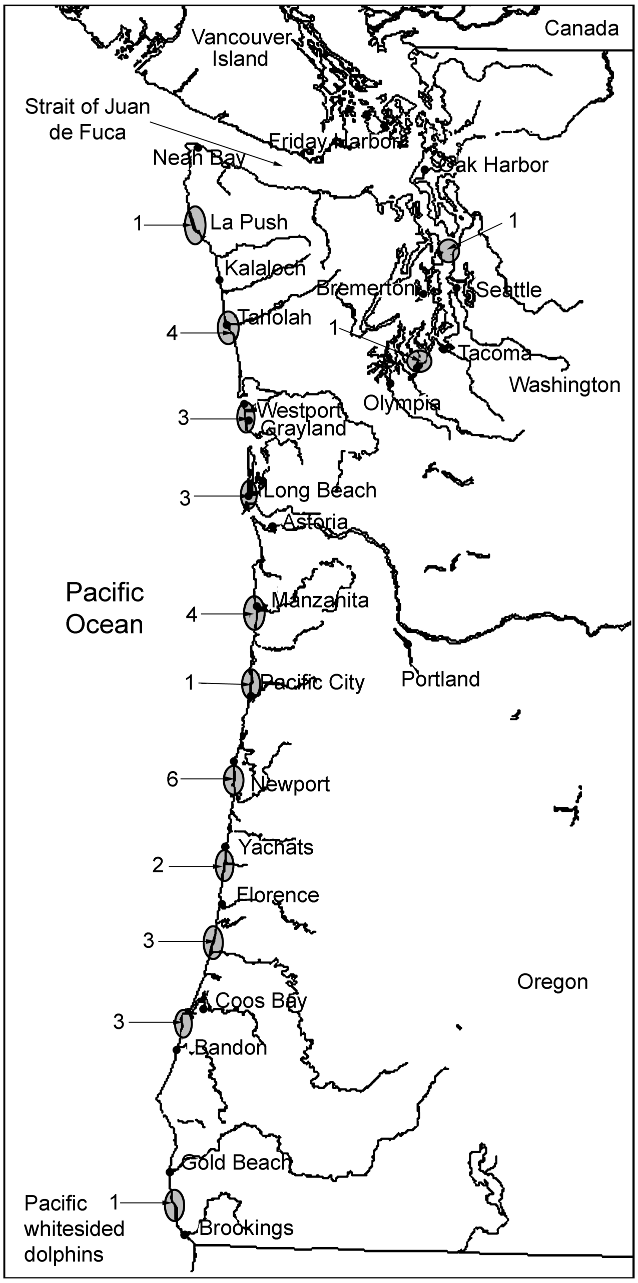

Fig. 5. Spatial distribution of stranded Pacific white-sided dolphins in Oregon and Washington (1930-2002).

Temporal distribution of strandings

Seasonality

In the NWR, cetacean strandings were recorded throughout the year, although generally there were more strandings reported from May to September (Fig. 7). This is probably due to one or more of (1) increased presence of the public at the coast; (2) increased abundance of certain species during this period; (3) oceanographic features (e.g. wind speed and direction, currents or upwelling/downwelling – see the 'Oceanography' section above). This general trend, was not applicable to all species or species groups (see below). Coastal upwelling occurs most frequently in summer and autumn when it is promoted by northerly and northwesterly winds. The upwelling season runs from April to October, with maximum intensity in July and August (Bakun, 1973). Conclusions regarding seasonality of strandings could not be drawn for species with small stranding sample sizes (<15 stranding events has been arbitarily chosen). Seasonal distribution of stranding events was analysed for species in which the total sample size was >15 over the whole period covered in this report (Table 4).

For species listed in Table 4, actual seasonal distribution was compared to an expected even distribution across all seasons using a Chi-squared test. Seasonal stranding patterns differed significantly ($P < 0.001$) from expected even seasonal distribution for harbour porpoise, gray whales and Dall's porpoise, whereas the other species showed no significant differences.

Spring (March-May)

There are several species that stranded most frequently in the spring months (Table 4). Although a small portion of the gray whale population spends the summer along the Pacific coast between Vancouver Island and central California (Flaherty, 1983; Sumich, 1984; Calambokidis and Quan, 1999), most gray whales migrate along the coast in the NWR travelling between Mexico and the Bering and Chukchi

Table 2

Strandings of extralimital species in the NWR relative to ENSO years. An ENSO year is the year leading into the winter of the mature event (Bunkers *et al*., 1996).

Species	Stranding date	ENSO year
Short-finned pilot whale	1 September 1937	1939
	24 March 1968	1968
	12 November 1977	1977
	7 December 1980	1982
	14 March 1996	1997/1998
	2 June 1998	1998
	15 August 2002	2002
False killer whale	15 May 1937	1939
	15 May 1984	1986
	5 May 1987	1986
Bottlenose dolphin	9 March 1988	1986
Common dolphin	February 1942	1941
	6 March 1976	1977
	24 November 1983	1982
	25 November 1985	1986
	10 January 1996	1997/1998
Rough-toothed dolphin	August 1980	1982
	14 January 1991	1991
	4 October 1992	1991

Seas. However, they migrate closest to the NWR coastline during the spring months (April–June) when most of their strandings are observed (Fig. 8b). Animals located in the far north Arctic region (e.g. north central Bering Sea) during the summer months usually begin migrating south in late autumn to early winter (Rugh *et al*., 2001). Surveys have been conducted off the Washington coast during winter to ascertain whale distribution there that time of year, as it appears whales are also present across the continental shelf during periods of non-migration (Shelden *et al*., 1999). Subadults (n = 29; 32%) and adults (n = 27; 30%) represented over half (62%) of the gray whales that stranded in the spring, based on age classes defined in Norman *et al*. (2000).

Although killer whales are present year-round in Washington waters, they are most commonly sighted in Puget Sound during summer and early autumn (Leatherwood *et al*., 1982). They have been reported off the Washington coast during April (Fiscus and Niggol, 1965); however, data on winter distribution are lacking (Baird, 2001). Killer whale populations in the NWR are divided into two distinct 'forms' called *residents* and *transients* (Baird and Stacey, 1988; Hoelzel *et al*., 1998; Ford *et al*., 2000). The residents can be further divided into three geographically-based communities: northern and southern residents and offshore whales, the latter two of which are found most commonly in NWR waters (Bigg *et al*., 1987; Baird, 2001). Of the killer whale strandings, 41% (*n* = 7) stranded in the spring; four of which were neonates or young calves. The number of calf strandings is not surprising given this age class is especially vulnerable to disease, predation and separation from the pod.

Although Dall's porpoise strandings were reported in every month, the highest numbers were in spring (n = 47; 44%; Table 4; Fig. 8a).

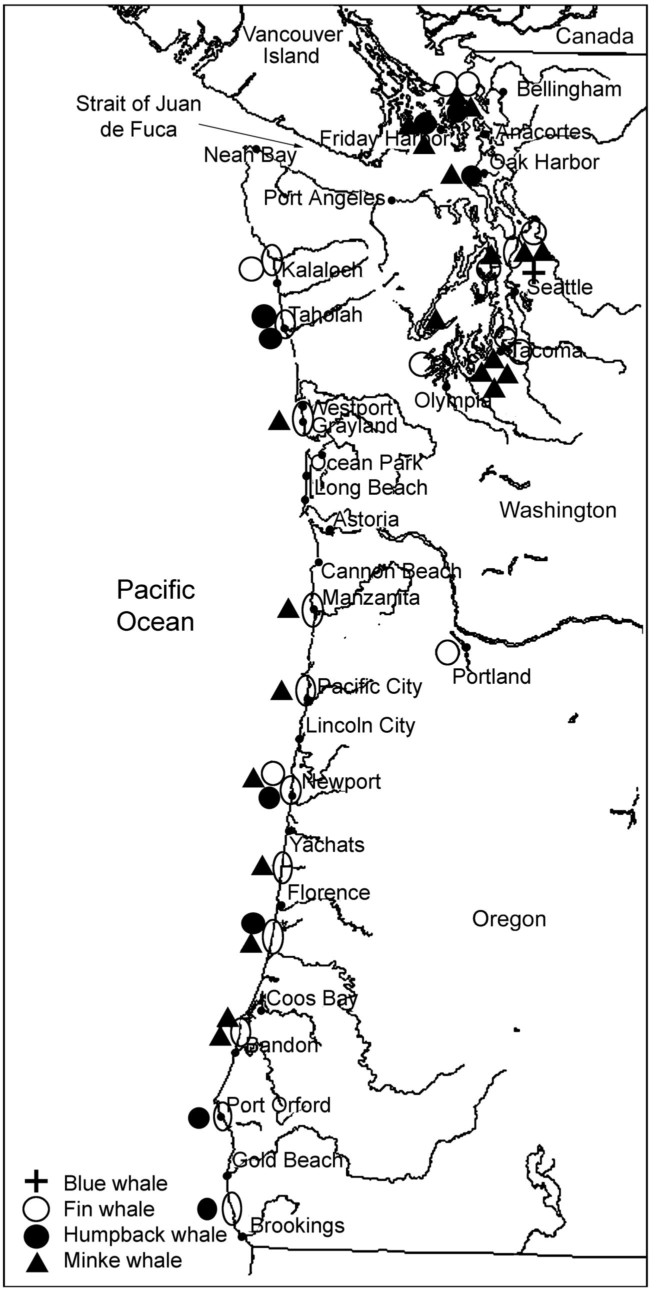

Fig. 6. Spatial distribution of stranded balaenopterid whales in Oregon and Washington (1930-2002).

Table 3

Summary of stranding events and annual strandings rate by decade (all species combined).

Period	Total strandings	Annual rate	SD
1930-39	6	0.6	0.8
1940-49	10	1.0	1.73
1959-59	1	0.1	0.3
1960-69	4	0.4	0.66
1970-79	52	5.2	5.67
1980-89	325	32.5	12.7
1990-99	395	39.5	7.65
2000-2002	111	37.0	9.09

Summer (June-August)

The number of harbour porpoise strandings is highest in July and August (Fig. 8c) and January (see below). This may be partially due to the summer gillnet fishery 1 May – 15 September, with peak landings of chinook salmon in July and August in north Washington and along the southwest coast of the Strait of Juan de Fuca (Gearin *et al*., 1994). The

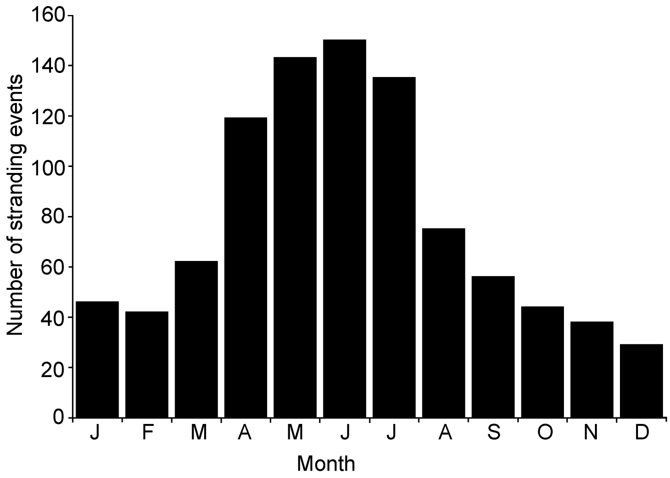

Fig. 7. Monthly distribution of cetacean stranding events in Oregon and Washington (1930-2002).

Table 4

Seasonal distribution of stranding events for species where the total sample size is 15+ over the whole period.

Species	Total	Spring (Mar-May)	Summer (Jun-Aug)	Autumn (Sep-Nov)	Winter (Dec-Feb)
Minke whale	21	11 (52%)	6 (29%)	3 (14%)	1 (5%)
Gray whale	200	105 (53%)	60 (30%)	12 (6%)	22 (11%)
Sperm whale	18	6 (33%)	3 (17%)	6 (33%)	3 (17%)
Cuvier's beaked whale	17	7 (41%)	4 (24%)	2 (11%)	4 (24%)
Killer whale	16	7 (44%)	1 (6%)	3 (19%)	5 (31%)
White-sided dolphin	34	9 (26%)	8 (24%)	8 (24%)	9 (26%)
Harbour porpoise	303	76 (25%)	150 (50%)	46 (15%)	31 (10%)
Dall's porpoise	107	47 (44%)	34 (32%)	16 (15%)	10 (9%)

seasonal distribution of harbour porpoises is unknown, but Barlow (1987) observed higher densities of harbour porpoises in northern Oregon and Washington in a September survey compared to surveys completed in January and February. In a year-long survey conducted by Calambokidis *et al.* (1987) in the Strait of Juan de Fuca, harbour porpoises were the most commonly sighted cetacean with the most numerous sightings recorded in autumn (specifically September). Based on the latter survey, one would expect to see more harbour porpoise strandings in September, but this may not be the case due to the fact that reporting effort is more efficient in the summer months due to increased numbers of individuals inhabiting the coastlines and encountering stranded animals at this time of year.

Dall's porpoise also show higher numbers of stranding events in the spring and summer ($n = 81$, 75%; Fig. 8a); although at least in Puget Sound they occur year-round (Miller, 1989; 1990). In Calambokidis *et al.* (1987), an insufficient number of Dall's porpoise sightings were made to make inferences about seasonal distribution. However, Everitt *et al.* (1980) noted that although this species has been sighted throughout the inland waters of Washington State year-round, it was more abundant during the spring and summer months.

The seasonal distribution for most ziphiids is not well defined. Therefore, no reliable inferences could made from the stranding data for these species other than that more beaked whales were reported stranded in the spring and summer months, presumably due to better weather and increased human presence along the coastline during these times of year.

Autumn/Winter (September-February)

Pygmy sperm whale (*Kogia breviceps*), common dolphin and Risso's dolphin (*Grampus griseus*) stranded primarily in the autumn and winter months ($n = 5$, 4, 5 events, respectively). These strandings most likely represent extralimital occurrences of these species that usually inhabit warm temperate and tropical water rather than representing populations found in the NWR. Of the killer whale strandings, 50% ($n = 8$) occurred during these months.

No seasonality

Sperm whale strandings occur throughout the year. During the summer months, this species can be found anywhere in the North Pacific. They were seen in every season except winter (Dec.- Feb.) in Washington and Oregon (Green *et al.*, 1992). Mate (1981) has found sperm whales to be relatively common off the coast of Oregon between June and September. This observation was not based on formal surveys, but rather on sighting information gathered while at sea for other projects.

Minke whales stranded in almost every month of the year in Washington, which seems to support a year-round presence of this species in the region. In survey efforts by Everitt *et al.* (1980), most observations of this species were made during the spring and summer months, although sightings did occur in all months except February and November. The reduction in number of autumn and winter sightings may reflect a reduction in sighting effort and efficiency rather than a seasonal reduction in numbers.

Pacific white-sided dolphins were the most abundant cetacean sighted in slope and offshore waters of Oregon and Washington during aerial surveys conducted in 1992 by Green *et al.* (1993) during the months of March-May. Pike and MacAskie (1969) noted this species annually moves inshore in winter and offshore in summer, with inshore densities highest in autumn. Strandings have occurred in every month except April, which may be an anomaly (Fig. 8d).

Four of the fin whale strandings are noteworthy since they occurred in the autumn months (Sep – Nov), outside the usual period of sighting this species in coastal northwest waters (Leatherwood *et al.*, 1982). Three of the four were animals struck by ships (a fourth fin whale was struck by a ship in summer – August 2002). Two of the ships originated from the Alaskan Peninsula (Dutch Harbor) and the third from Japan. Both of these ships crossed the Gulf of Alaska and arrived in Puget Sound waters with the whale draped over the bow of the ship. It was presumed the whales were struck somewhere in the Gulf of Alaska or near the entrance to the Strait of Juan de Fuca. The circumstances of the fourth autumn stranding were not described (Scheffer and Slipp, 1948). Likewise, of the 4 humpback whales that stranded in Oregon, 1 stranded in December which is also outside the usual season in which this species is observed in this area (Calambokidis *et al.*, 1996).

No inference possible

No inferences about seasonality could be made for species with small sample sizes (e.g. < 15 stranding events). Some of the species such as the false killer whale, short-finned pilot whale, bottlenose dolphin, common dolphin and rough-toothed dolphin are considered rare inhabitants and usually prefer warm temperate and tropical waters.

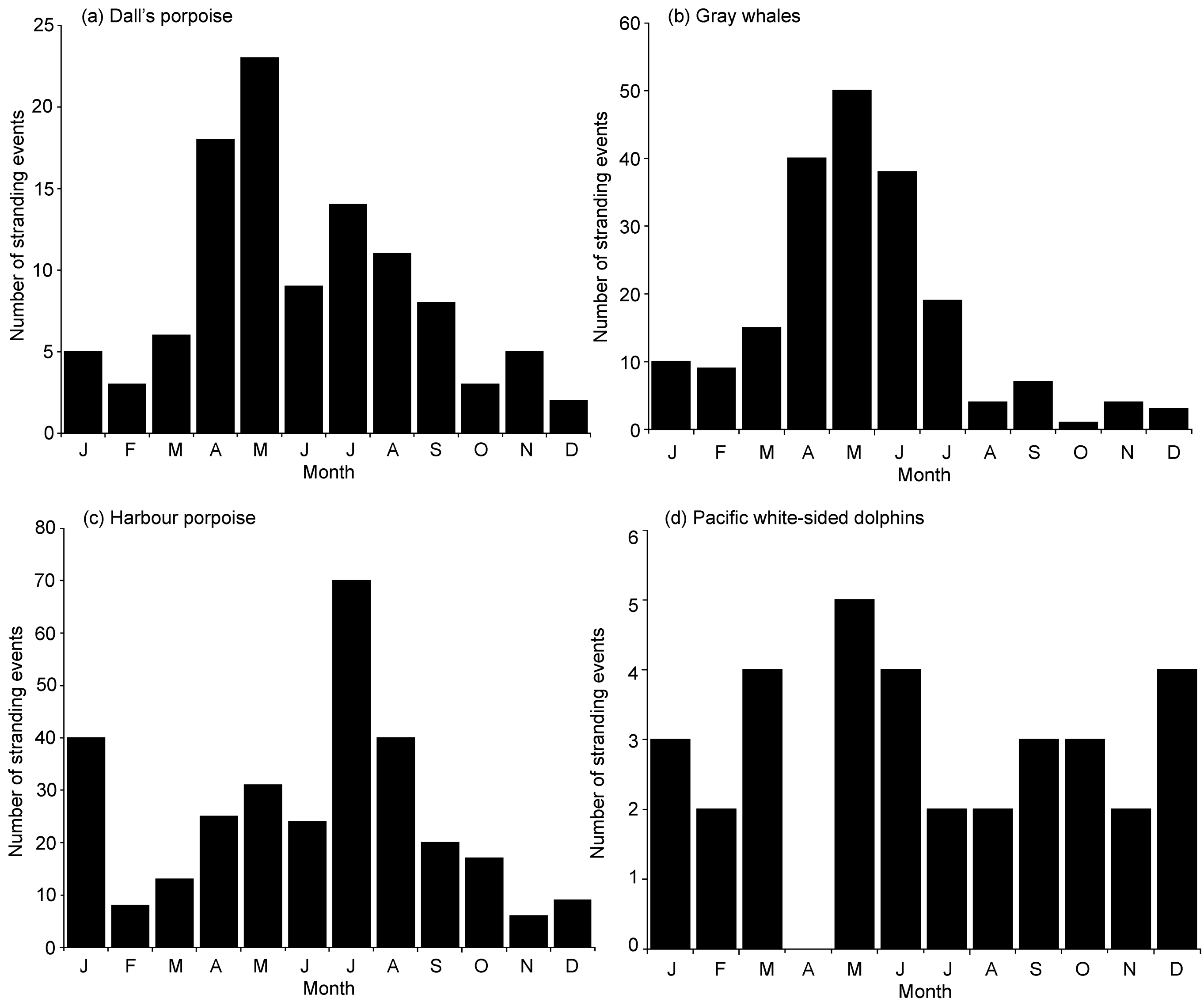

Fig. 8. Temporal distribution of the four most commonly stranded cetacean species in Oregon and Washington (1930-2002).

Spatial distribution of strandings

The spatial distribution of stranding events differed between the two states as well as within each state. The majority of stranding events took place in Washington ($n = 511$; 56%) compared to Oregon ($n = 393$; 44%). Within Washington (Fig. 9), three areas showed a higher percentage of total stranding events: (1) Willapa Bay/Long Beach peninsula (28%); (2) San Juan Islands archipelago (25%); and (3) the far northwest coast of the state near (11%). In Oregon (Fig. 9), the areas with the highest percentage of total stranding events were: (1) northern and central Lincoln County (28%); (2) Clatsop/northern Tillamook Counties (24 %); (3) southern Lincoln County/northern Lane County (11%); and (4) Coos County (9%). In Washington, areas (1) and (2) have high percentages of strandings due to: increased numbers of certain marine mammal species moving inshore in the summer (e.g. Pacific white-sided dolphins, killer whales), resulting in higher stranding numbers, and due to the increased human population in the same months, leading to increased reporting efficiency and effort. In area (3), there has been seasonal stranding coverage due to the presence of NMFS biologists in that area on a yearly basis every month of the year. In Oregon, areas (1-3) are the most populated areas of the coastline, with increased reporting effort during the summer months and increased numbers of marine mammals moving inshore at this time of year. Area (4) in the southern half of Oregon receives many stranding reports presumably due to the proximity of the slope waters to the coastline compared to the rest of the region, and greater upwelling intensity in this area, both of which may bring cetaceans closer to the coastline (Bakun, 1973). Fifty of the stranding events did not have specific enough geographic locale information for determination of stranding location.

Trends in the geographic distribution of stranding events are evident for some species or species groups. For instance, gray whales stranded along the coastline of both states, but most occurred on Washington's outer coast (Fig. 3). This species experienced an unusual mortality event during 1999 and 2000, when 32 and 25 animals, respectively, stranded in the NWR relative to annual averages of 6/year (SD = 32.2). This standard deviation incorporates upward bias since many years with possible zero stranding rates are not included. It is unknown whether those years had a true zero stranding rate or lack of reporting. The role of ship strikes, disease and biotoxins as factors in this mortality event could not be assessed as too few carcasses were sampled adequately to assess these factors. Intensive gray whale foraging may have caused localised prey depletion, or

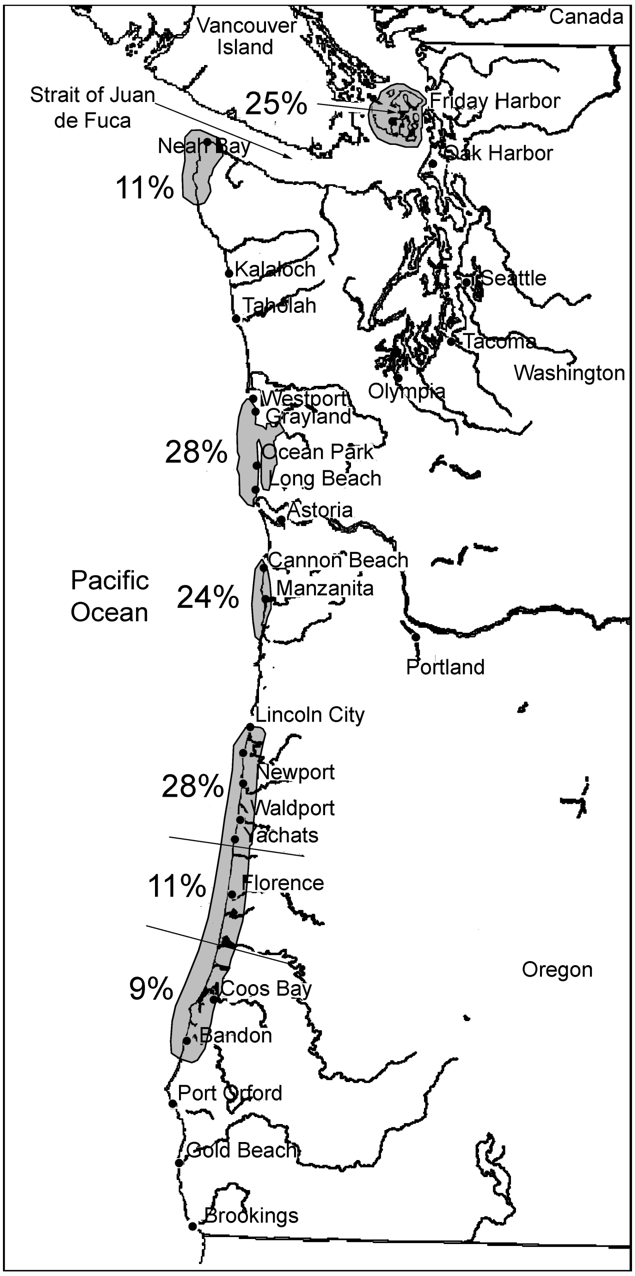

Fig. 9. Regions with the highest percentages of reported cetacean stranding events in Oregon and Washington (1930-2002).

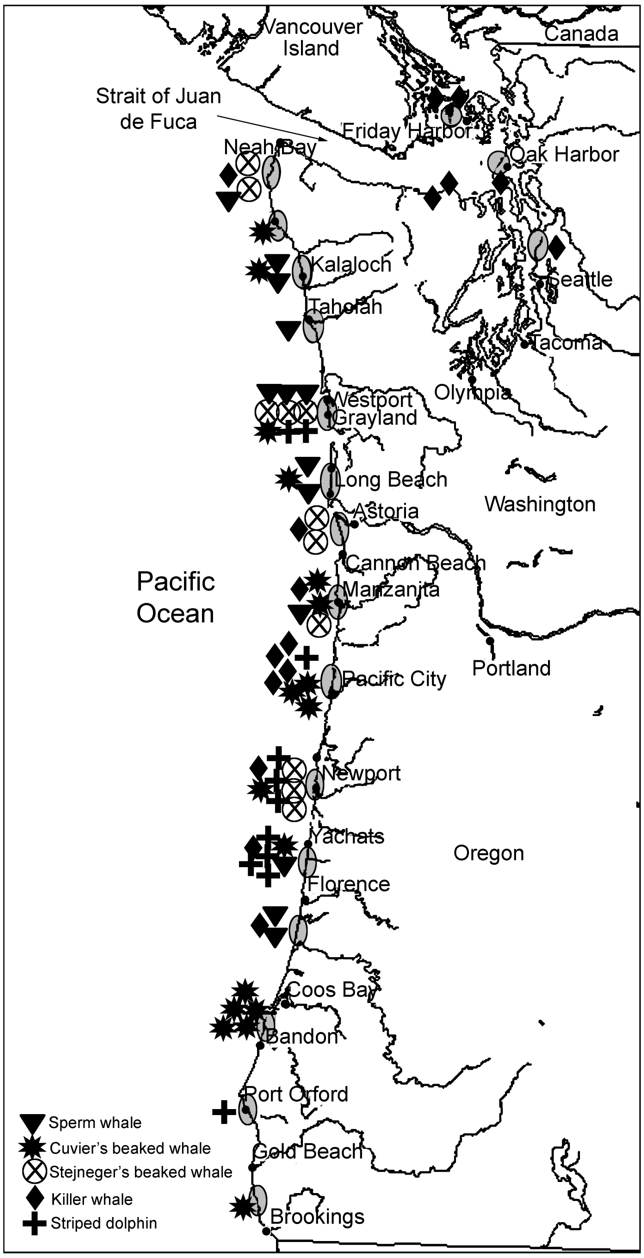

Fig. 10. Spatial distribution of the more commonly stranded delphinids and ziphiids in Oregon and Washington (1930-2002).

environmental changes such as the El Niño event in 1998, or longer-term climatic changes, could have resulted in shifts in prey availability in the summer feeding grounds (Le Boeuf *et al*., 2000; Moore *et al*., 2001; 2003).

The deep-diving species (Families Physeteridae, Kogiidae and Ziphiidae) were recorded along the entire coast of Oregon and outer Washington, but stranded more commonly in Oregon (Table 1; Fig. 10). All strandings of Baird's beaked whale (*Berardius bairdii*) occurred in Washington, while 75% of Cuvier's beaked whale strandings took place in Oregon. Strandings of Stejneger's beaked whale were evenly distributed between the two states Although sample sizes in these species are very small, reasons for their spatial distribution may be: (1) the close proximity of the slope waters (suitable habitat for beaked whales) to the shore in Oregon, versus Washington; (2) in Washington State, the continental shelf is furrowed by at least seven submarine canyons which may also be suitable habitat for beaked whales. Fourteen out of 15 (93%) strandings in Washington State were located on a beach across from a submarine canyon; and (3) winds and currents may affect distribution of carcasses onto the shore.

Of delphinid strandings, Pacific white-sided dolphins were the most numerous (Table 1; Fig. 5). They were the most abundant cetacean sighted off of Oregon and Washington in a survey conducted in April-May (Green *et al*., 1993), with greater numbers sighted off Oregon than Washington. Strandings occurred with a greater frequency in Oregon versus Washington. This may be due to their preference for shelf and slope waters (Stacey and Baird, 1994), which tend to occur closer to shore in Oregon. Killer whale numbers were fairly well distributed between Oregon and Washington (Fig. 10).

No inferences could be drawn on spatial stranding distribution of species with very small sample sizes. Species such as the bottlenose dolphin, rough-toothed dolphin, common dolphin, false killer whale, short-finned pilot whale and striped dolphin (*Stenella coeruleoalba*) are more likely to strand in the NWR when stretches of warm water reach northward.

Despite the small sample size for Risso's dolphins some inferences can be made about regional sightings of the species. They occur in the slope and offshore waters of Oregon and Washington (Green *et al*., 1992) and are represented by a fairly even distribution of strandings between the two states.

Harbour porpoises were the most numerous stranded cetacean in Oregon and the second most common in Washington. In Oregon, harbour porpoises stranded most commonly in the northern and central parts of the state (Fig. 2). In Washington, Dall's porpoise strandings were concentrated within Puget Sound (Fig. 4). The large number of harbour and Dall's porpoise strandings in the NWR supports what is known about their abundance and distribution in this region (Leatherwood *et al*., 1982; Barlow, 1987; Miller, 1989; 1990; Calambokidis and Barlow, 1991; Calambokidis and Quan, 1999). Prior to 1975, there was only one harbour porpoise stranding record from the NWR (in 1943). However, since the mid-1970s, stranding numbers for this species have remained fairly consistent (~10-25/year).

It is possible that the proportions of species in the stranding record reflect the relative abundance of live animals of the species in the respective region (Sergeant, 1979; Woodhouse, 1991). For instance, most species that are relatively rare in the NWR are represented by a small number of strandings. However, strandings may also reflect nothing more than a general region of occurrence and may not be related to specific habitat preference. We conclude that the stranding of a cetacean in a certain area at a particular time does not mean that it is representative of live animal distribution.

Stranding event numbers were compared to neighbouring regions: California and Alaska. In California, 1,800 cetaceans stranded from 1983-2000, representing 25 species and in Alaska 1,390 cetaceans stranded from 1975-2000, consisting of 15 species (US Department of Commerce, 1975-2000). In terms of species composition, the most commonly stranded species in California were common dolphin (*Delphinus* spp.; $n = 435$), gray whale ($n = 309$), harbour porpoise ($n = 306$) and Pacific white-sided dolphin ($n = 70$). The most commonly stranded species in Alaska were gray whale ($n = 275$), harbour porpoise ($n = 75$), killer whale ($n = 69$) and humpback whale ($n = 65$). Stranding summaries from the late 1970s and early 1980s were not consistently broken down by species so these numbers may be artificially low. Three of the four most commonly stranded cetaceans in the NWR (harbour porpoise, gray whale and Pacific white-sided dolphin) were also in the top four stranded species for California. This is not surprising as these species are distributed in both regions and would therefore be expected to have similar stranding frequencies and occurrences. Common dolphins did not contribute to a significant portion of the NWR stranding numbers, however, as they are rarely found in the NWR. In Alaska, gray whales and harbour porpoises comprised the two most stranded species as they did in the NWR, but in reverse order. This again is not unexpected since large aggregations of gray whales migrate to their summer feeding grounds in Alaska. Although Dall's porpoises were sighted more often then harbour porpoises during summer ship and aerial surveys in Alaska (Waite and Hobbs, 1998; Waite *et al*., 2001; Moore *et al*., 2002), they do not seem to strand as frequently as harbour porpoises presumably due to their preference for generally deeper waters than harbour porpoises, therefore their carcasses may sink before reaching shore. Greater killer and humpback whale stranding numbers may occur in Alaska due to larger populations of these species inhabiting the waters of this state.

Sex of stranded animals

Sex was determined for 609 stranded individuals (Table 1). Sex could not be determined in 342 individuals (36%) due to advanced decomposition of the carcass, examiner's inexperience in sexing animals or carcass position. Sex ratios were not significantly different from 1:1 for the most commonly stranded species: harbour porpoise (105 males:93 females, $\chi^2 = 2.48$, $P = 0.115$), gray whales (85 males:63 females, $\chi^2 = 2.78$, $P = 0.095$), Dall's porpoise (44 males:25 females, $\chi^2 = 3.06$, $P = 0.080$) and Pacific white-sided dolphin (18 males:10 females, $\chi^2 = 2.29$, $P = 0.131$).

Mass strandings

The only mass stranding in the database involved sperm whales. On 16 June 1979 near Florence, Oregon, a group of 41 animals (28 females and 13 males) live-stranded (Rice *et al*., 1986). All of the males were subadults, of the adult females, 3 of the 9 were pregnant and none were lactating. The oldest female was 58 years old. One of the females was sexually immature and the remaining were sexually mature. There were neither calves nor animals under 10 years of age. The low number of mass strandings in the NWR may reflect the lack of relative coastline features which may make cetaceans vulnerable (e.g. sloping beaches, geomagnetic disturbances).

Uses of stranding data for management

Data gathered from stranding events can help facilitate management in several ways. It provides an overview of distribution and stranding trends usually observed in the NWR which can provide an early warning system in the event of an unusual stranding event. Monitoring of stranding patterns (spatial and temporal) helps identify unusual mortality events. For instance, an extraordinarily high number of strandings of gray whales in 1999 and 2000 warranted further attention (Le Boeuf *et al*., 2000; Norman *et al*., 2000). In addition, stranding data may supplement existing knowledge on distribution of cetaceans in the NWR already obtained from aerial and ship surveys of the region (e.g. Fiscus and Niggol, 1965; Everitt *et al*., 1979; Barlow, 1987; Brueggeman, 1990; 1992; Green *et al*., 1992; Green *et al*., 1993; Calambokidis *et al*., 1997). For some species of cetaceans, little is known beyond what is learned from strandings. For example, in the NWR little is known about northern right whale dolphin (*Lissodelphis borealis*) distribution and ecology except from stranded specimens ($n = 8$). Few specimens of Hubb's beaked whale (*Mesoplodon carlhubbsi*) have been recovered in the NWR. They are very cryptic and difficult to identify at sea. Their presence in the NWR would be unknown if not for two stranded animals. Stranded specimens provide an invaluable source of information on anatomy and taxonomy (particularly through genetic analysis), since access to live animals is limited and expensive and there are few direct hunts (or bycatch schemes) that can provide specimen material.

Stranded marine mammals do not constitute an ideal sentinel system for population health as they do not represent the entire population (Aguilar and Borrell, 1994). In addition, samples from stranded animals are infrequently age and sex structured. Biological data such as life history, reproductive success, feeding habit, and disease progression are not typically available. Nonetheless, contaminant analysis of tissues collected over a stock's range may identify patterns of exposure (Varanasi *et al*., 1993; 1994; Krahn *et al*., 2001) There are limitations, however, to the use of stranded specimens for contaminant analysis. The effect of disease and nutritive condition may affect lipid content of the tissues (Aguilar *et al*., 1999). Most often the time of death of a stranded animal is unknown, hence samples collected may not adequately reflect tissue pollutant concentrations. Changes in the levels of contaminants occur post-mortem due to the inevitable physiological changes and breakdown of tissues associated with autolysis (Reijnders *et al*., 1999). The effect of weather (e.g. wind and direct sun) on a carcass may also cause loss of the more volatile organic compounds present in tissues (Aguilar *et al*., 1999).

Examination for evidence of human interaction in strandings may point to a need for closer monitoring of a specific geographic area or for development of appropriate mitigation measures to reduce take levels in certain fisheries (Gearin *et al*., 1994; 2000) as well as threats from ship strikes, shooting or other direct mortality. Fishery interactions with gray whales and ship strikes have been reported. There were six mortalities due to fisheries interactions reported in 1999 and eight in 2000, and two fatal ship strikes, one in 1999 and one in 2000 (Angliss and Lodge, 2002). In 2000, the Center for Coastal Studies (Provincetown, MA) and NMFS cosponsored a large whale disentanglement training workshop in Seattle, WA for primary network responders in the NWR. The discovery of stranded animals bearing evidence of ship strike (e.g. four ship-struck fin whales reported in the NWR in 2002) may prompt future management measures such as reduction of vessel speed through areas of known large whale aggregations or sensitive habitat (Laist *et al*., 2001). In cases of suspected shooting (which are often a result of fishery interaction), involvement of state (e.g. Oregon and Washington Departments of Fish and Wildlife) and federal (e.g. NMFS) enforcement agencies will help mitigate marine mammal-fishery interaction problems. Cetaceans may be affected by oil spills such as in a primary feeding area by contaminating prey items (Moore and Clarke, 2002).

Stranded animals may also provide information on population movement patterns or residency of a given species. It may be possible to draw correlations between beached species and their parent populations in the region (Woodhouse, 1991). For instance, the location of a NWR resident killer whale stranding during the winter provides information on residency of the population that otherwise is little known during that time of year (Olesiuk *et al*., 1990). Likewise, the stranding of a seasonal 'resident' gray whale in Puget Sound during the summer confirms that some gray whales do not complete the migration to the usual summer feeding grounds in the Bering and Chukchi Seas, but rather remain in NWR waters to feed (Sumich and Gilmore, 1977; Calambokidis and Quan, 1999).

The existence of a parent population in the region may not necessarily be reflected by the presence of strandings. For example, summer and autumn feeding aggregations of humpback whales have been reported off the Washington coast (Scheffer and Slipp, 1948; Calambokidis *et al*., 2000), however, they are underrepresented in the stranding records ($n = 6$). One explanation may be that the whales remain far enough offshore that when they die, the carcass sinks before reaching shore or is swept away by currents.

Analyses of stranded animals may lead to the identification of novel diseases or patterns of antibiotic resistance not previously known in cetaceans (Foster *et al*., 1996; Fox *et al*., 2000). Health trends of free-ranging populations of marine mammals may be assessed through investigation of stranded animals, particularly those that have live-stranded. Necropsy investigations of stranded animals provides data on pathogens that could possibly cause disease in humans or domestic animals that come in contact with these animals.

Since the implementation of a coordinated stranding network in Oregon and Washington, a greater number of strandings have been recorded and a significant amount of data has been collected. For example, contaminant levels in stranded NWR gray whales have been compared to harvested animals in Russia (Krahn *et al*., 2001). Identification of infectious diseases in stranded cetaceans can serve as a basis for developing a standardised necropsy and disease testing protocol (Gaydos *et al*., 2004) for stranded southern resident killer whales which were recently listed as depleted under the Marine Mammal Protection Act (NMFS, 2003). Future participation of the network will continue to further understanding and insight into the mortality, life history, disease processes and stock structure of cetaceans within the waters of the NWR.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Northwest Region Stranding Network and the many volunteers who reported strandings. Many of the Network members responded to strandings with their own funds. The collection and handling of specimens was carried out under permit of NOAA's National Marine Fisheries Service's Protected Species Management Branch. The authors would also like to thank the following for their assistance in responding to strandings and collecting data: Robin Brown (Oregon Department of Fish and Wildlife, Corvallis, Oregon); Keith Chandler (Seaside Aquarium, Seaside, Oregon); San Juan County Marine Mammal Stranding Network/Whale Museum (Friday Harbor, Washington); Hatfield Marine Science Center, Oregon State University, Newport, Oregon and the Oregon Institute of Marine Biology, University of Oregon, Charleston, Oregon and all other network volunteers. Glen Watabayashi, of the Hazardous Materials Response Division, Office of Response and Restoration, National Ocean Service (NOS), NOAA provided wind and current data for the Northwest Region. David Rugh and Janice Waite, both biologists at the National Marine Mammal Laboratory (NMML), kindly reviewed this manuscript. Robert DeLong, Leader of the California Current Ecosystems Program at NMML also provided helpful comments and suggestions. Comments by the reviewers and the Editor greatly improved the manuscript. Richard Morse of the Damage Assessment and Restoration Center, NOS, NOAA developed the maps.

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