FINAL REPORT

RANGE AND MOVEMENTS OF SEASONAL RESIDENT GRAY WHALES FROM CALIFORNIA TO SOUTHEAST ALASKA

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We report on the collaborative results of photographic identification research conducted in the Pacific Northwest on gray whales between northern California and southeastern Alaska from spring to fall 1998. We describe the movements of gray whales utilizing these waters outside the normal migration and estimate their abundance. Identification photographs of gray whales were collected by eight collaborating organizations between 12 March and 18 November 1998 from northern California to southeastern Alaska. Effort by region was variable with most intensive coverage along the southern and western coast of Vancouver Island.

From the 1,242 occasions when suitable photographs of a gray whale were obtained in 1998, we identified 155 unique whales. The largest number of individuals were identified off the southern coast of Vancouver Island, especially in June and July, and from central Vancouver Island around Clayoquot Sound in July and August. Each individual was photographed from 1 to 42 times (mean of 8.0, SD=8.4). Time between multiple sightings of individual whales was ranged from 1 to 170 days (average of 56 days, SD=41). Whales seen over a period of longer than 3 months generally were seen in multiple regions. Movements among regions in 1998 were documented for 57 whales with the most frequent interchange among three adjacent sites from northern Washington to central Vancouver Island. The overall pattern of movements among regions was complex. Whales were not always moving in the same direction at the same time of year. Movements within 1998 among more distant locations including Oregon and California did occur but were less common. Total distances between resighting positions for individual whales ranged from less than 1 to 526 nmi (great-circle route).

Most of the whales photographed in 1998 had been identified in previous years. At least 85 (55%) of the whales identified had been previously identified either by Cascadia or by one of the research groups. The rate of matching to past years was highest for whales identified off northern Washington and the three regions of British Columbia from southern Vancouver Island to north of Vancouver Island. In these areas, from 70 to 100% of the whales seen in each region had been identified in a previous year. At the southern and northern end of our effort, off Oregon, California, and southeastern Alaska there were few identification photographs available from previous years. Even though the match rate was lower, some of the whales in all three of these areas were known from past sightings in other regions. Whales identified in a few areas including southern Puget Sound and Boundary Bay generally were not seen in other areas or known from previous years. Mark-recapture abundance estimates using annual samples from 1998 and either 1996 or 1997 yielded estimates of 186 and 196, respectively. Slightly lower estimates of 169 and 175 were obtained if identifications made before 1 June (in any year) were excluded.

The management implication of seasonal resident whales has been become controversial recently due to the resumption of whaling by the Makah tribe in northern Washington. Seasonal resident gray whales are a relatively small proportion of the overall gray whale population. This study documents the range, abundance and movements of this group of animals. How these animals are recruited into this group and the degree to which seasonal resident gray whales should be managed as a unit separate from the overall gray whale population if not resolved.

INTRODUCTION

Gray whales make one of the longest migrations of any mammal between their winter breeding grounds off Baja California, Mexico, and their principal feeding grounds in the Bering and Chukchi Seas. Migrations past the Pacific Northwest coast occur in December and January when the animals are southbound and northbound in spring. Outside these migratory time periods, summer feeding aggregations of gray whales have been observed in a number areas along the coasts of California (Patten and Samaras 1977, Malonee 1991, Avery and Hawkinson 1992), Oregon (Sumich 1984), Washington (Flaherty 1983, Calambokidis *et al.* 1992, 1994, Wietkamp *et al.* 1992) and British Columbia (Darling 1984, Murison *et al.* 1984, Plews *et al.* 1985).

Repeated sightings of the same photographically identified whales off Vancouver Islands in the early 1970s demonstrated site fidelity to this region with the same animals returning annually to feed (Hatler and Darling 1974, Darling 1984). A similar pattern was documented in some areas off Washington State (Calambokidis *et al.* 1994) and northern British Columbia (Megill and Randal 1999, Megill *et al.* 2000). Darling (1984) suspected gray whales seen along the coast of British Columbia in summer months were part of a larger "northwest coast" sub-population that numbered at least 100 animals. These seasonal residents appear to be part of the overall eastern North Pacific gray whale population and generally arrive and depart from these feeding grounds concurrently with the migration to and from the wintering grounds. Gray whales in these regions have been observed feeding on a variety of prey including herring eggs/larvae, crab larvae, amphipods, mysids, and ghost shrimp (Darling *et al.* 1998, Nerini 1984, Duffus 1996, Weitkamp 1992, Murison *et al.* 1984, Oliver *et al.* 1984). Movements over distances of less than 100 km and changes in distribution of animals in response to shifting prey types have been documented (Darling 1984, Darling *et al.* 1998).

The status of this feeding aggregation of gray whales has become of management importance due to the resumption in hunting of gray whales by the Makah Tribe in northwest Washington State. Although the current management plan for hunting of gray whales calls for targeting migratory animals, it may be difficult to avoid taking whales from this seasonal feeding aggregation (Quan 2000). It is unclear how loyal these animals are to these feeding grounds, how they adopt this alternate feeding strategy and habitat, and their range of movements.

We report on the collaborative results of photographic identification research conducted in the Pacific Northwest on gray whales between northern California and southeastern Alaska from spring to fall 1998. We describe the movements of gray whales utilizing these waters outside the normal migration and estimate their abundance.

METHODS

Identification photographs of gray whales were collected by eight collaborating organizations between 12 March and 18 November 1998 from northern California to southeastern Alaska (Table 1). Effort by region was variable with most intensive coverage along the southern and western coast of Vancouver Island. Effort and identifications were grouped into 12 regions (Figure 1) based on bodies of water and operating areas for surveys. Latitude and longitude for each sighting was used to calculate movement distances between multiple sightings of the same whale.

Photographic identification methods

Although a variety of vessels were used in different areas, most of the effort was conducted using small vessels (<10m) and photographic identification methods were similar. Whales were approached slowly from the side typically to a distance of 50-100m. Both left and right sides of the dorsal region around the dorsal hump and the flukes of gray whales were photographed if possible. Most groups used 35mm cameras usually equipped with 300mm lenses and high-speed black and white negative film. Markings used to distinguish whales included pigmentation of the skin, mottling, and scarring, which varied among individuals and have provided a reliable means of identifying gray whales over periods of close to 20 years (Darling 1984, Darling *et al.* 1998). We also utilized the relative spacing between the knuckles along the ridge of the back behind the dorsal hump.

Photographic matching

Comparison of whale photographs to determine matches was made in a series of steps. First, the negatives of gray whales were examined and the best image of the right and left side of each whale (for each sighting) was selected and printed (7 x 2.5 inch). To determine the number of whales seen during the season, we compared all photographs from 1998 to one another to identify whales seen multiple days. Finally a comparison was made between the best photograph in 1998 and our catalog of whales seen in past years. Whale photographs that were deemed of suitable quality but did not match our existing catalog (compared by two independent matchers) were assigned a new identification number.

Information on sightings from previous years came from two sources. Cascadia's catalog from past years consisted of 835 records of 171 unique gray whales identified between 1984 and 1997. While most of these identifications were from Washington State, including Puget Sound and inland waters, small samples were also collected off California and southern British Columbia. These photographs were collected by Cascadia Research personnel or other collaborating scientists and naturalists. Additionally, individual research groups participating in the 1998 collaboration provided information on past years' sightings of animals they saw in 1998. Because these groups only compared photographs from their own regions to their past collections, there was not a complete comparison among these collections. The proportion of individuals identified in previous years therefore, are reported as minimums.

RESULTS

Sighting patterns and movements within 1998

From the 1,242 occasions when suitable photographs of a gray whale were obtained in 1998, we identified 155 unique whales (Table 1). Each individual was photographed from 1 to 42 times (mean of 8.0, SD=8.4). The largest number of individuals were identified off the southern coast of Vancouver Island, especially in June and July, and from central Vancouver Island around Clayoquot Sound in July and August (Table 2).

Movements among regions in 1998 was documented for 58 whales (Table 3); 38 seen in two regions, 19 in three regions, and one in five regions. The most frequent interchange was documented among three adjacent sites from northern Washington to central Vancouver Island (Table 4a). Thirty-three individuals were seen along both the West Coast Trail (southern Vancouver Is.) and in Clayoquot Sound (Central Vancouver Is.). Seventeen whales were seen off both the northern Washington coast and southern Vancouver Island.

The overall pattern of movements among regions was complex (Figure 2). Whales were not always moving in the same direction at the same time of year. Despite the wide variations in movement patterns of different individuals, a few patterns were more common. A high concentrations of whales identified in off S Vancouver Island in June (40 individuals) and July (45) then appeared to disperse somewhat with 19 transits observed from this area north to Clayoquot Sound in July and, to a lesser degree, August. Some animals also moved south from southern Vancouver Is. at this same time with 10 transits to the Washington Coast and several more toward Oregon and California (arriving in later months). In August, the number of whales in the Clayoquot Sound area (42 individuals) peaked and a high number of transits were observed late in the month and extending into September from this area back to southern Vancouver Is. (14 transits) as well as other areas primarily to the south.

Movements within 1998 among more distant locations including Oregon and California did occur but were less common. Only one whale moved from northern California to another location. Whale ID#76 was seen multiple times between 12 June and 9 July off southern Vancouver Island then went unseen until 10 October when it was seen feeding off Pt. St. George in northern California. This case, where a whale went 3 months without being seen and transited through areas that were being surveyed in Washington and Oregon, reveals the limitations of the survey coverage. Identifications were primarily late in the season off Oregon (August) and California (October).

Because we used regions that reflect research effort for our transit analyses, we also examined distance and speed traveled for the 117 whales that were seen on more than one day (Figure 3). Total distances between resighting positions for individual whales ranged from less than 1 to 526 nmi (great-circle route). The distance a whale was documented traveling through the season averaged 111 nmi (SD=137) and was generally directly related to the number of times and span of time over which it was seen. The majority of travel speeds were well under 1 knot as would be expected for feeding whales and given that our estimates underestimate the true distance covered and therefore the speed.

There were dramatic differences between the movement distances of whales. The lack of movement of some whales was exemplified by ID# 231 which was seen 30 times over a 136 day period (23 May to 6 October 1998) in southern Vancouver Island. It accumulated a total distance traveled of only 74 nmi. The most rapid movement was for an animal (ID# 295) seen seven times from 10-25 August but which moved from central Vancouver Is to Oregon in that period. This represented 295 nmi that was covered in less than 10 days (only slightly slower than the speed calculated for migrating gray whales). For the eight whales documented moving over 400 nmi, one transited in one direction from Vancouver Island to California, while the remaining seven made multiple transits in different directions between locations.

Of the 155 whales, 117 (75%) were identified on more than one day. Time between multiple sightings of individual whales was ranged from 1 to 170 days (average of 57 days, SD=42). Whales seen over a period of longer than 3 months generally were seen in multiple regions (Figure 4). The longest period a whale was seen, 170 days, was for an individual whale (ID#192) first seen on 4 May off southern Vancouver Island and was resighted 42 times through 21 October. This whale was seen from 4 May to 6 July off the West Coast Trail of southern Vancouver Island. It was then seen from 9 to 31 July in the Clayoquot Sound vicinity of central Vancouver Island with a single resighting off the West Coast Trail on 24 July. From 6 to 27 August it was seen again off the West Coast Trail. Finally, from 5 September to 21 October it was seen repeatedly off the northern Washington coast.

Inter-year resightings

Most of the whales photographed in 1998 had been identified in previous years (Tables 3 and 4b). At least 86 (55%) of the whales identified had been previously identified either by Cascadia or by one of the research groups. These matches to past years come from comparison of all 155 of the whales identified in 1998 to the historical catalog maintained by Cascadia Research of mostly whales seen off Washington. There were also matches to previous years identified by several of the collaborating research groups but these were confined to comparisons of whales identified in the same area (the full 155 whales were not compared to the historical catalogs of the other collaborating research groups). Such a comparison would yield additional documentation of resightings of whales in previous years.

The rate of matching to past years was highest for whales identified off northern Washington and the three regions of British Columbia from southern Vancouver Island to north of Vancouver Island. In these areas, from 72 to 100% of the whales seen in each region had been identified in a previous year. These areas are the regions with the heaviest consistent survey effort in past years.

For some areas, such as Oregon and California, there were few identification photographs available from previous years so matches to past years were primarily animals that had been seen previously in a different region. For Oregon, where no identification photographs were available, 8 of 18 (44%) whales identified in 1998 had been seen in six other regions from Grays Harbor to northern British Columbia in the previous years (Table 4b). Whales identified off California in 1998 had been seen in previous years in the Grays Harbor area, the northern Washington Coast,

and the Strait of Juan de Fuca. Three of the whales identified off California were matched to the only sample we had from a past year, 13 whales identified in November 1991 in the exact same area they were seen in 1998 off Pt. St. George.

Whales identified in 1998 in S Puget Sound and Boundary Bay had not been seen in a previous year in any region. This finding from southern Puget Sound is consistent with observations from past years that have revealed that presence of gray whales in this area is highly variable each year and have never been whales known from previous years. Four of six whales identified in 1998 in northern Puget Sound, however, were known from sightings in past years. All four of these whales had been identified multiple times from 1990 or 1991. Whales seen in northern Puget Sound generally have been seen from March through May and then move to other unknown areas.

During 1998, whales that had been identified in previous years were seen more times (mean of 10.6 versus 4.7, $t=4.73$, $p<0.001$) over a longer period of time (61 versus 21 days, $t=6.32$, $p<0.001$) (starting earlier and extending later) than whales that had not been identified in previous years (Table 5). This was partly a function of the lower proportion of whales known from previous years in areas like California, Oregon, and Puget Sound where resightings within 1998 were less common. Even with the elimination of this regional bias, however, this general trend remained within our three best-sampled regions (N. WA, and S and central Vancouver Is.). Whales in these three regions known from previous years were seen more times in 1998 than those that had not been seen previous years, although these differences were short of statistical significance.

Although only four whales were identified in southeastern Alaska in 1998 (and none previously), one of these was a whale that had been seen in past years off Washington. Although it was not seen elsewhere in 1998 it had been sighted 18 times in five of the previous six years off both the Washington outer coast and in the Strait of Juan de Fuca. Despite the small sample size the re-identification in southeastern Alaska of this whale that had been previously seen regularly off Washington suggests the range of movement of these whales extended farther north than our primary effort.

Seasonal patterns in resighting rates

There were seasonal differences in the resighting rates of animals in 1998 (Table 6). Whales identified early (March and April) and late (November) in 1998 were less likely to have been identified in a previous year (Table 6). These whales were disproportionaly sampled in Grays Harbor and in Puget Sound so this could partly be an artifact of the region. It also likely reflects the increased probability of sampling migrating whales closer to the time of the migration past the Pacific Northwest.

Geographical recruitment

Although it appears that many seasonal resident whales consistently spend most of the feeding season in Pacific Northwest waters, it is not known how they are recruited into this group. This is an important question critical for evaluating how exploitation would impact this

group (Quan 2000, Quan *et al.* 1999). Some of the sightings in 1998 provide insight into one possible mechanism for the means by which animals adopt this alternate feeding area.

To examine the role maternally directed site fidelity played in whales feeding in the Pacific Northwest, we examined some of the sighting history of identified cows and calves. Although females with calves were sighted infrequently, three of the whales sighted in 1997 or 1998 were known reproducing females, and one was a returning calf. One known seasonal resident of Washington and British Columbia (ID#43) has been seen in many years since 1984, including every year from 1992 to 1998. It was documented with a calf in July 1994 (ID#107) and the calf was seen independently off Washington in three following years, 1995, 1997, and 1998. In two other cases an adult female who was seen multiple years and was seen with a calf in one year but the calf was not resighted. One of these females (ID#105) and calf (ID#104) were first seen off Washington in July 1994. The calf has not been resighted in a following year but the cow was seen in 1996 north of Vancouver Island and in 1998 off Vancouver Island and Oregon. In the second case a known seasonal resident (ID#67) was seen in 1992 and between 1995 and 1997. In 1995 it appeared to be with a calf (ID#167) which was not seen since. In at least one of these two cases where the calf has not been seen, the calf photograph was of marginal quality and there is a chance we would have not recognized it even if it had returned.

Estimation of abundance

The current single-year sample only provides a reliable minimum estimate of the total number of whales feeding in summer months from northern California to southeastern Alaska. Although a total of 155 whales were identified, a better minimum estimate would be based on those animals identified within specific subareas and during summer months. Only 134 of these whales were seen after 1 June (outside the timing of the northern migration) and in areas other than Puget Sound (Table 7).

Mark-recapture estimates using annual samples from 1998 and either 1996 or 1997 yielded estimates of 186 and 196, respectively, without a date restriction (Table 7). These excluded whales identified in the Puget Sound area and in and around Grays Harbor earlier in the season. Slightly lower estimates of 169 and 175 were obtained if all identifications made before 1 June (in any year) were excluded. These estimates using the Petersen mark-recapture method require several assumptions that are not totally met by the current samples:

1. **The population is closed**. There would have been some natality and mortality between annual samples, although this should be small. There also may be emigration or immigration of animals of with the overall population of gray whales.

2. **All animals have an equal probability of capture in at least one of the samples**. The 1998 sample is the most complete sample we have obtained and covers a broad geographic area. Even in 1998, however, effort was not systematic and some areas were covered far more thoroughly than others; there was no effort in some portions of the known range of these season-resident animals.

3. **The two samples are independent of each other such that animals caught or not caught in one sample both have equal probability of being caught in the other sample**. The 1996 and 1997 samples are clearly geographically biased and are based on identifications made in a relatively small area (N Washington, Strait of Juan de Fuca, and S Vancouver Is.). Because there is some bias in the 1998 sample as well and animals do not appear to redistribute randomly, this would create heterogeneity of capture probabilities.

4. **All matches if present are found and there are not false matches**. There is little probability of false matches because only matches based on photographs showing multiple markings and verified by a second observer were used. Some matches could have been missed although this was kept to a low number by only including IDs based on good quality photographs and requiring all comparisons to be made by two matchers.

Violations of assumption #1 and the most likely violation of #4 (missed matches) would both bias the estimate upward while the violations of #2 and 3 would bias the estimate downward. Because violations of #1 and 4 are likely small, we believe the most significant bias would be a downward one caused by our unequal sampling. This would mean our preliminary estimates are likely underestimates. Multiple-year samples that more completely and evenly sample the range of these seasonal resident whales are needed to refine the estimate.

DISCUSSION

The existence of seasonal resident gray whales in the Pacific Northwest has been documented in the past. Darling (1984) reported resightings of whales off Vancouver Island over an 8-year period. He documented movements of animals between different areas of up to 80 km in the same season and 150 km between seasons and estimated that the Vancouver Island area was occupied by 35-50 whales each summer. There were gaps, however, in the sighting histories of these whales, with some individuals not identified in the study area for several years.

Our study shows that these whales inhabit a broad region during the spring, summer, and fall extending from at least northern California to southeastern Alaska. Within this range, gray whales can move widely both within and between years. The use of this broad area by these whales provides one explanation for why many of these individuals would not be seen in specific areas in some years. Even with the broad field effort we report here, only a relatively small portion of the potential areas of use by these animals are being searched (Figure 1). Animals not seen in a particular year could be utilizing neighboring areas where there was not research coverage.

These seasonal resident gray whales are a relatively small proportion of the overall gray whale population. The total gray whale population was estimated at 26,000 in 1999 based on censuses conducted on the southbound migration (Hobbs and Rugh 1999). The few hundred animals identified by photographic identification and based on mark-recapture estimates would make up less than 1% of this population.

Some species of baleen whales show a high degree of maternally directed site-fidelity to specific feeding areas. This has been examined in detail for humpback whales in both the North Pacific and North Atlantic. In the North Atlantic, humpback whales breed at one primary wintering ground (Mattila *et al.* 1994, Clapham *et al.* 1993) but during the spring disperse to a number of distinct feeding areas in the North Atlantic. Interchange among these North Atlantic feeding grounds is limited (Katona and Beard 1990) and there are differences in mtDNA among some of these areas (Palsbøll *et al.* 1997). Similarly, humpback whales in the North Pacific utilize a number of distinct feeding areas with little interchange among them (Calambokidis *et al.* 1996, 1997), although interbreeding among these groups is occurring to some degree on the wintering grounds (Darling and McSweeney 1985, Baker *et al.* 1986, Calambokidis *et al.* 1997). As in the North Atlantic, maternally directed site fidelity to specific feeding grounds has resulted in pronounced mtDNA differences between these areas (Baker *et al.* 1990, 1998).

Only limited genetic studies have been done on gray whales. Steeves (1998) compared mtDNA from a sample of 16 seasonal resident whales from off Vancouver Island and compared them to 41 samples taken from northbound migrating whales or archived samples. She detected no significant differences in mtDNA patterns between the seasonal resident and migrating whales. The lack of a difference could result from one or more of the following: small sample size, too short time-frame for isolation to develop detectable differences, or lack of isolation of this group. The power to detect differences genetically could be limited. Rosel and Kocher (1997) were unable to detect major differences in mtDNA between 9 samples from western

North Pacific gray whales and 31 from eastern North Pacific gray whales even through these are considered separate populations.

Adequate protection of marine mammals is sensitive to the definition of the population unit used (Taylor 1997). Treating two sub-populations as one when dispersal between them is less than several percent per year could result in depleting one of these sub-populations (Taylor 1997). There is evidence from whaling data to support the existence of sub-populations of baleen whales on a relatively small geographic scale that were depleted and failed to recover (Clapham and Hatch 2000).

The degree to which seasonal resident gray whales should be managed as a unit separate from the overall gray whale population is unclear. The animals that feed in Pacific Northwest waters appear to make the southern migration to Mexico each winter and therefore are part of the larger breeding population of gray whales. Depending on the stability of this group and how animals are recruited to this strategy, they may represent a unit that should be managed separately. Although we found some evidence for maternally directed site fidelity in gray whales, as has been documented in humpback whales, there are also clear differences. The low proportion of gray whale calves documented and the possible evidence for a male bias in this group (Steeves 1998) are different than for humpback whale feeding areas. Additionally, the overall gray whale population migrates past the Pacific Northwest on route to their main feeding grounds in the Bering and Chuckchi Seas. This would provide a mechanism for animals to encounter productive feeding areas on this migration and potentially adopt this alternate feeding area.

The management implications of seasonal resident whales has been become controversial recently due to the resumption of whaling by the Makah tribe in northern Washington (Quan 2000). The management plan for the Makah hunt calls for targeting migrating whales but it is unclear how effectively current strategies would be in avoiding takes of seasonal resident whales (Quan 2000). This study shows that many gray whales identified as early as March during the gray whale migration were animals that had been seen in previous years and stayed through the summer and fall. This would make it more difficult to effectively target whales that were not part of this smaller season resident group.

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TABLES AND FIGURES

TABLES

FIGURES

Table 1. Summary of areas of effort, participating organizations, number of identifications, and dates of identifications in 1998.

Region	Region code	Description	Organizations	Identifi-cations	Unique IDs	Dates of identifications	
						Begin	End
Northern California	CA	Eureka to Oregon border wth most identifications from Patricks Pt. and Pt. St. George	Humboldt State University (HSU) Cascadia Research Collective (CRC)	27	15	21-Jul-98	10-Oct-98
Oregon coast	OR	Primarily central coast near Depoe Bay and Newport, OR	Humboldt State University (HSU) Cascadia Research Collective (CRC)	46	18	29-Jul-98	04-Oct-98
Grays Harbor & S Washington	GH+	Includes waters inside Grays Harbor and coastal waters along the S Washington coast	Cascadia Research Collective (CRC)	59	7	21-Mar-98	11-May-98
N. Washington coast	N WA	Northern outer coast waters with most effort from Cape Alava to Cape Flatery	National Marine Mammal Laboratory (NMML) Cascadia Research Collective (CRC)	44	21	06-Jun-98	18-Nov-98
U.S. Strait of Juan de Fuca	SJF	U.S. waters east of Cape Flattery extending to Admiralty Inlet (entrance to Puget Sound)	National Marine Mammal Laboratory (NMML) Cascadia Research Collective (CRC)	38	17	17-Aug-98	11-Nov-98
Northern Puget Sound	NPS	Inside waters and embayments from Edmonds to the Canadian border	Cascadia Research Collective (CRC)	27	6	12-Mar-98	20-May-98
Southern Puget Sound	SPS	Central and southern Puget Sound (south of Edmonds) and Hood Canal	Cascadia Research Collective (CRC)	6	4	18-Mar-98	17-Nov-98
Boundary Bay	BB	Canadian inside waters in and around Boundary Bay, only a single survey	Vancouver Aquarium	3	3	07-Apr-98	07-Apr-98
S. Vancouver Island	SVI	Canadian waters of the Strait of Juan de Fuca along Vancouver Is from Victoria to Barkley Sound, most effort along the West Coast Trail	West Coast Whale Research Found. (WCWRF) Juan de Fuca Express University of British Columbia (UBC) National Marine Mammal Laboratory (NMML) Cascadia Research Collective (CRC) Department of Fisheries and Oceans (DFO)	487	61	04-May-98	09-Oct-98
Central Vancouver Island	CBC	Central portion of the western coast of Vancouver Is. with heaviest effort in and around Clayoquot Sound	West Coast Whale Research Found. (WCWRF) University of Victoria (UVIC)	401	57	13-Jun-98	03-Sep-98
N of Vancouver Island, BC	NBC	British Columbia waters north of Vancouver Is., with principal effort around Cape Caution	Coastal Ecosystem Research Foundation (CERF)	100	22	03-Jul-98	11-Sep-98
SE Alaska	SEAK	Waters of southeastern Alaska with the only effort in the vicinity of Sitka (single survey)	Cascadia Research Collective (CRC)	4	4	08-Nov-98	08-Nov-98
All areas				1242	155	12-Mar-98	18-Nov-98

Table 2. Number of unique individual gray whales photographed in each region by month in 1998.

	Month									All
	Mar	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Months**
Northern California					2	1		13	1	15
Oregon coast					4	17		1		18
Grays Harbor & S Washingtor	4	7	1							7
N. Washington coast				1	12	4	8	5	1	21
U.S. Strait of Juan de Fuca						3	2	9	7	17
Northern Puget Sound	6	4	1							6
Southern Puget Sound	1							1	2	4
Boundary Bay		3								3
S. Vancouver Island			8	40	45	15	30	9		61
Central Vancouver Island				17	40	42	7			57
N of Vancouver Island, BC					18	14	3			22
SE Alaska									4	4
All areas	11	14	10	54	88	81	43	37	15	155

Table 3. Summary of identications and resighting rates of gray whales in 1998 by region.

Region	Unique IDs	No. seen more than once in 1998	No. seen in same region in a previous year	No. seen in another region in 1998	No. seen in any region in a previous year	% seen in any region in a previous year
Northern California	15	6	3	1	7	47%
Oregon coast	18	14	0	8	8	44%
Grays Harbor & S Washington	7	7	3	0	3	43%
N. Washington coast	21	19	17	17	17	81%
U.S. Strait of Juan de Fuca	17	14	3	8	7	41%
Northern Puget Sound	6	4	4	0	4	67%
Southern Puget Sound	4	2	0	0	0	0%
Boundary Bay	3	0	0	0	0	0%
S. Vancouver Island	61	60	21	49	45	74%
Central Vancouver Island	57	55	20	43	41	72%
N of Vancouver Island, BC	22	18	10	14	22	100%
SE Alaska	4	0	0	0	1	25%
All areas	155	119		57	86	55%

Table 4a. Matrix of matches between region within 1998. Bold numbers along the diagonal show number of animals resighted

Region		**Region**									
	n	**CA**	**OR**	**GH+**	**N WA**	**SJF**	**PS/BB**	**SVI**	**CBC**	**NBC**	**SEAK**
Northern California	15	**5**									
Oregon coast	18		**12**								
Grays Harbor & S Washington	7			**7**							
N. Washington coast	21		1		**19**						
U.S. Strait of Juan de Fuca	17				3	**14**					
Puget Sound/Boundary Bay	13						**4**				
S. Vancouver Island	61	1	6		17	8		**60**			
Central Vancouver Island	57		6		8	4		33	**57**		
N of Vancouver Island, BC	22				1	1		7	9	**18**	
SE Alaska	4										**0**

Table 4b. Matrix of matches for whales sighted in 1998 and other years between regions. Diagonal (bold) shows number of whales seen both in 1998 and a previous year in the same region.

	n for	**Region sighted prior to 1998**									
Region sighted in 1998	**1998**	**CA**	**OR**	**GH+**	**N WA**	**SJF**	**PS/BB**	**SVI**	**CBC**	**NBC**	**SEAK**
Northern California	15	**4**		2	1	2					
Oregon coast	18		**0**	2	6	1		3	2	1	
Grays Harbor & S Washington	7			**3**	1						
N. Washington coast	21				**19**	9		10	6	5	
U.S. Strait of Juan de Fuca	17				2	**3**		5	5	5	
Puget Sound/Boundary Bay	13						**4**	1			
S. Vancouver Island	61			1	25	16		**21**	20	20	
Central Vancouver Island	57	1		3	17	8		10	**20**	19	
N of Vancouver Island, BC	22				2	1		2	3	**21**	
SE Alaska	4				1	1					**0**

Table 5. Summary of sighting rates and parameters for gray whales identified in 1998 for whales ientified in previous years and whales not identified in previous years.

	All whales			Seen previous years			Not seen prev. years		
	n	**Ave**	**SD**	**n**	**Ave**	**SD**	**n**	**Ave**	**SD**
Times seen by region									
Northern California	15	1.8	1.3	7	1.9	1.6	8	1.8	1.2
Oregon coast	18	2.6	2.4	8	2.1	2.1	10	3.0	2.6
Grays Harbor & S Washington	7	8.3	3.9	3	6.0	4.0	4	10.0	3.4
N. Washington coast	21	2.1	2.3	17	2.2	2.5	4	1.8	1.0
U.S. Strait of Juan de Fuca	17	2.2	1.7	7	1.3	0.5	10	2.8	2.0
Northern Puget Sound	6	4.5	2.8	4	4.8	2.6	2	4.0	4.2
Southern Puget Sound	4	1.5	0.6	0			4	1.5	0.6
Boundary Bay	3	1.0	0.0	0			3	1.0	0.0
S. Vancouver Island	61	8.0	7.3	45	8.8	7.3	16	5.6	6.9
Central Vancouver Island	57	7.0	7.0	41	7.4	6.4	16	6.1	8.6
N of Vancouver Island, BC	22	4.5	4.6	22	4.5	4.6	0		
SE Alaska	4	1.0	0.0	1	1.0		3	1.0	0.0
All areas	155	8.0	8.3	86	10.6	9.0	69	4.7	6.1
Number of regions seen	155	1.5	0.8	86	1.8	0.8	69	1.2	0.4
First date seen (SD in days)	155	13-Jul	61.4	86	29-Jun	47.7	69	30-Jul	71.7
Last date seen (SD in days)	155	24-Aug	57.9	86	28-Aug	49.2	69	19-Aug	67.3
Tenure (minimum days)	155	42.8	44.0	86	60.6	45.9	69	20.6	29.2

Table 6. Summary of identications and resighting rates of gray whales in 1998 in relation to season.

Season	Unique IDs	No. seen in more than one month/season in 1998	% seen in more than one season in 1998	No. known from a previous year	% known from a previous year
By month					
March	11	8	73%	5	45%
April	14	9	64%	6	43%
May	10	9	90%	6	60%
June	54	54	100%	44	81%
July	89	80	90%	62	70%
August	83	69	83%	60	72%
September	43	41	95%	35	81%
October	37	21	57%	21	57%
November	14	5	36%	3	21%
By season					
Spring (March to May)	25	7	28%	13	52%
Summer (June to August)	107	45	42%	72	67%
Fall (September to November)	74	44	59%	46	62%
All seasons	155	45	29%	86	55%

Table 7. Petersen capture-recapture estimates for seasonal resident gray whales
Both samples exclude IDs from only Puget Sound area and Grays Harbor.

Sample 1		Sample 2				
Year	**n**	**Year**	**n**	**Match**	**Est.**	**CV**
1997	30	1998	145	22	**196**	0.10
1996	31	1998	145	24	**186**	0.08

With added exclussion of animals seen only before 1 June

Sample 1		Sample 2				
Year	**n**	**Year**	**n**	**Match**	**Est.**	**CV**
1997	29	1998	134	22	**175**	0.09
1996	28	1998	134	22	**169**	0.09

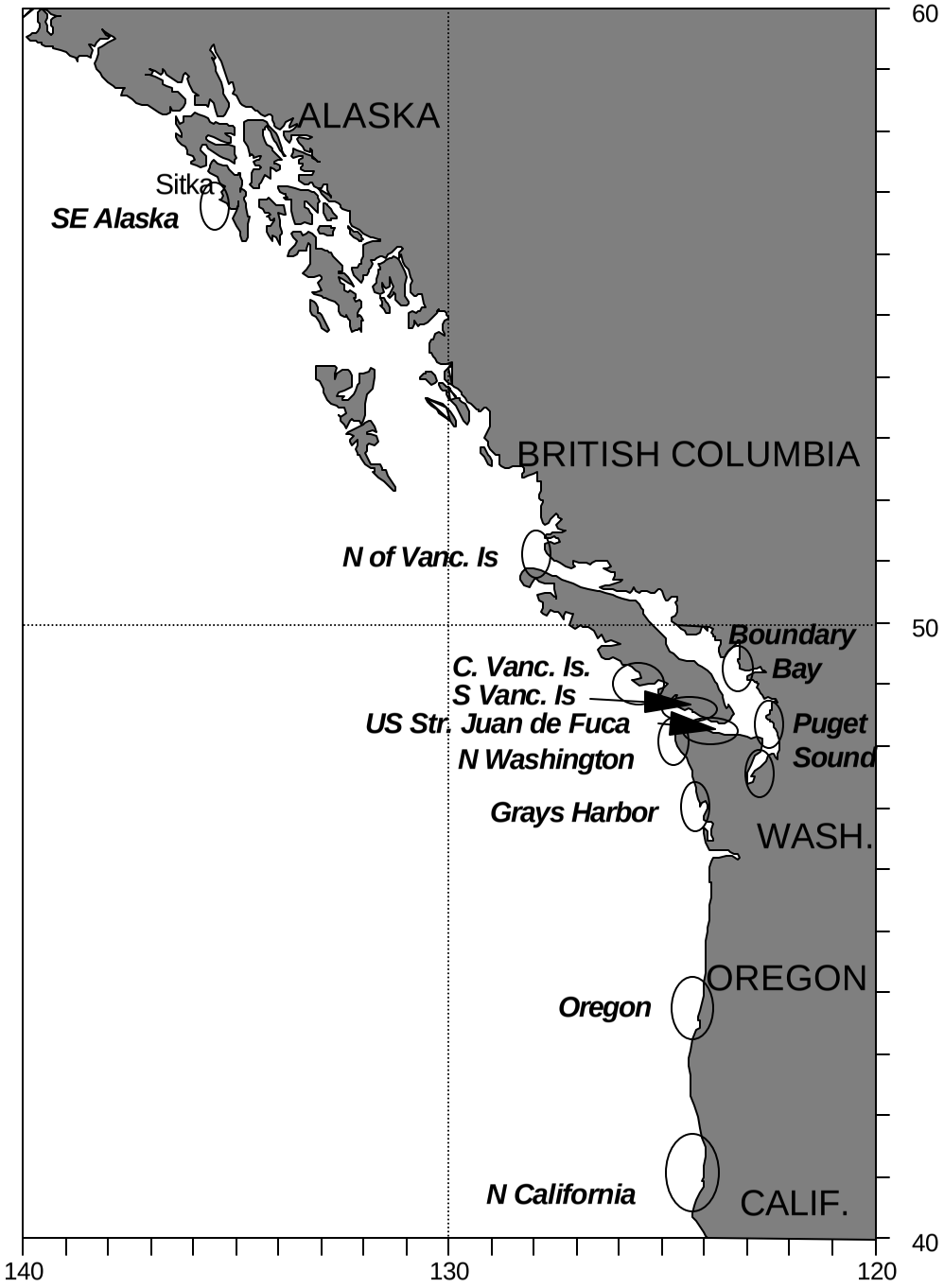

Figure 1. Study area showing principal areas of effort.

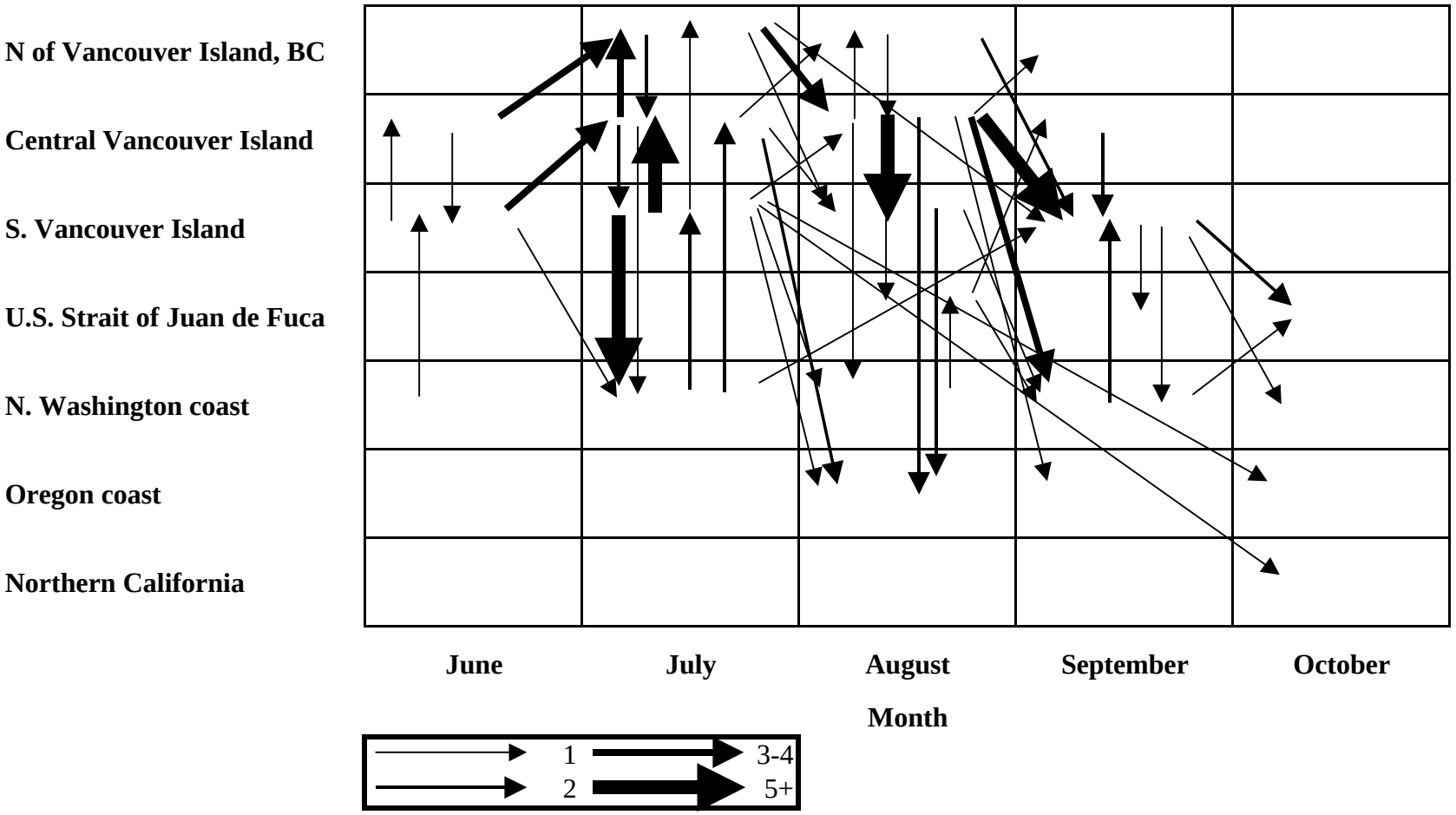

Figure 2. Movements of gray whales among locations in 1998. Size of arrow indicates number of transits. Movements within a month are shown as vertical lines and moves from one month to the next are on diagonals.

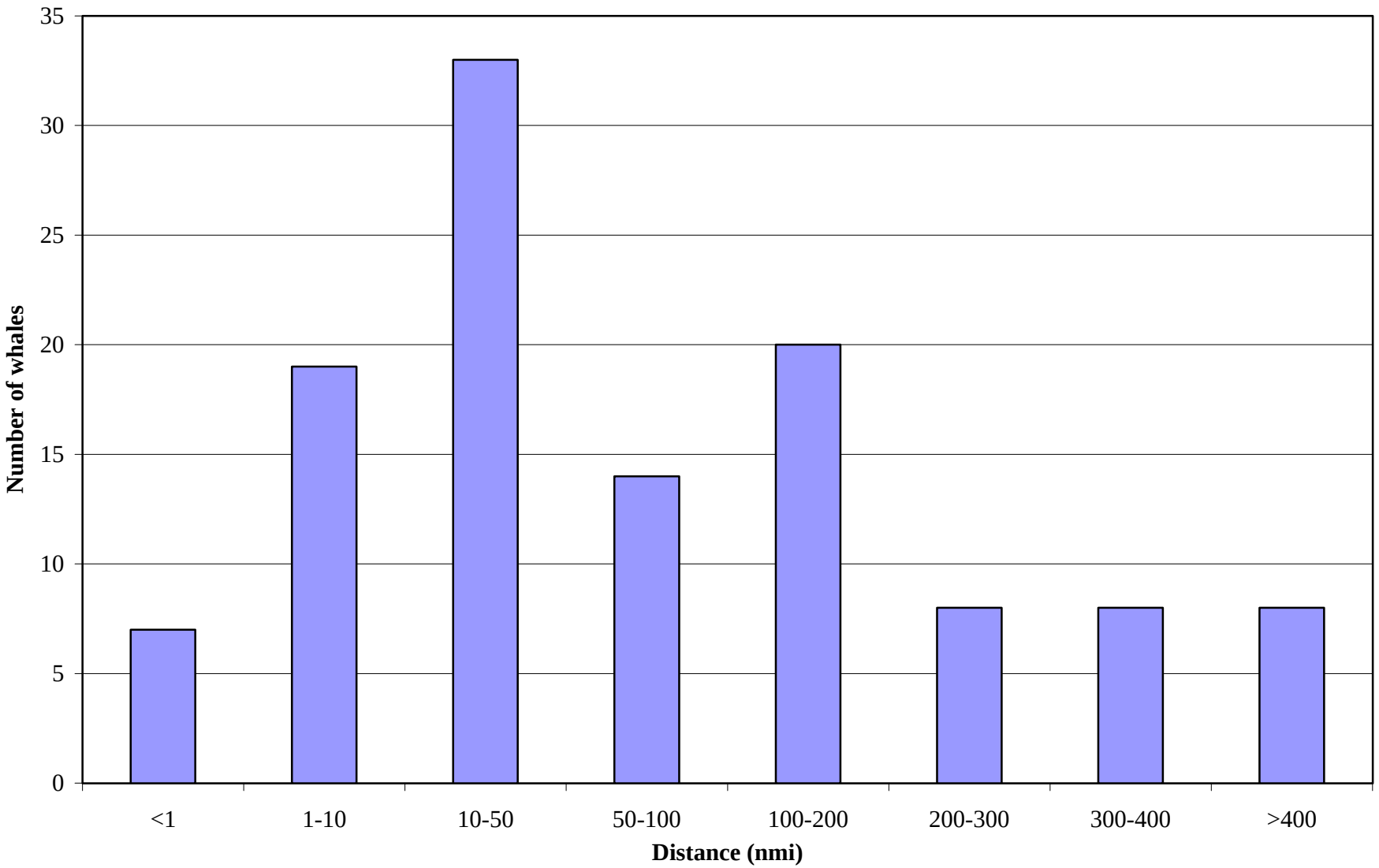

Figure 3. Histogram showing range of minimum distances documented for 116 gray whales identified multiple times.

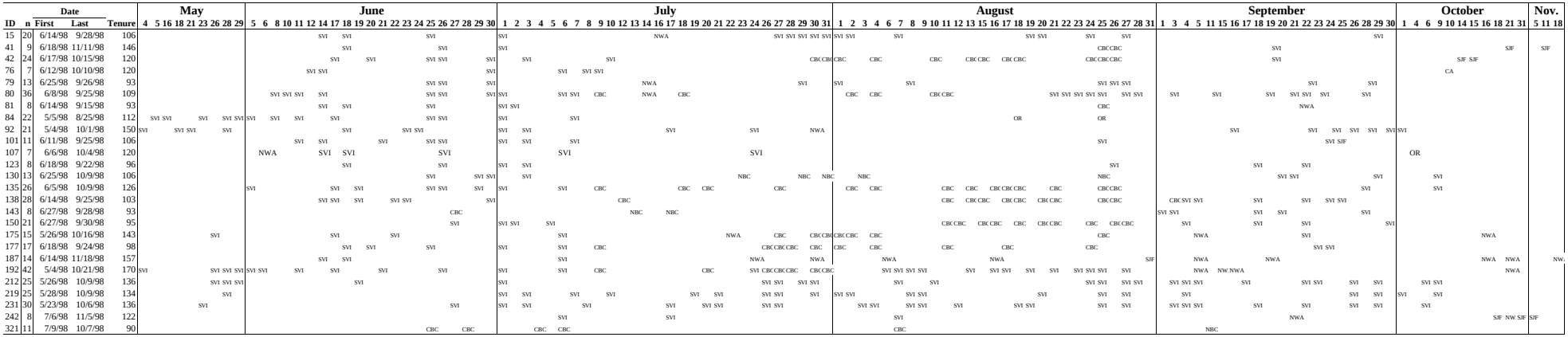

Figure 4. Dates and locations whales were seen for individuals seen over a 90 day period or longer.