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Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas revision of estimates in SC/66b/IA21

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INTERNATIONAL WHALING COMMISSION

Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas – revision of estimates in SC/66b/IA21

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The first comprehensive photo-identification study of humpback whales throughout the North Pacific occurred in 2004-2006 during the SPLASH project (Structure of Populations, Levels of Abundance and Status of Humpbacks). Total abundance for the entire North Pacific was estimated by Barlow et al. (2011) to be 21,808 (CV=0.04). Wade et al. (SC/66b/IA21) presented estimates of abundance from the SPLASH data for all sampled winter and summer areas in the North Pacific, as well as estimate migration rates between these areas.

Subsequent to the IWC SC meeting, it was discovered that the multistrata model analyses were not necessarily converging to the correct answer. The program MARK, used for the analyses via RMark code, has an option to use a more robust convergence routine called "simulated annealing". Therefore, the analyses were repeated using the simulated annealing option, which takes about 200-300 times longer than the regular convergence routine, with some models taking several days to run. The best model is the same as in SC/66b/IA21, where a single survival rate is fixed for all areas, capture probability varies by stratum and year, and the movement probabilities are non-markov, where the probability of moving to a stratum is dependent on whether an individual whale had been seen there before.

Compared to the results in SC/66b/IA21, the revised results for summer areas led to much lower estimates of abundance for Kamchatka, Southeast Alaska/Northern British Columbia, and California, with the estimate for the Aleutian Islands and Bering Sea much higher (Fig 2-3, Table 1). The winter area estimates were not changed as much (Fig 2, Fig 4, Table 2).

As noted previously, the summer area abundance estimates are sensitive to the assumed annual survival rate (Fig 5). However, they are not sensitive to changes within the range 0.92 to 0.98, which likely contains the true value. When the analysis is allowed to try to estimate the survival rate, the estimate is an annual rate of 0.753, which is much too low. The winter area estimates are not sensitive to the assumed survival rate.

Different formulations of the data from Mexico were run, as it is known that whales from the Revillagigedo offshore islands have different migration probabilities than whales from Mainland Mexico. Therefore, two models with 5 winter-areas were tried, where the Revillagigedo Islands form one stratum, and Mainland Mexico forms a second stratum. In one, the data from Baja were discarded, and in the other, the data from Baja were added to the Mainland Mexico stratum. The resulting migration probabilities show the very different migration destinations for these two areas (Table 4).

References

Wade, P.R., Quinn II, T.J., Barlow, J, Baker, C.S., Burdin, A.M., Calambokidis, J., Clapham, P.J., Falcone, E., Ford, J.K.B., Gabriele, C.M., Leduc, R., Mattila, D.K., Rojas-Bracho, L., Straley, J., Taylor, B.L., Urbán R., J., Weller, D., Witteveen, B.H., Yamaguchi, M. 2016. Estimates of abundance and migratory destination for North Pacific humpback whales in both summer feeding areas and winter mating and calving areas. Paper SC/66b/IA21 submitted to the Scientific Committee of the International Whaling Commission, June 2016, Bled, Slovenia

Figure 1. Regional Strata for the analysis, with summer areas in blue and winter areas in green. Within Asia, subareas are connected with thin green lines, representing Okinawa ("A"), Philippines ("B"), and Ogasawara ("C"). Within the Aleutian Islands and Bering Sea, a thin blue line connects the Gulf of Anadyr subarea to the rest of the area. The polygons roughly enclose where survey effort occurred for each area.

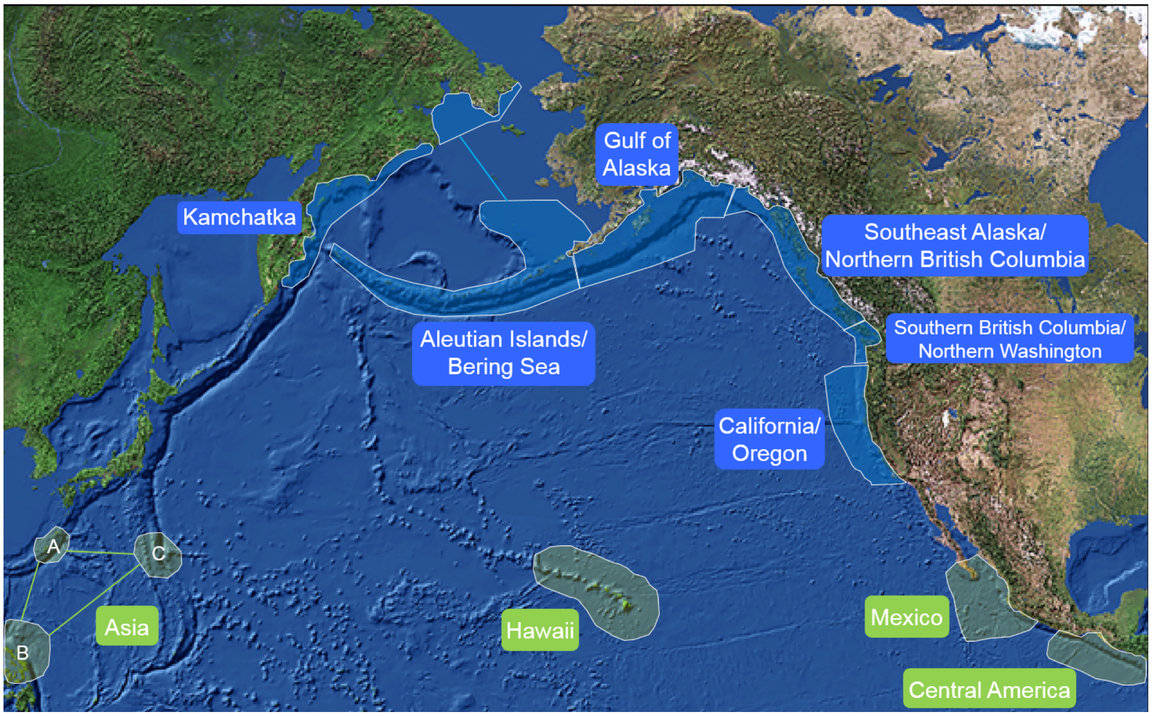


Figure 2. Abundance by area for summer (blue) and winter (green) areas, with 95% log-normal confidence limits in parentheses. Also shown are the estimated migratory destinations for each summer area (representing the breeding population composition found in the summer area), with the width of the arrow proportional to the percentage of whales in the feeding area that move to that winter/breeding area. Exact estimates are in Table 3. Areas are as in Figure 1.

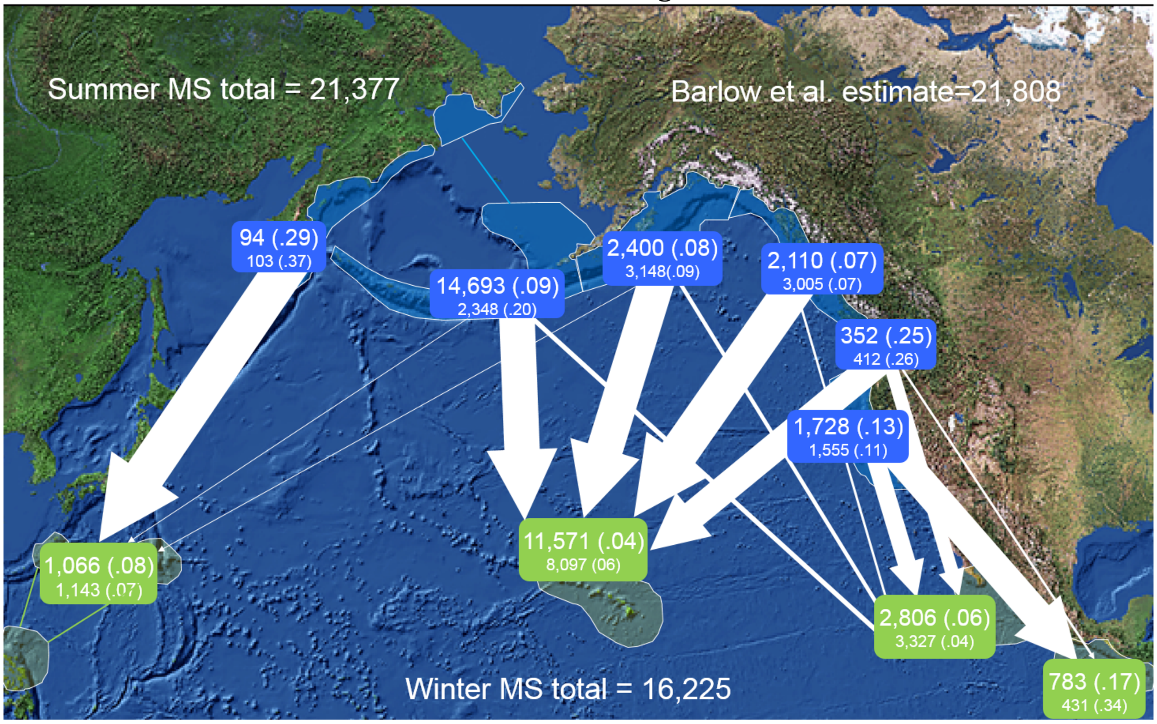
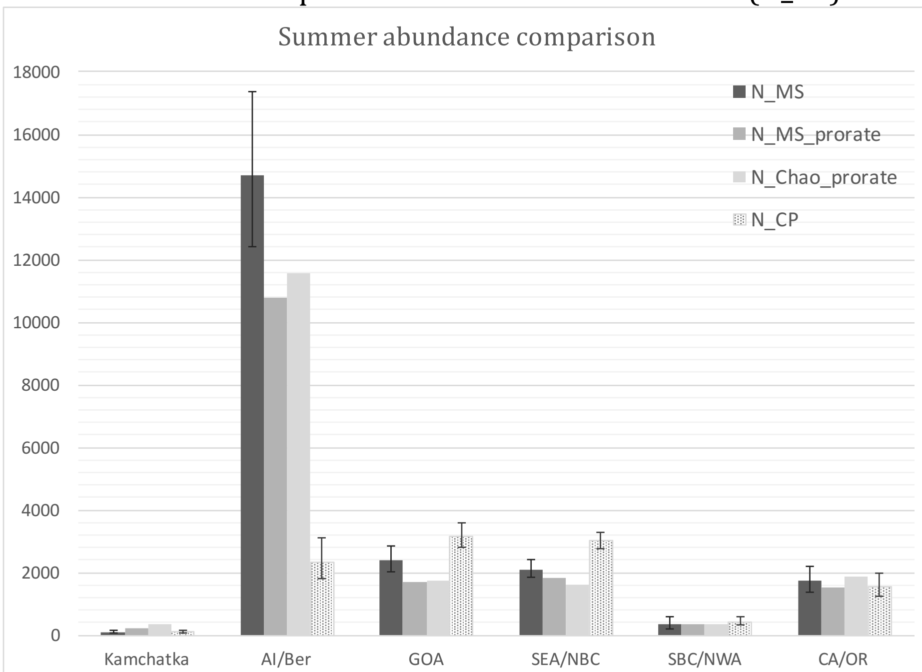


Figure 3. Comparison of summer abundance estimates, including the Multistrata estimates (N_MS), estimates extrapolated from the Multistrata winter abundance prorated by migration rates (N_MS_prorated), estimates extrapolated from the Chao winter abundance prorated by the Multistrata migration rates (N_Chao_prorated), and the summer-summer Chapman-Peterson model estimates (N_CP).



With an expanded y-axis

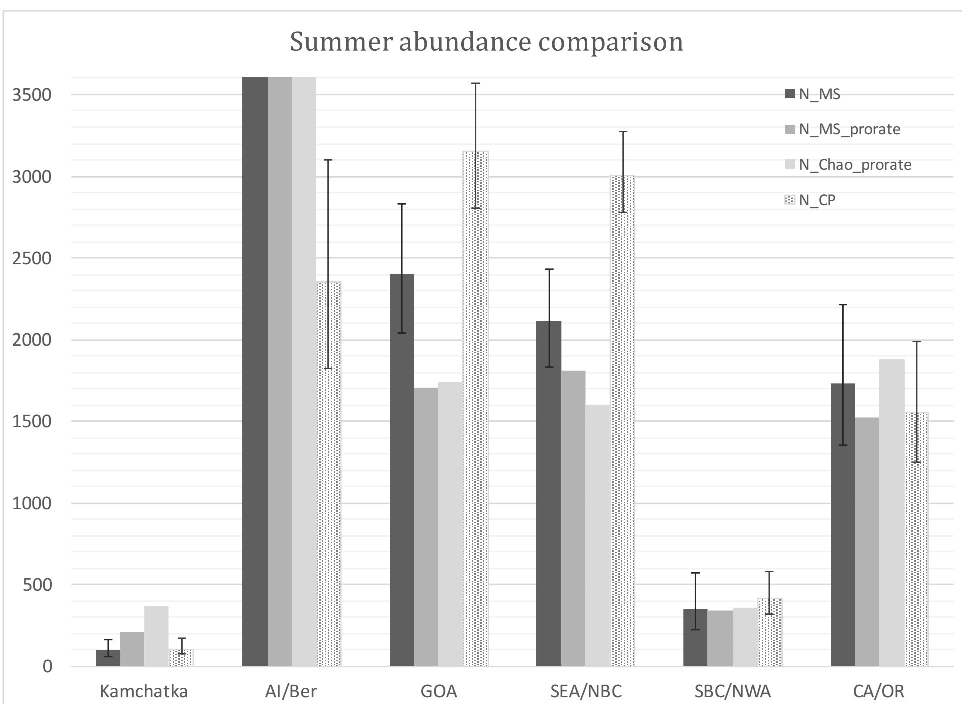
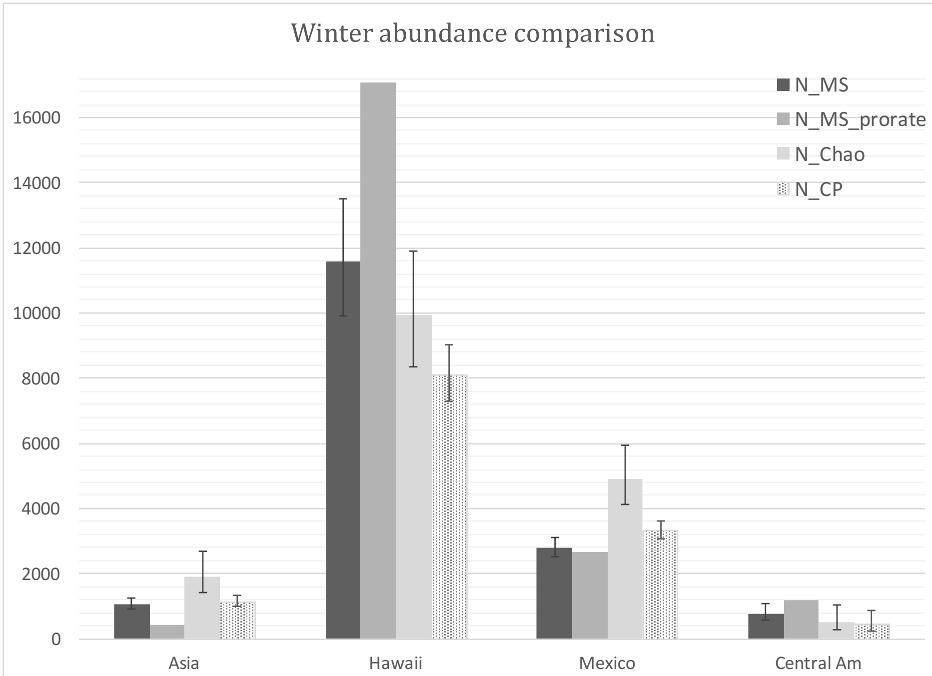


Figure 4. Comparison of winter abundance estimates, including the Multistrata estimates (N_MS), estimates extrapolated from the Multistrata summer abundance prorated by migration rates (N_MS_prorated), the Chao Mth winter-winter estimates (N_Chao), and the winter-winter Chapman-Peterson model estimates (N_CP).



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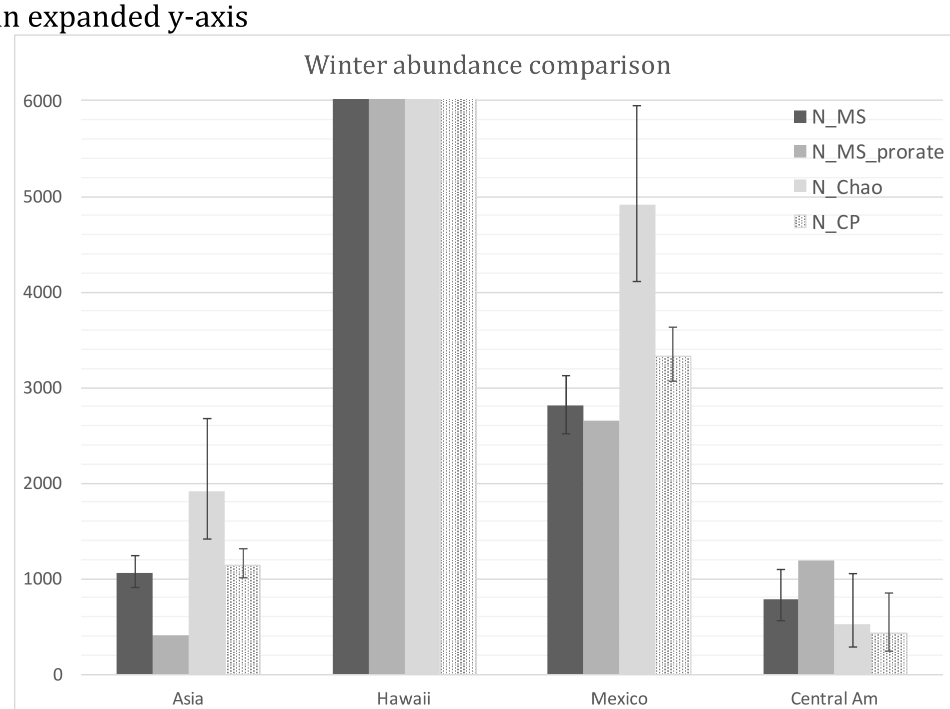
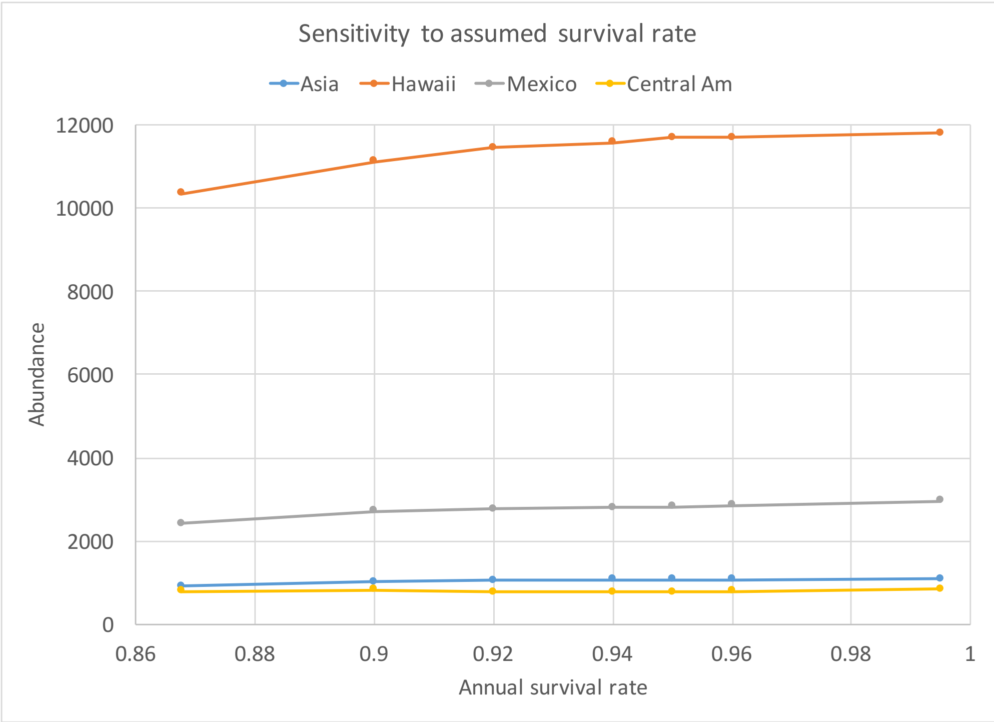


Figure 5. Sensitivity to the assumed survival rate. When allowed to be estimated, the estimate was an annual rate of 0.753, which is too low.

A. Winter area abundance estimates.



B. Summer area abundance estimates.

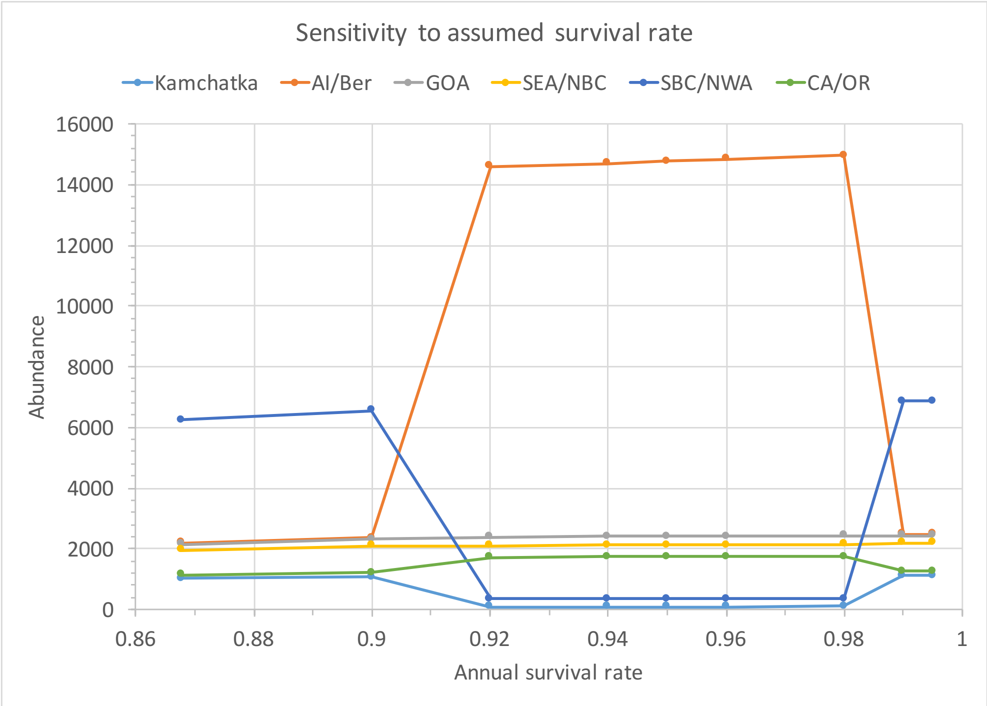


Table 1. Estimates of abundance for summer areas, with estimates from the Multistrata model (N_{multi}) and the Chapman-Peterson summer-summer model (N_{CP}). In each case, CV is the Coefficient of Variation. Total is the total abundance summed across all strata.

Stratum	N_{multi}	CV	N_{CP}	CV
Kamchatka	94	0.288	103	0.230
AI/Ber	14,693	0.086	2,348	0.137
GOA	2,400	0.084	3,148	0.062
SEA/NBC	2,110	0.073	3,005	0.042
SBC/NWA	352	0.249	412	0.156
CA/OR	1,728	0.126	1,555	0.119
Total	15,805		10,572	

Table 2. Abundance estimates for winter areas, defined as n/p. N_{multi} is the estimate from the Multistrata model using both winter and summer data, N_{CP} is the estimate from the Chapman-Peterson winter-winter model, and N_{Chao} is the estimate from the Chao winter-winter model. In each case, CV is the Coefficient of Variation. Total is the total abundance summed across all strata.

Stratum	N_{multi}	CV	N_{CP}	CV	N_{Chao}	CV
Asia	1,066	0.079	1,143	0.068	1,907	0.165
Hawaii	11,571	0.042	8,097	0.055	9,920	0.090
Mexico	2,806	0.055	3,327	0.043	4,910	0.095
Central Am	783	0.170	431	0.339	519	0.353
Total	16,225		12,999		17,256	

Table 3. Movement probabilities for the multi-strata model.
a. Probability of moving from each winter area (on left) to each summer area (as columns).

	Area moving to					
Area moving from	Kamchatka	AI/Bering	GOA	SE/NBC	SBC/WA	OR/CA
Asia	0.054	0.946	0.000	0.000	0.000	0.000
Hawaii	0.000	0.711	0.120	0.152	0.016	0.000
Mexico	0.000	0.552	0.111	0.020	0.033	0.284
Central America	0.000	0.000	0.000	0.000	0.074	0.926

b. Probability of moving from each summer area (on left) to each winter area (as columns).

	Area moving to			
Area moving from	Asia	Hawaii	Mexico	Central America
Kamchatka	1.000	0.000	0.000	0.000
AI/Bering	0.021	0.868	0.110	0.000
GOA	0.004	0.872	0.120	0.000
SE/NBC	0.000	0.961	0.038	0.000
SBC/WA	0.000	0.635	0.279	0.087
OR/CA	0.000	0.000	0.327	0.672

Table 4. Movement probabilities from the multi-strata model for three different treatments of the data from Mexico. In the first, the data from Mexico were pooled as a single stratum. In the second, the data were split into 2 strata (Revillagigedo and Mainland Mexico) so that there were 5 winter areas, rather than 4, with the data from Baja discarded. The third variant was as the second, but with the data from Baja pooled with data from Mainland Mexico.

	Area moving to					
Area moving from	Kamchatka	AI/Bering	GOA	SE/NBC	SBC/WA	OR/CA
Mexico (pooled)	0.000	0.552	0.111	0.020	0.033	0.284
Mex - Revillagigedo	0.000	0.803	0.163	0.023	0.011	0.000
Mex - Mainland	0.000	0.135	0.034	0.012	0.043	0.775
Mex - Revillagigedo	0.000	0.784	0.182	0.022	0.012	0.000
Mex - Mainland + Baja	0.000	0.412	0.062	0.017	0.043	0.466