The following supplement accompanies the article

Abundance estimates for management of endangered false killer whales in the main Hawaiian Islands

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Table S1. Estimated mark-recapture parameters resulting from the: (1) POPAN abundance estimation of the full main Hawaiian Island false killer whale dataset (2000-2015); (2) POPAN sensitivity analyses using various data subsets, specifically data collected by only Cascadia Research Collective (CRC), data from only the years 2008-2015, data from only the months of July through December, and data obtained only from Hawai‘i Island; and (3) Cormack-Jolly-Seber (CJS) survival estimation of the full dataset. Parameter notation is explained in the Materials and methods: Abundance estimation in the main text; the SE follows each model-averaged estimate.

	All		*CRC*		*08-15*		*Jul-Dec*		*Hawai‘i*		*CJS*	
Parameter	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
$\phi_{cluster\ 1}$	0.939	0.012	0.954	0.014	0.856	0.030	0.913	0.014	0.963	0.023	0.943	0.013
$\phi_{cluster\ 2}$	0.939	0.012	0.954	0.014	0.856	0.030	0.913	0.014	0.963	0.023	0.954	0.023
$\phi_{cluster\ 3}$	0.939	0.012	0.954	0.014	0.856	0.030	0.913	0.014	0.963	0.023	0.944	0.016
$p_{2000,\ cluster\ 1}$	0.194	0.059	0.217	0.105	n/a	n/a	0.184	0.070	n/a	n/a	n/a	n/a
$p_{2001,\ cluster\ 1}$	0.228	0.064	0.255	0.122	n/a	n/a	0.000	0.000	n/a	n/a	0.250	0.132
$p_{2002,\ cluster\ 1}$	0.056	0.034	0.033	0.018	n/a	n/a	0.089	0.052	n/a	n/a	<0.001	<0.001
$p_{2003,\ cluster\ 1}$	0.329	0.076	0.170	0.041	n/a	n/a	0.000	0.000	n/a	n/a	0.104	0.069
$p_{2004,\ cluster\ 1}$	0.564	0.085	0.317	0.057	n/a	n/a	0.786	0.082	>0.999	0.007	0.578	0.089
$p_{2005,\ cluster\ 1}$	0.347	0.079	0.000	0.000	n/a	n/a	0.184	0.081	0.072	0.042	0.330	0.081
$p_{2006,\ cluster\ 1}$	0.273	0.060	0.048	0.023	n/a	n/a	0.127	0.041	0.116	0.054	0.251	0.070
$p_{2007,\ cluster\ 1}$	0.213	0.056	0.081	0.031	n/a	n/a	0.246	0.055	0.134	0.058	0.232	0.066
$p_{2008,\ cluster\ 1}$	0.670	0.060	0.396	0.066	0.593	0.247	0.700	0.060	0.691	0.090	0.727	0.060
$p_{2009,\ cluster\ 1}$	0.595	0.057	0.205	0.044	0.671	0.095	0.64	0.053	0.304	0.068	0.602	0.069

	All		*CRC*		*08-15*		*Jul-Dec*		*Hawai'i*		*CJS*	
Parameter	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
$p_{2010,\ cluster\ 1}$	0.876	0.037	0.777	0.068	0.938	0.030	0.952	0.018	0.772	0.064	0.825	0.050
$p_{2011,\ cluster\ 1}$	0.754	0.056	0.517	0.075	0.868	0.053	0.845	0.043	0.656	0.082	0.736	0.060
$p_{2012,\ cluster\ 1}$	0.294	0.067	0.000	0.000	0.349	0.096	0.209	0.063	0.150	0.055	0.286	0.068
$p_{2013,\ cluster\ 1}$	0.319	0.073	0.031	0.020	0.415	0.113	0.429	0.082	0.178	0.063	0.303	0.073
$p_{2014,\ cluster\ 1}$	0.473	0.083	0.033	0.021	0.659	0.113	0.300	0.08	0.149	0.060	0.458	0.083
$p_{2015,\ cluster\ 1}$	0.501	0.087	0.152	0.051	0.746	0.124	0.438	0.093	0.287	0.088	0.468	0.087
$p_{2000,\ cluster\ 2}$	0.044	0.018	0.186	0.109	n/a	n/a	0.025	0.012	n/a	n/a	n/a	n/a
$p_{2001,\ cluster\ 2}$	0.054	0.021	0.220	0.126	n/a	n/a	0.000	0.000	n/a	n/a	0.072	0.051
$p_{2002,\ cluster\ 2}$	0.011	0.007	0.027	0.017	n/a	n/a	0.011	0.007	n/a	n/a	<0.001	<0.001
$p_{2003,\ cluster\ 2}$	0.086	0.031	0.144	0.051	n/a	n/a	0.000	0.000	n/a	n/a	0.027	0.020
$p_{2004,\ cluster\ 2}$	0.199	0.062	0.274	0.081	n/a	n/a	0.293	0.092	>0.999	0.007	0.243	0.080
$p_{2005,\ cluster\ 2}$	0.093	0.033	0.000	0.000	n/a	n/a	0.025	0.013	0.033	0.022	0.104	0.041
$p_{2006,\ cluster\ 2}$	0.067	0.023	0.040	0.023	n/a	n/a	0.016	0.007	0.055	0.030	0.073	0.030
$p_{2007,\ cluster\ 2}$	0.049	0.019	0.068	0.032	n/a	n/a	0.036	0.012	0.063	0.033	0.066	0.027
$p_{2008,\ cluster\ 2}$	0.281	0.066	0.347	0.093	0.138	0.108	0.208	0.050	0.495	0.121	0.383	0.085
$p_{2009,\ cluster\ 2}$	0.220	0.049	0.172	0.047	0.182	0.068	0.167	0.038	0.160	0.049	0.262	0.069
$p_{2010,\ cluster\ 2}$	0.575	0.081	0.736	0.070	0.625	0.114	0.690	0.079	0.598	0.082	0.525	0.092
$p_{2011,\ cluster\ 2}$	0.371	0.070	0.461	0.072	0.419	0.103	0.382	0.066	0.455	0.083	0.394	0.074
$p_{2012,\ cluster\ 2}$	0.074	0.025	0.000	0.000	0.055	0.027	0.029	0.012	0.072	0.030	0.086	0.030
$p_{2013,\ cluster\ 2}$	0.082	0.028	0.025	0.016	0.072	0.035	0.078	0.025	0.087	0.035	0.093	0.032
$p_{2014,\ cluster\ 2}$	0.147	0.044	0.027	0.017	0.175	0.073	0.046	0.018	0.072	0.032	0.165	0.049
$p_{2015,\ cluster\ 2}$	0.162	0.048	0.125	0.041	0.243	0.109	0.081	0.028	0.150	0.054	0.171	0.052
$p_{2000,\ cluster\ 3}$	0.097	0.033	0.220	0.118	n/a	n/a	0.054	0.023	n/a	n/a	n/a	n/a
$p_{2001,\ cluster\ 3}$	0.116	0.038	0.259	0.136	n/a	n/a	0.000	0.000	n/a	n/a	0.110	0.073
$p_{2002,\ cluster\ 3}$	0.026	0.016	0.033	0.018	n/a	n/a	0.024	0.015	n/a	n/a	<0.001	<0.001
$p_{2003,\ cluster\ 3}$	0.179	0.050	0.172	0.043	n/a	n/a	0.000	0.000	n/a	n/a	0.041	0.031
$p_{2004,\ cluster\ 3}$	0.365	0.077	0.321	0.060	n/a	n/a	0.483	0.098	>0.999	0.007	0.337	0.086
$p_{2005,\ cluster\ 3}$	0.191	0.057	0.000	0.000	n/a	n/a	0.054	0.026	0.016	0.011	0.155	0.051
$p_{2006,\ cluster\ 3}$	0.143	0.041	0.049	0.024	n/a	n/a	0.036	0.014	0.027	0.015	0.111	0.040
$p_{2007,\ cluster\ 3}$	0.108	0.035	0.082	0.032	n/a	n/a	0.077	0.024	0.031	0.017	0.101	0.037
$p_{2008,\ cluster\ 3}$	0.475	0.075	0.401	0.071	0.292	0.170	0.373	0.066	0.316	0.095	0.496	0.081
$p_{2009,\ cluster\ 3}$	0.395	0.065	0.209	0.050	0.366	0.099	0.311	0.056	0.083	0.032	0.360	0.075

	All		*CRC*		*08-15*		*Jul-Dec*		*Hawai'i*		*CJS*	
Parameter	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
$p_{2010,\ cluster\ 3}$	0.758	0.068	0.780	0.072	0.811	0.084	0.834	0.058	0.413	0.104	0.637	0.087
$p_{2011,\ cluster\ 3}$	0.577	0.081	0.522	0.084	0.651	0.110	0.582	0.079	0.283	0.087	0.508	0.084
$p_{2012,\ cluster\ 3}$	0.156	0.047	0.000	0.000	0.131	0.060	0.063	0.025	0.035	0.018	0.129	0.042
$p_{2013,\ cluster\ 3}$	0.172	0.053	0.032	0.021	0.167	0.074	0.161	0.048	0.043	0.021	0.139	0.046
$p_{2014,\ cluster\ 3}$	0.285	0.073	0.034	0.022	0.354	0.117	0.099	0.036	0.035	0.019	0.239	0.067
$p_{2015,\ cluster\ 3}$	0.309	0.079	0.155	0.057	0.454	0.149	0.166	0.053	0.077	0.035	0.246	0.070
b_{2001}	<0.001	<0.001	<0.001	<0.001	n/a	n/a	<0.001	<0.001	n/a	n/a	n/a	n/a
b_{2002}	<0.001	<0.001	0.300	0.186	n/a	n/a	<0.001	<0.001	n/a	n/a	n/a	n/a
b_{2003}	<0.001	<0.001	<0.001	<0.001	n/a	n/a	<0.001	<0.001	n/a	n/a	n/a	n/a
b_{2004}	<0.001	<0.001	<0.001	<0.001	n/a	n/a	<0.001	<0.001	n/a	n/a	n/a	n/a
b_{2005}	0.118	0.099	<0.001	<0.001	n/a	n/a	<0.001	<0.001	0.406	0.098	n/a	n/a
b_{2006}	0.016	0.079	<0.001	<0.001	n/a	n/a	0.344	0.070	<0.001	<0.001	n/a	n/a
b_{2007}	<0.001	<0.001	<0.001	<0.001	n/a	n/a	<0.001	<0.001	<0.001	0.006	n/a	n/a
b_{2008}	<0.001	<0.001	<0.001	<0.001	n/a	n/a	<0.001	<0.001	<0.001	<0.001	n/a	n/a
b_{2009}	0.154	0.044	0.169	0.066	<0.001	0.330	0.068	0.041	0.173	0.082	n/a	n/a
b_{2010}	<0.001	<0.001	<0.001	<0.001	0.007	0.069	<0.001	<0.001	<0.001	<0.001	n/a	n/a
b_{2011}	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.009	0.010	<0.001	<0.001	n/a	n/a
b_{2012}	0.014	0.019	<0.001	<0.001	0.077	0.050	<0.001	<0.001	0.104	0.070	n/a	n/a
b_{2013}	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	n/a	n/a
b_{2014}	0.033	0.032	<0.001	<0.001	0.010	0.036	0.031	0.032	<0.001	<0.001	n/a	n/a
b_{2015}	0.079	0.050	0.135	0.081	0.068	0.048	0.066	0.050	0.139	0.120	n/a	n/a
$N_{cluster\ 1}$	96	6	80	9	81	7	79	6	78	10	n/a	n/a
$N_{cluster\ 2}$	69	10	60	9	64	12	76	11	60	10	n/a	n/a
$N_{cluster\ 3}$	61	6	53	7	51	7	67	8	70	14	n/a	n/a

Table S2. Model selection results from the: (1) POPAN sensitivity analyses, related to the mark-recapture abundance estimation of main Hawaiian Island false killer whales, that used various data subsets, specifically data collected by only Cascadia Research Collective (CRC), data from only the years 2008-2015, data from only the months of July through December, and data obtained only from Hawai‘i Island; and 2) Cormack-Jolly-Seber (CJS) survival estimation of the full dataset (2000-2015). The notation of the models and parameters is explained in ‘Materials and methods: Abundance estimation’ in the main text. QAICc is the quasi-Akaike’s information criterion corrected for small sample size; ΔQAICc is the difference in the QAICc of a given model from the QAICc of the best model; QAICc weight is the quasi-Akaike weight used for model averaging. Note the data from the July through December subset were not overdispersed; thus, AICc values were used.

Model	QAICc	ΔQAICc	QAICc weight	No. parameters
CRC				
$\phi(.)\ p(t)\ b(t)\ N(c)$	965.55	0.00	0.602	35
$\phi(.)\ p(t+c)\ b(t)\ N(c)$	966.38	0.83	0.398	37
$\phi(.)\ p(s(T))\ b(t)\ N(c)$	1064.34	98.79	0.000	26
$\phi(.)\ p(s(T)+c)\ b(t)\ N(c)$	1067.77	102.22	0.000	28
$\phi(.)\ p(T)\ b(t)\ N(c)$	1285.56	320.00	0.000	21
$\phi(.)\ p(.)\ b(t)\ N(c)$	1286.32	320.77	0.000	20
$\phi(.)\ p(c)\ b(t)\ N(c)$	1288.06	322.51	0.000	22
$\phi(.)\ p(T+c)\ b(t)\ N(c)$	1289.33	323.78	0.000	23
08-15				
$\phi(.)\ p(t+c)\ b(t)\ N(c)$	453.35	0.00	>0.999	21
$\phi(.)\ p(s(T)+c)\ b(t)\ N(c)$	471.49	18.14	<0.001	17
$\phi(.)\ p(t)\ b(t)\ N(c)$	484.38	31.03	<0.001	19
$\phi(.)\ p(T+c)\ b(t)\ N(c)$	489.72	36.37	<0.001	15
$\phi(.)\ p(s(T))\ b(t)\ N(c)$	490.13	36.78	<0.001	15
$\phi(.)\ p(c)\ b(t)\ N(c)$	494.27	40.93	<0.001	14
$\phi(.)\ p(T)\ b(t)\ N(c)$	502.35	49.00	<0.001	13
$\phi(.)\ p(.)\ b(t)\ N(c)$	509.08	55.73	<0.001	12
Jul-Dec				
$\phi(.)\ p(t+c)\ b(t)\ N(c)$	1154.78	0.00	1.000	37
$\phi(.)\ p(t)\ b(t)\ N(c)$	1225.40	70.62	0.000	35
$\phi(.)\ p(s(T)+c)\ b(t)\ N(c)$	1276.82	122.04	0.000	28
$\phi(.)\ p(s(T))\ b(t)\ N(c)$	1324.63	169.85	0.000	26
$\phi(.)\ p(T+c)\ b(t)\ N(c)$	1421.68	266.90	0.000	23
$\phi(.)\ p(c)\ b(t)\ N(c)$	1422.81	268.03	0.000	22
$\phi(.)\ p(T)\ b(t)\ N(c)$	1470.63	315.85	0.000	21
$\phi(.)\ p(.)\ b(t)\ N(c)$	1476.69	321.91	0.000	20
Hawai‘i				
$\phi(.)\ p(t+c)\ b(t)\ N(c)$	619.59	0.00	>0.999	29
$\phi(.)\ p(t)\ b(t)\ N(c)$	638.04	18.45	<0.001	27
$\phi(.)\ p(s(T)+c)\ b(t)\ N(c)$	656.33	36.74	<0.001	23
$\phi(.)\ p(s(T))\ b(t)\ N(c)$	668.62	49.03	<0.001	21
$\phi(.)\ p(T+c)\ b(t)\ N(c)$	732.55	112.96	<0.001	19
$\phi(.)\ p(c)\ b(t)\ N(c)$	737.69	118.10	<0.001	18
$\phi(.)\ p(.)\ b(t)\ N(c)$	743.83	124.24	<0.001	16
$\phi(.)\ p(T)\ b(t)\ N(c)$	744.52	124.92	<0.001	17
CJS				
$\phi(.)\ p(t+c)$	1012.83	0.00	0.761	18

Model	QAICc	ΔQAICc	QAICc weight	No. parameters
$\phi(c)\ p(t + c)$	1015.15	2.32	0.239	20
$\phi(.)\ p(s(T) + c)$	1042.77	29.94	0.000	10
$\phi(c)\ p(s(T) + c)$	1045.00	32.17	0.000	12
$\phi(.)\ p(t)$	1047.49	34.66	0.000	16
$\phi(\ c)\ p(t)$	1049.40	36.57	0.000	18
$\phi(.)\ p(s(T))$	1074.26	61.43	0.000	8
$\phi(c)\ p(s(T))$	1076.02	63.19	0.000	10
$\phi(.)\ p(T + c)$	1119.29	106.46	0.000	5
$\phi(\ c)\ p(T + c)$	1123.17	110.34	0.000	7
$\phi(.)\ p(c)$	1128.44	115.61	0.000	4
$\phi(c)\ p(c)$	1131.82	118.99	0.000	6
$\phi(c)\ p(T)$	1145.88	133.05	0.000	5
$\phi(.)\ p(T)$	1146.91	134.08	0.000	3
$\phi(.)\ p(.)$	1150.28	137.45	0.000	2
$\phi(c)\ p(.)$	1150.57	137.73	0.000	4

Table S3. Maximum likelihood estimates resulting from the full linear model evaluating the effect of covariates Year, Duration, Frames, Group size, and Cluster on the proportion of distinctive individuals in sightings of main Hawaiian Island false killer whale groups. The first row represents the model intercept and the remaining rows the covariate coefficients. For Cluster, Cluster = 1 served as the reference category.

Covariate	Estimate	SE	*t*-statistic	p-value
Intercept	2.183	13.580	0.161	0.873
Year	-0.001	0.007	-0.110	0.913
Duration	0.003	0.015	0.182	0.857
Frames	0.000	0.000	-0.902	0.375
Group size	0.002	0.002	0.656	0.517
Cluster = 2	0.061	0.073	0.830	0.413
Cluster = 3	0.027	0.047	0.581	0.566

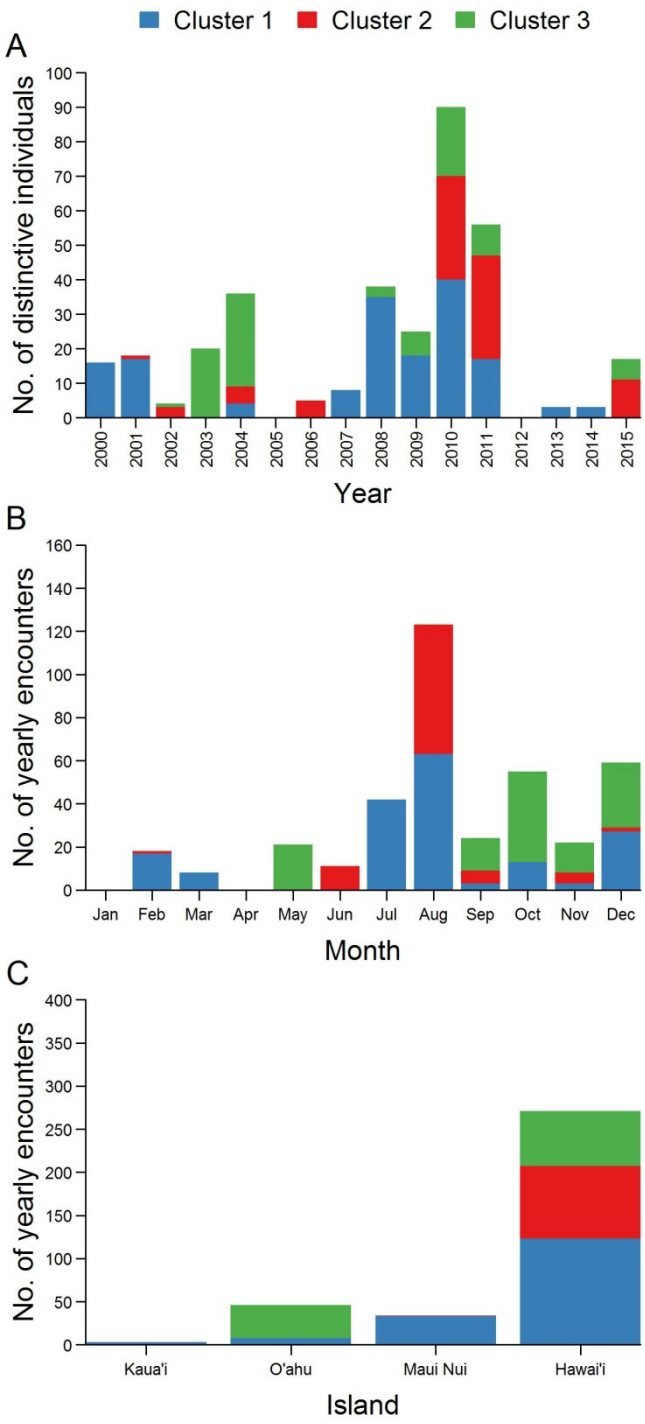

Figure S1. Encounter histories of distinctive main Hawaiian Island false killer whales (n = 143) encountered by Cascadia Research Collective from 2000 to 2015. (A) Yearly encounters of distinctive individuals (n = 339) used in the mark-recapture abundance estimation. (B) Yearly encounters of distinctive individuals by month (n = 383). (C) Yearly encounters of distinctive individuals by island area (n = 354). Encounter histories are shown by social cluster. Maui Nui refers to the islands of Molokaʻi, Lānaʻi, Kahoʻolawe, and Maui (from west to east).

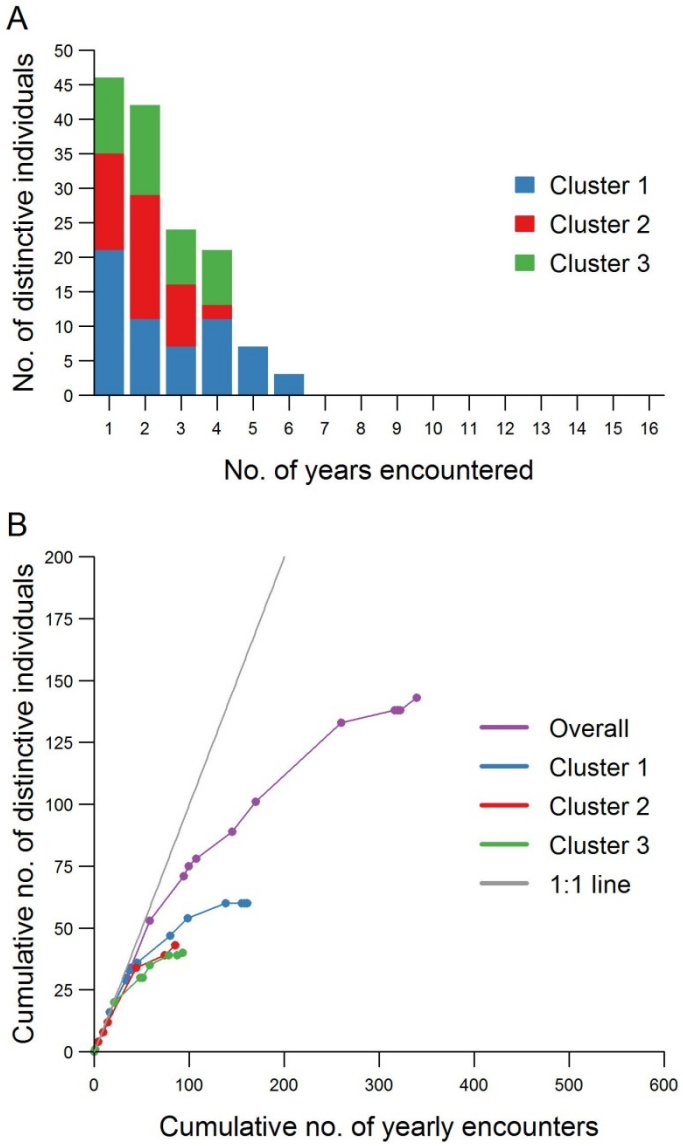

Figure S2. Summaries of distinctive main Hawaiian Island false killer whales (n = 171) encountered by Cascadia Research Collective from 2000 to 2015. (A) Frequency of yearly encounters of distinctive individuals. (B) Rate of discovery of these individuals (overall and by social cluster). The discovery curve relates the cumulative number of yearly encounters (n = 339) to the cumulative number of distinctive individuals (n = 143), with the 1:1 line representing the trajectory that would occur if all individuals encountered were previously unidentified. The points on each line represent years of the study period.