Black Abalone (*Haliotis cracherodii*) Population Density, Recruitment, Size Structure, and Population Growth at Naval Base Ventura County, San Nicolas Island, California, 2013–22

Open-File Report 2025–1015

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey, Reston, Virginia: 2025

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
Area		
square meter (m^2)	0.0002471	acre

Abbreviations

CI   confidence interval

SL   shell length

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Abstract

The range of the endangered black abalone (*Haliotis cracherodii*) is divided into the North Central California region, the Central California region, the Southern California Mainland region, the Channel Islands region, and the Baja California region by the National Marine Fisheries Service for management purposes. San Nicolas Island is one of eight subregions of the Channel Islands region. The black abalone recovery plan establishes five demographic criteria for the possible delisting or downlisting of the species. The U.S. Geological Survey monitors nine long-term intertidal black abalone sites at San Nicolas Island, California, in cooperation with the U.S. Navy, which owns the island. This report uses data collected between 2013 and 2022 and the delisting criteria to analyze and describe the density, recruitment, size structure, and population trends at the nine U.S. Geological Survey monitoring sites at San Nicolas Island.

Introduction

For management purposes, the Final Endangered Species Act Recovery Plan for Black Abalone (*Haliotis cracherodii*; National Marine Fisheries Service [2020] at https://repository.library.noaa.gov/view/noaa/27415; hereinafter referred to as the Recovery Plan) considers the range of the black abalone to be distributed among five regions. These regions are the North Central California region, the Central California region, the Southern California Mainland region, the Channel Islands region, and the Baja California region. San Nicolas Island is one of eight subregions of the Channel Islands region. The Recovery Plan establishes five demographic criteria for the possible delisting or downlisting of the species. The criteria are similar for downlisting and delisting and differ only in the number of subregions within each region that should meet the conditions for each criterion. At the time that the Recovery Plan was developed, a test run analysis was done on data collected up to 2015 or 2016, depending on the subregion, to help determine and refine the thresholds for the criteria.

This report updates the analysis and describes the density, recruitment, size structure, and population trends in the data collected through 2022 at the nine long-term monitoring sites at San Nicolas Island (fig. 1). As stated in the "Criterion 1: Geographic range occupied" section of the Recovery Plan, this criterion is met at the subregion level if the species is present in each of the last 5 years. At San Nicolas Island, black abalone were detected and counted annually at all the sites from 2001 to 2022 (Kenner and Yee, 2025). Data that can be used by managers to evaluate the remaining four population-based criteria are presented below. As context, we reiterate the Recovery Plan criteria for the subregion level here. We provide data related to these criteria but do not evaluate whether the criteria have been met because that evaluation is the purview of those managing the taxon and is beyond the scope of U.S. Geological Survey.

The "Criterion 2: Habitat-based density" section of the Recovery Plan states that the criterion is met if the measured density of black abalone is at least the expected density, based on the quality of habitat, at 50 percent or more of study sites, for at least each of the past 5 years. The expected density for the different habitat quality categories has not yet been developed for the many geographic subregions of the black abalone population. Developing these expected densities is a recovery action task laid out in the Recovery Plan.

Figure 1.   Black abalone (*Haliotis cracherodii*) monitoring sites on San Nicolas Island, California, showing location, number of transects, and total sampling area at each site. Abbreviations: CNES/Airbus DS, National Centre for Space Studies/Airbus Defense and Space; IGN, Institut Geographique National; m², square meters; USDA, U.S. Department of Agriculture; USGS, U.S. Geological Survey; WGS 1984, World Geodetic System of 1984.

The "Criterion 3: Recruitment" section of the Recovery Plan states that the criterion is met if black abalone recruit successfully, at 50 percent or more of study sites, determined by evidence of recruitment events observed in at least 2 non-consecutive years over the past 10 years. The "Criterion 4: Size structure" section of the Recovery Plan states that the criterion is met if black abalone populations are characterized by a broad distribution of size classes representing multiple cohorts that are stable at 50 percent or more of study sites over at least the past 5 years. The size distribution should consist of at least 40 percent small adults (from 50 to 100 millimeters [mm] shell length [SL]) and at least 10 percent large adults (greater than 100 mm SL).

Finally, the "Criterion 5: Population trend" section of the Recovery Plan states that the criterion is met if population growth for reproductively mature individuals (greater than 50 mm SL) is stable or increasing when averaged across all study sites and at 50 percent or more of the individual study sites over at least the past 10 years, indicating that juveniles

are surviving to adulthood to reproduce and maintain or increase populations over time. Each of the study sites also must meet or exceed a minimum population growth rate. The minimum population rate proposed in the Recovery Plan is based on black abalone populations from Monterey County that have not suffered withering syndrome declines and exist in the presence of southern sea otters (*Enhydra lutris nereis*). This is a preliminary report with tables that provide data for San Nicolas Island black abalone populations with respect to these population criteria.

Methods and Results

Information on the location of the nine San Nicolas Island sites and monitoring field methods is in Kenner and Yee (2025). Other methods used for this analysis are described in the following sections.

Habitat-Based Density

For Criterion 2: Habitat-based density, the population density for at least half the monitored sites within a subregion must meet the expected density for the habitat quality in each of the last 5 years (National Marine Fisheries Service, 2020). Therefore, the rating of the habitat quality of the nine San Nicolas Island sites needed to be determined, and the expected habitat-based density needed to be agreed upon. It is not clear how habitat quality at the San Nicolas Island sites was assessed for the test run analysis (appendix B of National Marine Fisheries Service [2020]), nor what quantitative mix of habitat quality each site was ultimately assigned. Three categories of habitat quality have been designated in habitat surveys completed along the California coast: (1) good, (2) moderate, and (3) poor (National Marine Fisheries Service, 2020). Good habitat is characterized by deep cracks or crevices greater than 10–15 centimeters (cm), or boulders. Moderate habitat is characterized by shallow or wide cracks, crevices, or depressions. Poor habitat is defined by flat, open, bare substrate, with no or minimal protection. In the 2022 field season, each of the 2,054 annually monitored permanent 1-square meter (m^2) quadrats at San Nicolas Island was rated into one of the three habitat categories. Photographs of most of the transects are in Kenner (2020).

Although the Recovery Plan states that regional expected densities will eventually be developed, central California habitat-based densities were used as the expected densities for the test run analysis reported in the Recovery Plan because the central California populations were non-depleted but exposed to natural predators, including sea otters, and anthropogenic pressures (National Marine Fisheries Service, 2020). The values used in the test run and in this report are defined for each habitat quality category: Good habitat expected density is 1.58 abalone per m^2; Moderate habitat expected density is 0.278 abalone per m^2; and Poor habitat expected density is 0.0049 abalone per m^2.

To evaluate habitat-based density for each of the San Nicolas Island sites for this report, the proportion of each of the three habitat quality categories at a site was multiplied by the expected density for each category, and the products were summed, yielding an expected density for each site (table 1). The total number of abalone counted at each site in each of the last 5 years, 2018–22, was used to calculate a measured density for each site and year. The annual observed density for each site can be compared to the calculated expected density provided for each site. The measured density exceeded the calculated expected density at three of the sites (6, 7, and 8) during each of the last 5 years (2018–22). These values are presented in table 2.

Table 1. Total number of 1-square meter (m^2) quadrats, number of quadrats in each habitat quality category (good, moderate, poor), and expected density (abalone per m^2) for each of the nine black abalone (*Haliotis cracherodii*) monitoring sites at San Nicolas Island, California.

[Good habitat is characterized by deep cracks or crevices greater than 10–15 centimeters (cm), or boulders. Moderate habitat is characterized by shallow or wide cracks, crevices, or depressions. Poor habitat is defined by flat, open, bare substrate, with no or minimal protection. The proportion of each of the three habitat quality categories at a site was multiplied by the expected density for each, and the products were summed. The expected densities used were Good, 1.58 abalone per m^2; Moderate, 0.278 abalone per m^2; Poor, 0.0049 abalone per m^2]

Site	Total quadrats	Good	Moderate	Poor	Expected density of site
1	360	93	199	68	0.56
2	274	132	139	3	0.90
3	300	71	162	67	0.53
4	52	14	25	13	0.56
5	70	12	43	15	0.44
6	252	9	65	178	0.13
7	270	63	136	71	0.51
8	278	121	131	26	0.82
9	198	37	138	23	0.49

Table 2. Black abalone (*Haliotis cracherodii*) densities from 2018 to 2022 at the nine monitoring sites at San Nicolas Island, California.

[To calculate the expected density of a site, the proportion of each of the three habitat quality categories observed at a site was multiplied by the expected density for each, and the products were summed. The expected densities used were Good, 1.58 abalone per square meter (m²); Moderate, 0.278 abalone per m²; Poor, 0.0049 abalone per m²]

Year	Total abalone	Measured density (abalone per m²)	Expected density of site (abalone per m²)
Site 1			
2018	97	0.27	0.56
2019	69	0.19	
2020	78	0.22	
2021	141	0.39	
2022	144	0.40	
Site 2			
2018	53	0.19	0.90
2019	36	0.13	
2020	54	0.20	
2021	55	0.20	
2022	47	0.17	
Site 3			
2018	49	0.16	0.53
2019	42	0.14	
2020	47	0.16	
2021	43	0.14	
2022	51	0.17	
Site 4			
2018	50	0.96	0.56
2019	27	0.52	
2020	54	1.04	
2021	48	0.92	
2022	67	1.29	
Site 5			
2018	32	0.46	0.44
2019	24	0.34	
2020	32	0.46	
2021	56	0.80	
2022	44	0.63	
Site 6			
2018	112	0.44	0.13
2019	114	0.45	
2020	168	0.67	
2021	156	0.62	
2022	136	0.54	

Year	Total abalone	Measured density (abalone per m²)	Expected density of site (abalone per m²)
Site 7			
2018	611	2.26	0.51
2019	664	2.46	
2020	728	2.70	
2021	772	2.86	
2022	812	3.01	
Site 8			
2018	973	3.50	0.82
2019	1017	3.66	
2020	1103	3.97	
2021	706	2.54	
2022	787	2.83	
Site 9			
2018	39	0.20	0.49
2019	29	0.15	
2020	77	0.39	
2021	46	0.23	
2022	68	0.34	

Recruitment

For Criterion 3: Recruitment, it must be evident in at least 2 non-sequential years in a 10-year period at 50 percent or more of the sites in a subregion. Evidence of recruitment is defined in the Recovery Plan as the presence at a site of at least 10 individuals less than or equal to 30 mm in length (National Marine Fisheries Service, 2020). In the San Nicolas Island black abalone sampling protocols, we measure all accessible abalone on a site until at least 200 have been measured, if that many are counted. Beginning in 2019, for individuals that were not measured because of accessibility problems or excess sample size, classifications of abalone as recruits (30 mm or less in length) or non-recruits (greater than 30 mm) were estimated visually. For the recruitment data presented here, estimated recruits are included as part of the measure of recruitment, but they are noted separately because they represent a change in methods starting in 2019 (table 3). Sites 3, 5, 7, 8, and 9 had two or more non-sequential recruitment events in the last 10 years.

Table 3. Number of recruits (R), defined as black abalone (*Haliotis cracherodii*) counted with a shell length less than or equal to 30 millimeters (mm), calculated annually from 2013 to 2022 at the nine monitoring sites at San Nicolas Island, California.

[R measured are those measured in the field. R estimated are those that appeared to be recruitment size but were not measured. R total is the sum of measured recruits and estimated recruits. Years with no recruits at a site are not listed. **Abbreviation**: —, recruits were not estimated]

Year	R measured	R estimated	R total
	Site 1		
2014	3	—	3
2015	0	—	0
2016	3	—	3
2017	12	—	12
2018	3	—	3
2019	3	3	6
2020	3	—	3
2021	0	7	7
2022	2	3	5
	Site 2		
2014	3	—	3
2015	1	—	1
2016	6	—	6
2019	2	3	5
2020	0	2	2
2022	1	1	2
	Site 3		
2013	6	—	6
2014	8	—	8
2015	16	—	16
2017	8	—	8
2018	1	—	1
2020	5	1	6
2021	11	0	11
2022	6	2	8
	Site 4		
2014	2	—	2
2017	3	—	3
2020	1	0	1
2021	2	1	3
2022	1	2	3
	Site 5		
2013	12	—	12
2014	6	—	6
2015	6	—	6
2016	4	—	4
2017	10	—	10

Year	R measured	R estimated	R total
	Site 5—Continued		
2018	1	—	1
2019	1	0	1
2020	6	0	6
2021	18	1	19
2022	20	0	20
	Site 6		
2015	1	—	1
2016	3	—	3
2017	5	—	5
2018	3	—	3
2020	2	0	2
2021	3	0	3
2022	5	0	5
	Site 7		
2013	35	—	35
2014	23	—	23
2015	30	—	30
2016	60	—	60
2017	31	—	31
2018	14	—	14
2019	13	37	50
2020	31	74	105
2021	17	59	76
2022	33	7	40
	Site 8		
2013	3	—	3
2014	23	—	23
2015	29	—	29
2016	9	—	9
2017	245	—	245
2018	86	—	86
2019	70	125	195
2020	76	223	299
2021	30	75	105
2022	105	178	283

Table 3.   Number of recruits (R), defined as black abalone (*Haliotis cracherodii*) counted with a shell length less than or equal to 30 millimeters (mm), calculated annually from 2013 to 2022 at the nine monitoring sites at San Nicolas Island, California.—Continued

[R measured are those measured in the field. R estimated are those that appeared to be recruitment size but were not measured. R total is the sum of measured recruits and estimated recruits. Years with no recruits at a site are not listed. **Abbreviation**: —, recruits were not estimated]

Year	R measured	R estimated	R total
		Site 9	
2015	1	—	1
2016	8	—	8
2017	18	—	18
2019	3	—	3
2020	7	4	11
2021	0	1	1
2022	5	3	8

Size Structure

Criterion 4 states that the size structure of the populations at 50 percent or more of the sites in a subregion must favor young adults such that at least 40 percent of the population at these sites must be 50–100 mm SL (small adults) and at least 10 percent must be more mature individuals that are greater than 100 mm SL (large adults). This analysis is to be based on a sample size of at least 50 measured individuals and is to be calculated as the most recent value of a running cumulative proportion over a 5-year period (National Marine Fisheries Service, 2020). Sites 7 and 8 have several hundred abalone, and at these sites, the measuring of SLs was curtailed after at least 200 measurements were made. Because most or all the reachable abalone on the first three transects were measured, this analysis uses only these transects at these two sites. The population structure conditions are presented in table 4. Only sites 6, 7, and 8 had more than 50 individuals every year over the past 5 years, and they had 64.5, 41.0, and 25.4 percent, respectively, in the small adult size category. All three sites had more than 10 percent in the large adult category.

Table 4.   Size structure of black abalone (*Haliotis cracherodii*) from 2018 to 2022 at the nine monitoring sites at San Nicolas Island, California. Counts and percentages of small (50–100 millimeter [mm] shell length [SL]) and large (greater than 100 mm SL) abalone for each site are displayed.

[Counts and percentages of small (50–100 millimeter [mm] shell length [SL]) and large (greater than 100 mm SL) abalone for each site are displayed. At sites 7 and 8, only the counts from the first three transects are listed and used to calculate percentages. **Abbreviation**: >, greater than]

Year	Number measured	Count of 50–100 mm	Count of >100 mm	Running average percentage of 50–100 mm	Running average percentage of >100 mm
		Site 1			
2018	64	32	17	40.6	46.9
2019	44	20	17		
2020	67	36	25		
2021	49	17	31		
2022	48	11	33		
		Site 2			
2018	32	12	17	31.7	61.0
2019	25	7	15		
2020	27	9	17		
2021	25	12	13		
2022	26	5	20		
		Site 3			
2018	48	27	16	48.8	31.2
2019	37	26	8		
2020	43	25	11		
2021	42	13	14		
2022	45	16	19		
		Site 4			
2018	41	28	7	69.4	18.1
2019	9	7	2		
2020	49	36	8		
2021	42	29	6		
2022	54	34	11		
		Site 5			
2018	31	17	2	32.3	5.2
2019	23	11	2		
2020	32	14	2		
2021	54	12	0		
2022	42	8	0		

Table 4. Size structure of black abalone (*Haliotis cracherodii*) from 2018 to 2022 at the nine monitoring sites at San Nicolas Island, California. Counts and percentages of small (50–100 millimeter [mm] shell length [SL]) and large (greater than 100 mm SL) abalone for each site are displayed.—Continued

[Counts and percentages of small (50–100 millimeter [mm] shell length [SL]) and large (greater than 100 mm SL) abalone for each site are displayed. At sites 7 and 8, only the counts from the first three transects are listed and used to calculate percentages. **Abbreviation**: >, greater than]

Year	Number mea-sured	Count of		Running average percentage of	
		50–100 mm	>100 mm	50–100 mm	>100 mm
Site 6					
2018	106	66	11	64.5	18.2
2019	108	88	11		
2020	166	116	26		
2021	148	97	35		
2022	118	66	37		
Site 7					
2018	208	79	65	41.0	32.4
2019	181	75	67		
2020	183	69	65		
2021	176	76	60		
2022	207	93	50		
Site 8					
2018	463	132	185	25.4	41.3
2019	505	164	216		
2020	370	127	127		
2021	200	45	110		
2022	234	33	81		
Site 9					
2018	37	27	3	60.9	20.5
2019	24	18	2		
2020	59	38	14		
2021	31	16	12		
2022	47	23	11		

Population Trend

Criterion 5 focuses on the population growth rate of reproductively mature individuals, defined in the Recovery Plan as having greater than 50 mm SL. The population growth rate for this size class measured over a 10-year period must be (1) stable or increasing when averaged over all sites in the subregion; (2) stable or increasing at 50 percent or more of the sites; and (3) greater than or equal to a minimum expected growth rate at all sites (National Marine Fisheries Service, 2020). The minimum expected growth rate suggested by the Recovery Plan is currently under review by the Black Abalone

Recovery Team but is expected to be the smallest growth rate calculated from apparently healthy populations in central California during 2009–16 (Susan Wang, National Marine Fisheries Service, oral commun., 2023).

The protocol for collecting size data at the San Nicolas Island sites that have high numbers of abalone can yield misleading results when calculating population growth of a specified size class. The protocol at these sites is to measure at least 200 abalone, which captures a reasonable size distribution sample without using too much valuable field time during the low tide sampling window. The actual number measured can vary considerably between field seasons depending on the accessibility of abalone, tidal heights, time of day, sea state, and other limiting weather conditions and is not related to changes in the population size. Because the analysis for this criterion requires that population growth be based on numbers of abalone of a certain size class (greater than 50 mm SL), the number being used to calculate population growth is affected by the size of the sample of measured individuals, not the counted number of total individuals. Sites 7 and 8 are the only sites where measurements are limited by sample size rather than just accessibility. At these sites, transects 1–3 were counted first to prioritize consistency, and most abalone counted on transects 4–5 were rarely measured after reaching the sample size limit for measurements. To reduce sampling variations when evaluating changes across time, only data from transects 1 to 3 were used in this analysis for sites 7 and 8. The numbers reported for these sites represent extrapolated estimates for counts of abalone in the greater than 50 mm SL size class on transects 1–3. To account for sampling error, we calculated 95-percent confidence intervals (CI) for the true proportion of abalone in that size class among all abalone counted on these transects by using the "svyciprop" function in the "survey" package of R statistical software (Korn and Graubard, 1998; Lumley, 2004; R Core Team, 2023) and then multiplied the CI limits of the proportion with the total abalone counted to derive 95-percent CI for the number of abalone in this size class.

To address (1) of Criterion 5, the average population growth rate at the nine San Nicolas Island black abalone monitoring sites from 2013 to 2022 was calculated from the slope over those 10 years of the Log_{10}[Mean(Total count)+1], where Mean(Total count) is the total number of measured abalone in the adult size class (greater than 50 mm SL) for all the sites divided by the number of sites. The resulting average population growth rate for San Nicolas Island was −0.003 (table 5). Growth rates at the individual sites were calculated to address (2) and (3), of Criterion 5, described earlier, using the slope over the last 10 years of the Log_{10}[(Total count)+1], where (Total count) is the total number of measured abalone in the adult size class at each site. Five sites (1, 2, 4, 6, and 9) had positive growth rates, and four sites (3, 5, 7, and 8) had negative growth rates (table 5). Site 6 had the highest calculated growth rate (0.097), and site 3 had the lowest calculated growth rate (−0.037).

Table 5.   Annual and average population growth trend for black abalone (*Haliotis cracherodii*) greater than 50 millimeters (mm) shell length (SL) over a 10-year period at the nine monitoring sites at San Nicolas Island, California.

[At sites 7 and 8, only size data from the first three transects were used. We calculated 95-percent confidence intervals (CI) for the true proportion of abalone greater than 50 mm among all abalone counted on these transects and then multiplied the CI limits of the proportion with the total abalone counted to derive 95-percent CI (shown in parentheses) for the number of abalone in this size class. **Abbreviation**: >, greater than]

Year	Abalone >50 mm	Annual growth $\text{Log}_{10}(\text{Count}+1)$	Average growth slope of $\text{Log}_{10}(\text{Count}+1)$
	All sites (mean count)		
2013	90.00	1.954	−0.003
2014	97.33	1.988	
2015	90.89	1.959	
2016	76.33	1.883	
2017	93.78	1.972	
2018	104.11	2.017	
2019	109.67	2.040	
2020	112.56	2.051	
2021	76.78	1.885	
2022	73.33	1.65	
	Site 1		
2013	22	1.362	0.033
2014	26	1.431	
2015	48	1.690	
2016	29	1.477	
2017	25	1.415	
2018	48	1.690	
2019	36	1.568	
2020	61	1.792	
2021	48	1.690	
2022	44	1.653	
	Site 2		
2013	13	1.146	0.027
2014	17	1.255	
2015	21	1.342	
2016	15	1.204	
2017	20	1.322	
2018	29	1.477	
2019	22	1.362	
2020	25	1.415	
2021	24	1.398	
2022	25	1.415	

Year	Abalone >50 mm	Annual growth $\text{Log}_{10}(\text{Count}+1)$	Average growth slope of $\text{Log}_{10}(\text{Count}+1)$
	Site 3		
2013	71	1.857	−0.037
2014	57	1.763	
2015	58	1.771	
2016	30	1.491	
2017	45	1.663	
2018	43	1.643	
2019	34	1.544	
2020	34	1.544	
2021	26	1.431	
2022	35	1.556	
	Site 4		
2013	5	0.778	0.071
2014	13	1.146	
2015	14	1.176	
2016	26	1.431	
2017	36	1.568	
2018	35	1.556	
2019	9	1.000	
2020	44	1.653	
2021	33	1.531	
2022	45	1.663	
	Site 5		
2013	20	1.322	−0.019
2014	16	1.230	
2015	8	0.954	
2016	7	0.903	
2017	12	1.114	
2018	18	1.279	
2019	12	1.114	
2020	13	1.146	
2021	7	0.903	
2022	10	1.041	

Table 5.   Annual and average population growth trend for black abalone (*Haliotis cracherodii*) greater than 50 millimeters (mm) shell length (SL) over a 10-year period at the nine monitoring sites at San Nicolas Island, California.—Continued

[At sites 7 and 8, only size data from the first three transects were used. We calculated 95-percent confidence intervals (CI) for the true proportion of abalone greater than 50 mm among all abalone counted on these transects and then multiplied the CI limits of the proportion with the total abalone counted to derive 95-percent CI (shown in parentheses) for the number of abalone in this size class. **Abbreviation**: >, greater than]

Year	Abalone >50 mm	Annual growth Log$_{10}$(Count+1)	Average growth slope of Log$_{10}$(Count+1)
Site 6			
2013	19	1.301	0.097
2014	27	1.447	
2015	25	1.415	
2016	38	1.591	
2017	45	1.663	
2018	75	1.881	
2019	95	1.982	
2020	133	2.127	
2021	130	2.117	
2022	103	2.017	
Site 7, transects 1, 2, and 3 only			
2013	213 (203, 222)	2.330	−0.011
2014	268 (258, 277)	2.430	
2015	188 (177, 198)	2.276	
2016	152 (144, 160)	2.185	
2017	181 (166, 194)	2.260	
2018	171 (164, 178)	2.236	
2019	202 (192, 210)	2.307	
2020	189 (179, 198)	2.279	
2021	173 (166, 180)	2.241	
2022	175 (167, 182)	2.246	

Year	Abalone >50 mm	Annual growth Log$_{10}$(Count+1)	Average growth slope of Log$_{10}$(Count+1)
Site 8, transects 1, 2, and 3 only			
2013	417 (400, 432)	2.621	−0.028
2014	426 (400, 450)	2.630	
2015	428 (398, 456)	2.632	
2016	368 (363, 372)	2.567	
2017	452 (441, 462)	2.656	
2018	481 (462, 499)	2.683	
2019	548 (532, 564)	2.740	
2020	453 (430, 475)	2.657	
2021	214 (204, 223)	2.332	
2022	180 (165, 195)	2.258	
Site 9			
2013	21	1.342	0.036
2014	17	1.255	
2015	19	1.301	
2016	13	1.146	
2017	19	1.301	
2018	28	1.462	
2019	20	1.322	
2020	52	1.724	
2021	27	1.447	
2022	34	1.544	

Discussion

Habitat-Based Density

Rating the habitat quality of each quadrat was subjective but not time-consuming. Because expected densities are different for the three habitat quality categories, varying interpretations of the categories may result in different site-specific expected densities. For example, preferentially rating habitat with low-quality ledges as moderate rather than poor will yield expectations of higher densities than warranted and could result in a lower or misleading rate of meeting the population density criterion. Some training between monitoring groups working in different regions and using different protocols could reduce this variability.

Recruitment

Classifying non-measured abalone as recruits or not has only been done since 2019. Only once in this analysis did the change in classification make a difference in raising the number of recruits above 10 in a year (site 9 in 2020). This change in protocol results in more abalone being classified as recruits, which eventually could result in more sites exceeding the 10-recruit threshold as the analysis is repeated in future years.

Size Structure

Out of the 9 sites at San Nicolas Island, 6 had less than 50 measured individuals in each of the last 5 years. Of these, only site 1 consistently had counts exceeding 50, but abalone were often inaccessible and could not be measured. Beginning in 2022, all abalone that were not measured were estimated into size bins. In a few years, these bins could be used to increase the number of sites with meaningful size-structure data. Several of the other sites are close to having 50 abalone counted and, if counts continue to increase, could contribute to this analysis in future years.

Population Trend

This analysis is based on changes in the numbers of reproductive-size abalone and is affected by the proportions of counted populations that are sized. Therefore, size samples that are incomplete because of inaccessible or numerous abalone can affect interpretations of the data. The size binning of non-measured abalone that began in 2022 could eventually alleviate this problem, but because the growth rate trend examines a 10-year period, data collected using the new protocol cannot be used to examine population trends for several years.

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