Assessment of Abalone Stocks in Southern California: The First Stage of Recovery

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Abstract

Seven species of abalones are found along the west coast of North America from Mexico to Alaska. Six of these species once supported valuable cultural, commercial, and recreational fisheries, but prohibitions of take of all but one species has been prohibited, a result of over fishing, disease, habitat loss, and recovery of natural predators. Nevertheless, there is a strong desire to re-establish fisheries on some of these abalones, particularly in southern California where fisheries on five species once occurred. The State of California recently completed the Abalone Recovery and Management Plan (ARMP) to guide efforts for recovery and eventual management of abalones. Recovery of abalone populations in an area the size of California will require an ambitious effort. The ARMP is designed to regularly evaluate recovery so that decisions about future use can be made expeditiously, but not prematurely. The plan requires that a significant number of areas be recovered before any consideration of a fishery, recognizing the relationships between local populations. The early assessment involves determining population structure at many index sites, a task that strains the available resources of the State. State biologists have partnered with AAUS scientists from the Aquarium of the Pacific to assess abalone populations in southern California. From the very beginning of this partnership useful information has been gathered which has provided a optimistic view about the recovery of abalones.

Introduction

The near shore marine environment of California contains seven species of abalones (Figure 1). The largest species, the red abalone, *Haliotis rufescens*, can grow to 12 inches in maximum dimension, although most are smaller. Abalone have traditionally been valued for their shells (decorations and tools) as well as their large muscular foot (an important food source for humans to the present time) (Cox 1963). As various immigrants arrived on the Pacific coast of North America, abalone became economically important, either as a commodity or a food source. The importance of abalone to California's economy is nicely presented by Cox (1963), who documents the fishery until the 1960s during which there were several years when 4 and 5 million pounds of abalone were landed (Haaker et al. 2001).

The modern California fishery began at the turn of the 20th Century, and was documented beginning in 1916 (Haaker et al. 2001). The fishery peaked in the 1950s and 1960s, followed by dramatic declines in all five species that comprised the fishery (red, green, pink, white, and black abalones). The fishery only appeared sustainable prior to its collapse due to the expansion of fishing areas and species fished as stocks declined resulting in serial depletion of abalones in California (Karpov et al 2000). Several additional factors also accelerated the demise of the fisheries, including disease, and in some areas, the recovery of the sea otter, an efficient predator on most marine invertebrates, including abalone.

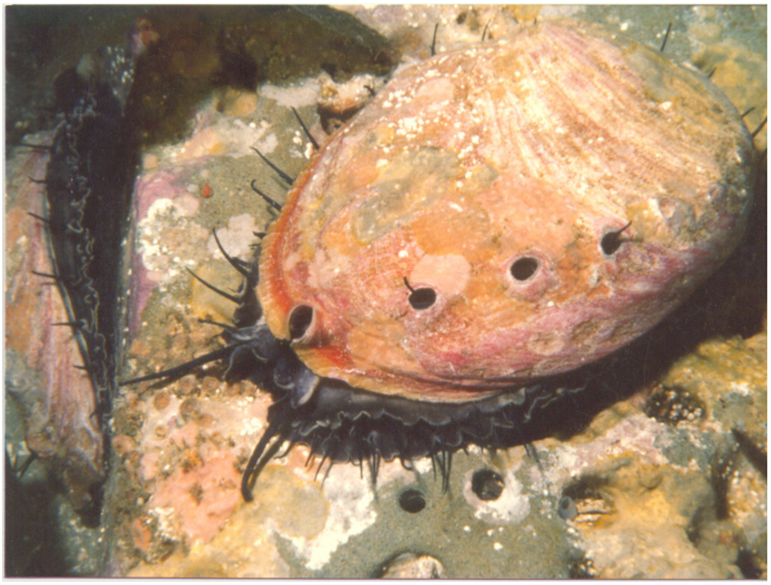


Figure 1. Red abalone, *Haliotis rufescens*. Note second abalone on left side of rock.

The fishery for abalone in California was closed in 1997, by the Fish and Game Commission (Commission), and was supported by legislative action. The latter, recognizing the importance of abalone in California's economy, mandated a plan to reestablish the abalone fishery, at least in some areas, to benefit California commercial and recreational abalone enthusiasts. The northern California recreational-only red abalone fishery was not included in the closure, because it was seen as sustainable, due to its remoteness, often severe ocean conditions, and *de facto* refugia (deeper water stocks inaccessible to skin divers) that were thought to prevent depletion. The California Legislature mandated the preparation of an Abalone Recovery and Management Plan (CDFG 2004) which was submitted to the Commission for approval and eventual implementation.

Both recovery (south of San Francisco Bay) and management (in the northern California recreational fishery) are addressed in the ARMP, but only the former will be addressed here. As abalones recover in southern California, the recovered species will be managed according to the management part of the plan.

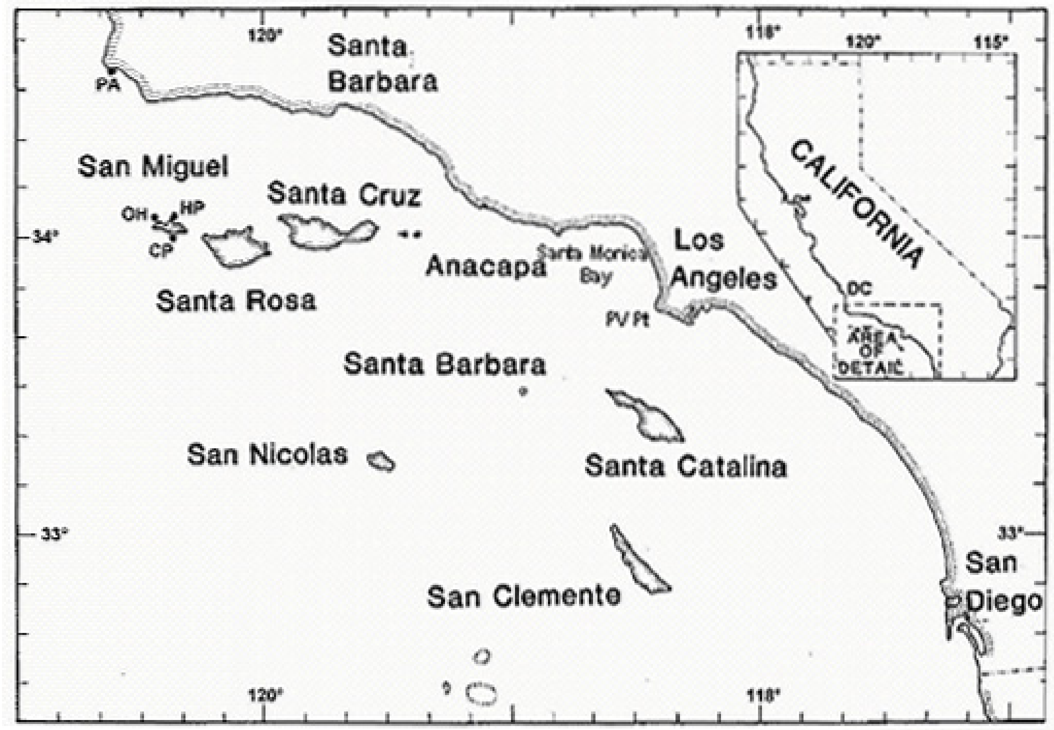
Recovery in the ARMP (CDFG 2004) includes a step wise procedure that will seek to accomplish the following recovery goals:

1. To reverse the decline in abalone populations that are in jeopardy of extinction

2. To establish self-sustaining populations throughout each abalone species historic range

3. To reach sustainable fishery levels in at least three-quarters of former ranges

To help organize and structure the recovery program to achieve the recovery goals for multiple abalone species over a large geographic area, the southern California area was divided into smaller units called key recovery locations (Figure 2). Key locations were identified for each abalone species where all recovery assessments and activities will occur. The central California coastal areas, while south of San Francisco, are excluded because presence of sea otters has precluded an abalone fishery.



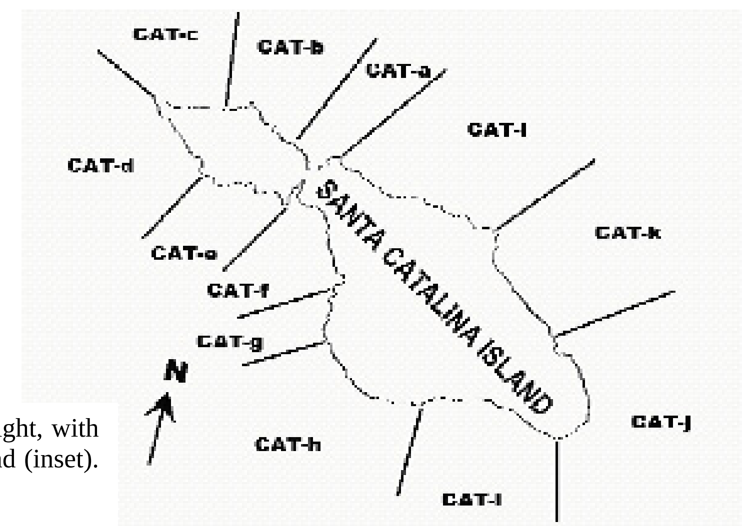


Figure 2. Map of southern California bight, with details of recovery sites at Catalina Island (inset). Each site is labeled CAT- a to l.

A qualitative resource assessment of abalone is being conducted at selected index sites (index sites are a selected subset of key locations), the number which varies by species. Each site must meet species specific size range requirements which are indicative of recent repetitive reproduction, population growth, and the occurrence of individuals that exceed minimum legal size (MLS).

The accomplishment of the criteria for the first goal triggers more intensive quantitative assessment of the index sites to assure that recovery has occurred more or less throughout southern California. While recovery at this stage would be dramatic, it would only likely be a reflection that the population is barely at the minimum viable population size, which is the point where the population can sustain itself through reproduction but there are not enough animals for a sustainable fishery. Random benthic transect surveys would quantify population density for one or more species and would be used to measure achievement of the second recovery goal, but this achievement would not trigger reopening a fishery. The third goal, is basically an extension of the second goal, with the addition of a higher abalone population density level, that when attained, would trigger consideration of a fishery by the Commission.

A major important benefit of these stepwise assessments is that initially, there is no initial necessity to conduct diver intensive, random, benthic transect surveys. Abalone populations are at extremely low levels (=rare) throughout southern California. Random transect surveys will yield zeroes at most sites, and would provide only reiteration that abalone populations are at low levels. Using a qualitative method in the first assessment yields more information; because the diver is not constrained to a specific transect area. Timed free ranging swims allow divers to inspect any appropriate habitat encountered during a dive. Any abalone found is measured and counted, and provides data that is specific to an index location. Another benefit is that timed swim surveys are not as stringent as random benthic transect surveys. In addition, any diver can be easily trained in the recording of data. This allows scientists to forge liaisons with recreational divers and other interested persons. In today's situation of under funded research, the incorporation of interested recreational and other divers into programs is a worthwhile activity that is satisfying to all parties involved.

In southern California, assessment is at the first stage. None of the abalones found in southern California can meet criteria that would shift assessment to a quantitative protocol. Here we will only be concerned with the first goal.

Methods

Site selection

Specific index sites have been established for each abalone species, and the number may vary by species (ARMP 2004). At the selected location, GPS position is typically recorded generally after the vessel is anchored. It is imperative that multiple surveys are not conducted at the same or overlapping areas. If live boat operations are used, the GPS position of each team at the start of the dive is recorded. Dive teams, usually pairs, choose a basic direction which would put them in appropriate abalone habitat, i.e., rocky bottom, sand channels, substrate relief, crevices, and an algal community. Divers swim the area around the chosen base direction always staying in appropriate habitat. Cracks and crevices are inspected, and smaller rocks on the bottom may be carefully over turned to search for cryptic individuals. If a rock is overturned, it must be carefully returned to its original position. We recommend that only experienced divers over turn rocks.

At about a third of the way through the dive, the dive team should move to one side of the base course, and then swim a reciprocal course back to the vicinity of the vessel. If live boating, the vessel should keep track of the divers.

Data collection and management

During the dive, both live abalones and empty shells (Figure 3), are identified and measured using a recording caliper (Figure 4) or standard calipers. The straight line maximum diameter of the shell is measured. Live abalone are not disturbed, but abalone shells found are returned to the vessel or can be identified and measured underwater. Each shell must be classified as old or fresh, as indicated by the luster and encrustation of the inside of the shell. Fresh shells are shiny without any encrusting organisms (Figure 3). Shells, particularly fresh shells, are used as indicators of likely abalone habitat. Live abalone and non-returned shells are marked with a forestry crayon, to indicate that data for that individual has been collected. Live abalone may be found alone, or in groups, defined as two or more individuals within a meter of one another. Groups are noted by the number of abalone in a group. A group is comprised only of abalone of the same species. The percentage of the abalone at a site (%in groups, Table 2), is an indicator of the ability of the abalone to reproduce. Since abalone need to be close together to effectively reproduce, the higher the percentage the more likely reproduction will occur (Allee et al. 1949, Babcock and Keesing 1999). We make the caveat that this is true only where there are higher numbers of abalone in the detected population, i.e., many individuals or groups.

Immediately after the dive, all data must be entered on prepared data sheets so that data is not inadvertently lost. The data collected includes basic information, i.e., Vessel, Date, Dive number (numbered consecutively for each diving day by dive teams), location, latitude and longitude of each dive. Dive specific information includes the diver's names, time in and out, search time, and depth. Each abalone, shell and groups are coded and entered. Every abalone must have species identification, a size, and a condition code. The data are archived in a computer data base for storage and analysis.

Data analysis

The primary use of the data collected is to determine if Criterion 1 (Broad Size Distribution) has been met at a location. To evaluate the resource condition two categories are established for each species of abalone. The first, 100 mm to recreational minimum legal size (RMLS), includes the emergent sublegal population that will eventually grow to legal size. The RMLS varies among species (i.e., RMLS for red, pink, green, white and black abalones are 178, 152, 152, 152, and 127 mm, respectively). The second category includes abalones greater than RMLS. The higher end of this category is the maximum known size for the species.

A third category includes sizes less than 100 mm, and represents the cryptic abalone population. Evaluating this segment of the population involves detailed habitat disruption and is not easily assessed. Data about this segment provides recent information about the population and any such data will be included in the analysis. However this data is not included in the ARMP evaluation. In the earlier stages of evaluation looking at the smaller sizes provides insight about recent reproduction and settlement trends. However, these abalone would not be expected to be seen for several years in the emergent population and are subject to high predation mortality.

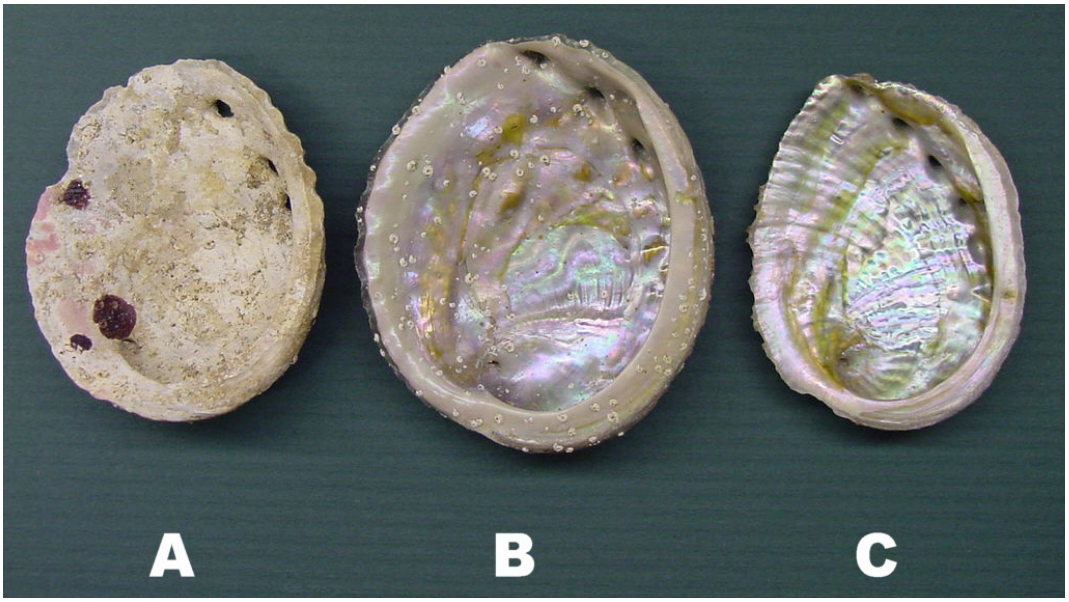


Figure 3. Abalone shells found during underwater transects. An old shell includes shells (A) that have no remaining nacreous (mother-of-pearl) layer, or has encrusting organisms growing on the shell (B). A fresh shell (C) has a clean shiny appearance.

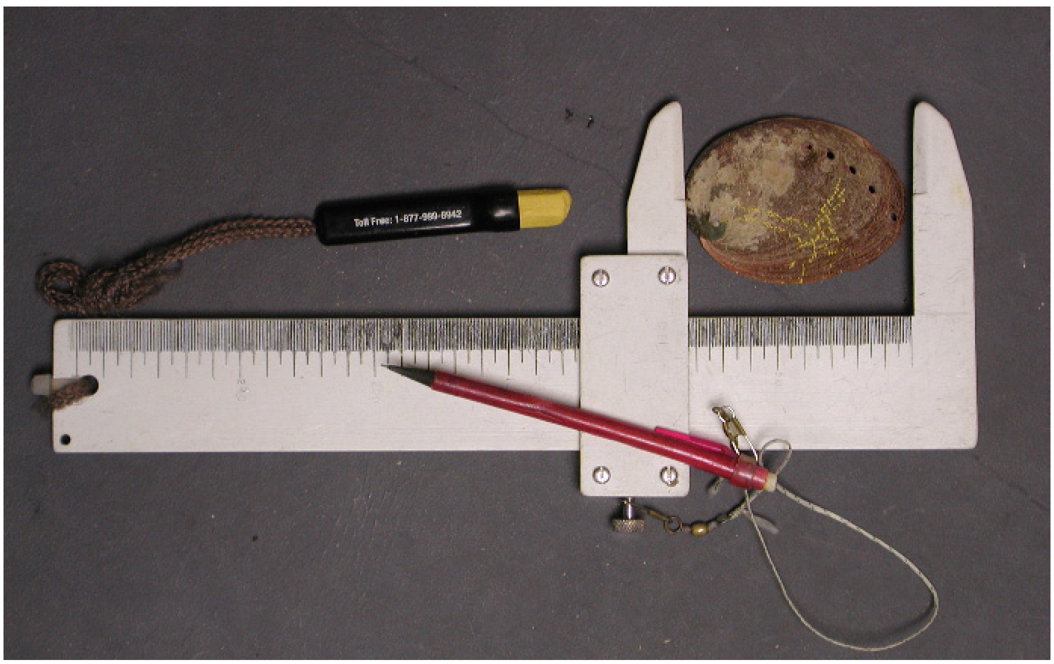


Figure 4. A recording caliper used to measure abalones underwater without the need to record every length. A mark is made on the caliper to indicate the size, which can be read and permanently recorded after the dive. The forestry crayon is used to mark the abalone to prevent subsequent re-measurement by another diver. Marks made on the caliper can be coded for different species.

Each category is further divided into 5mm groups. For instance, there are about 15 - 5 mm groups for red abalone in the emergent below legal group, (measuring 100 to 178 mm), and 24 – 5 mm groups in the larger category. The goal is to have at least one abalone occupy 90% of the first, and 25% of the second groups. When these size requirements are met at all the index sites, evaluation increases to a quantitative evaluation (Criterion 2).

Operational considerations

It likely will take many years to achieve completion of Criterion 1 goals for most abalones. The ARMP includes several ways to enhance recovery, but even with active enhancement, recovery will require a long term commitment. Current fiscal, personnel, and logistic constraints will require a considerable effort considering the size of the area of southern California. The first stage assessment does not include sophisticated scientific techniques. The actual data collection can be learned by virtually any experienced diver after a short instructional class that includes identification and location of abalones. Additionally, there is no long term commitment of the individual diver collecting the data. The actual data collection provides an excellent opportunity for involving knowledgeable divers in first stage assessment.

We have formed a partnership with the Long Beach Aquarium of the Pacific (AoP) to assess abalone populations in southern California, particularly at the southern Channel Islands. Both the California Department of Fish and Game (CDFG) and the AoP are American Academy of Underwater Science (AAUS) member organizations, and have recently joined together in a joint abalone assessment. CDFG biologists provided training classes on identification of abalones, abalone habitat, and the details of collecting and recording the data.

Results

Dive collection data

Since the beginning of the AoP/CDFG abalone assessment program in March 2004, 45 survey dives have been made at 23 locations primarily along the west end of Catalina Island. An additional seven dives were made to assess abalones in Santa Monica Bay and along the Palos Verdes Coast, a mainland peninsula north of Catalina Island (Figure 2). Eighteen AoP scientific divers have participated in at least one survey dive to date. This represents a significant effort in the assessment of abalones in southern California, an effort that could not have been accomplished by CDFG divers alone.

Table 1 presents the approximate locations of the dives, total search times, and the number of abalones found. There is also a calculation of the number of abalones found per hour.

Table 1. Results of abalone dive assessment surveys at Santa Catalina Island and Santa Monica Bay-Palos Verdes mainland coast during 2004. A dive includes the dive time and data for a two or three diver team. Time is total search time of the teams (in minutes) at a location. SCat – Santa Catalina Island, SMB – Santa Monica Bay, PVP – Palos Verdes Peninsula.

Date	Location	# dives	Time (min)	Green Abalone		Pink Abalone	
				no.	abs/hr	No.	abs/hr
31-Mar-04	SCat, Quarry	2	246	28	6.83		0.00
22-Apr-04	SCat, Arrow Point	4	396	8	1.21	4	0.61
22-Apr-04	SCat, Little Geiger	2	249	1	0.24		0.00
03-May-04	SCat, Emerald Bay	3	370	2	0.32	5	0.81
03-May-04	SCat, Blue Cavern	3	400	24	3.60	1	0.15
17-May-04	SCat, White Rock	2	206	4	1.17	2	0.58
17-May-04	SCat, Johnson Rock	2	230	24	6.26	1	0.26
27-May-04	SCat, Bird Rock	1	195	14	4.31	1	0.31
07-Jun-04	SCat, Bird Rock	3	399	23	3.46	3	0.45
07-Jun-04	SCat, Isthmus Reef	3	386	6	0.93	3	0.47
06-Jul-04	Scat, Isthmus Reef	1	180	2	0.67	1	0.33
06-Jul-04	SCat, Quarry east	1	192	10	3.13		0.00
20-Jul-04	SCat, Quarry east	1	116	3	1.55		0.00
20-Jul-04	SCat, Quarry east	1	140	3	1.29		0.00
20-Jul-04	SCat, Yellowtail Point	2	236	2	0.51		0.00
05-Aug-04	SCat, Iron Bound Cove	4	648	71	6.57	1	0.09
05-Aug-04	SCat, Star Bay	2	199	8	2.41	1	0.30
24-Aug-04	SCat, Cape Cortes	2	257	23	5.37	12	2.80
24-Aug-04	SCat, Lobster Bay	2	218	7	1.93	4	1.10
24-Aug-04	SCat, West End	2	277	24	5.20	1	0.22
06-Oct-04	SCat, Little Harbor	2	235	6	1.53	3	0.77
06-Oct-04	SCat, Little Harbor	2	232	2	0.52	4	1.03
17-Nov-04	Palos Verdes, Haggerty's	3	417		0.00	2	0.29
17-Nov-04	Palos Verdes, PV Point	3	363	3	0.50	2	0.33
17-Nov-04	Palos Verdes, Lunada Bay	1	141	1	0.43		0.00
17-Nov-04	Palos Verdes, Lunada Bay	1	141	1	0.43		0.00

Size distribution of live abalones

The abalones recorded at the dive locations were grouped together by key location, and the size frequency distributions were plotted and presented by area for green (Figures 5), and pink abalones (Figure 6).

Group sizes of live abalone

The groups of green abalone found are presented in Table 2. No groups of pink abalone were found. The range of percent in groups is broad (0 – 100%), but this is only an artifact of small sample size. Nevertheless, the occurrence of so many groups is a good sign of recovery.

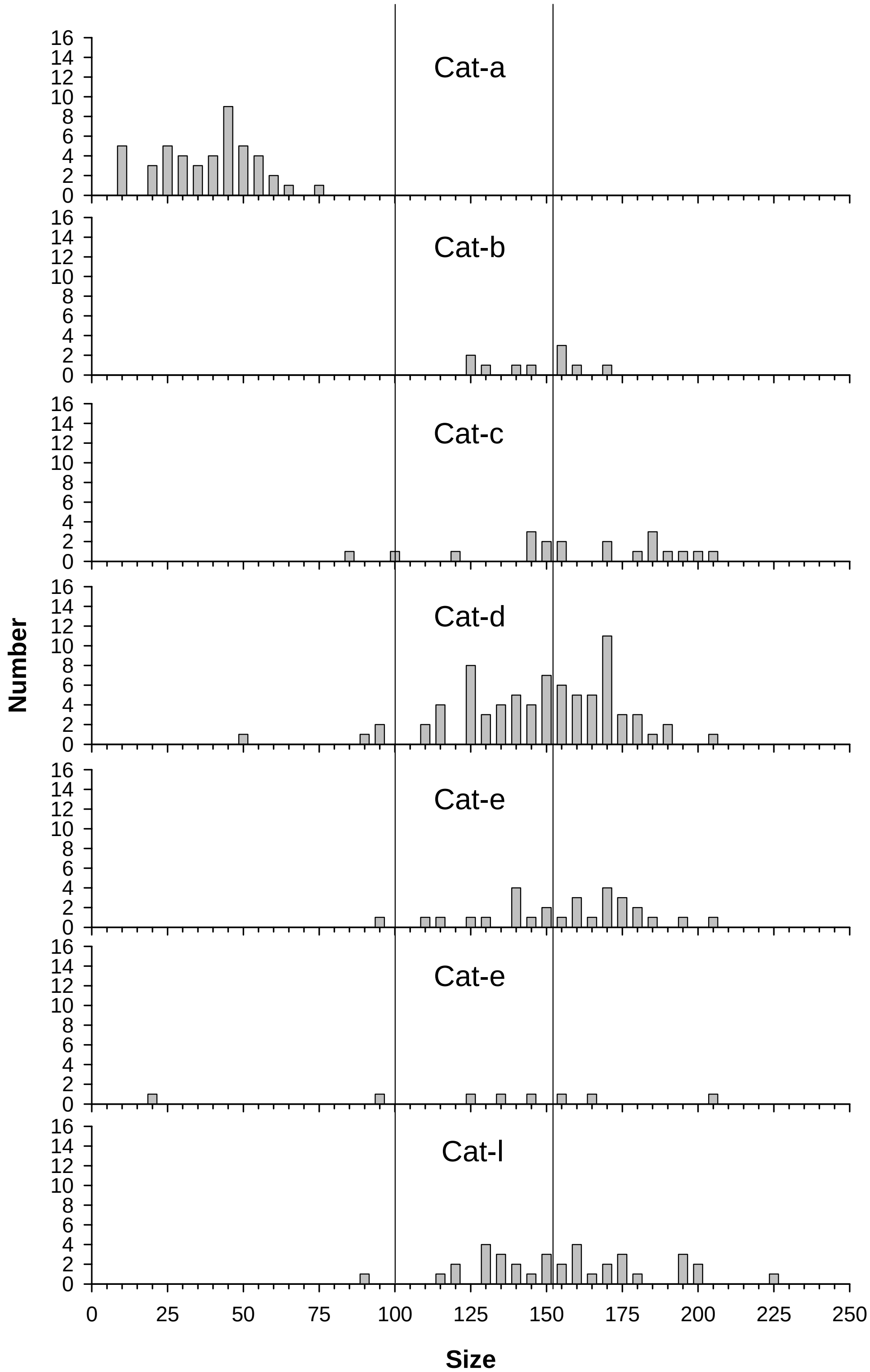


Figure 5. Green abalone size frequency at Catalina Island. The vertical line at 100 mm represents the approximate size at which green abalone become less cryptic. The vertical line at 152 mm was the recreational minimum size limit.

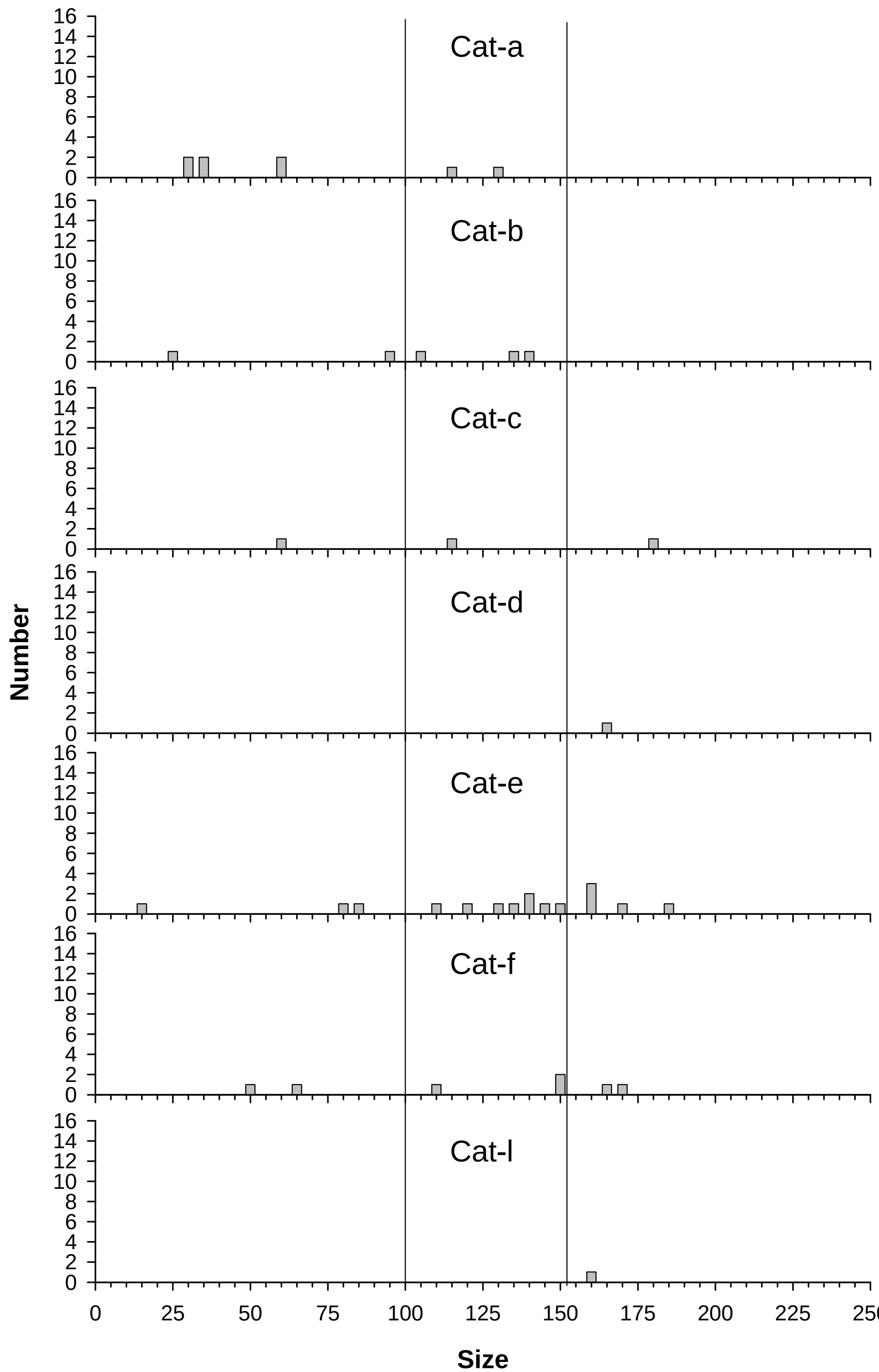


Figure 6. Pink abalone size frequency at Catalina Island. The vertical line at100 mm represents the approximate size at which pink abalone become less cryptic. The vertical line at 152 mm was the recreational minimum size limit.

Table 2. Size of groups of green abalone found during assessmentsurveys by location and the percentage of abalone in groups.

		Green abalone									
	Location Date	Group size									% in
		No.	2	3	4	5	6	7	8	9	groups
31-Mar-04	SCat, Quarry		2	1					1		53.6
22-Apr-04	SCat, Arrow Point		1								25.0
22-Apr-04	SCat, Little Geiger										0.0
03-May-04	SCat, Emerald Bay	2									0.0
03-May-04	SCat, Blue Cavern	24	2	2		1					41.7
17-May-04	SCat, White Rock	4									0.0
17-May-04	SCat, Johnson Rock	24									0.0
27-May-04	SCat, Bird Rock	14	2	3							92.9
07-Jun-04	SCat, Bird Rock	23									0.0
07-Jun-04	SCat, Isthmus Reef	6									0.0
06-Jul-04	Scat, Isthmus Reef	28									0.0
06-Jul-04	SCat, Quarry east	8		2							60.0
20-Jul-04	SCat, Quarry east	1		1							100.0
20-Jul-04	SCat, Quarry east	3									0.0
20-Jul-04	SCat, Yellowtail Point	2									0.0
05-Aug-04	SCat, Iron Bound Cove	71	7	3	2	1					43.7
05-Aug-04	SCat, Star Bay	8		1							37.5
24-Aug-04	SCat, Cape Cortes	23	4	1	1						65.2
24-Aug-04	SCat, Lobster Bay	7	2								57.1
24-Aug-04	SCat, West End	24	4								33.3
06-Oct-04	SCat, Little Harbor	6	1								33.3
06-Oct-04	SCat, Little Harbor	2									0.0
17-Nov-04	Palos Verdes, Haggerty's	0									
17-Nov-04	Palos Verdes, PV Point	3									0.0
17-Nov-04	Palos Verdes, Lunada Bay	1									0.0

Discussion

The results of the CDFG/AoP abalone assessment program presented here are preliminary, as the program only began in March 2004. Nevertheless, this assessment will be mandated by the acceptance of the ARMP by the California Fish and Game Commission, and it will be extended to areas throughout southern California.

Cooperation between CDFG and AoP scientific diving programs has accelerated the assessment of abalone populations in southern California to a greater extent than CDFG divers could accomplish alone. Establishment of the program was facilitated in a large part because both CDFG and AoP were members of the American Academy of Underwater Sciences, and each had established scientific dive programs. The reciprocity afforded by the AAUS memberships, allows divers from both organizations to use each other's vessels to conduct diving operations. The AoP, which has a strong conservation ethic, was also interested in abalone from that point of view. This relationship provides an excellent opportunity for the interested non-scientist diver to become involved in a worthwhile State mandated survey of an important fishery species. It can also serve as a model for other projects which have been delayed by inadequate State and Federal funding. The results of the first year of the assessment were surprising. A total of 54 dives were made with a total of almost 113 hours of search time. During the dives 299 green and 30 pink abalones were found. The detection rate (abs/ hour) ranged from 0 to 6.83 for green abalone, and from 0 to 2.80 for pink abalone (Table 1).

The size distributions for the abalones at the various sites varied by site, but some locations had surprisingly broad distributions (Figures 5 and 6), and indication that reproduction has been occurring over the past few years. The occurrence of relatively large numbers of cryptic (< 100 mm) individuals was surprising, and constitutes a very good indication of natural recovery of green abalone. Even when there may be few individuals at a location, a broad size distribution is an indication that reproduction and subsequent growth has occurred.

Significantly higher numbers of green abalone were detected than pink abalone, i.e., 299 vs. 30, respectively. The pink abalone has a much broader depth distribution, 20 to well over 100 ft., perhaps the broadest of all California abalones. Green abalone is a shallow water species, just sub-tidal to about 20 ft., which includes less available habitat. The observed differences in the total numbers of the two abalones may be an artifact of the surveys being conducted at Catalina Island, which has a narrow rocky subtidal benthic substrate more conducive to green abalone. However, pink abalone was once common at Santa Catalina Island, where landings were higher than those for green (Burge et al. 1975). The differences in the numbers of each species found will have to be addressed after more surveys are conducted at Santa Catalina Island and locations elsewhere.

We are enthusiastic about the future of the CDFG/AoP abalone program. There certainly will be a need to continue the abalone program at Catalina, and at other areas on the mainland. Two other islands, Santa Barbara and San Clemente, once had good populations of abalones, and will need to be surveyed. When the need to move to the next level of evaluation for an abalone arises, the trained scientific diver base provided by the AoP will likely be called upon.

AoP already has liaisons with local universities, and these may soon provide opportunities for abalone research, and in other disciplines as well.

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