Abalone Recovery and Management Plan Status Report - Northern California Red Abalone Fishery

Marine Region Invertebrate Management Project

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STATE OF CALIFORNIA
THE RESOURCES AGENCY
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List of Acronyms

ARMP - Abalone Recovery and Management Plan

ARMs - Abalone Recruitment Modules

CEQA - California Environmental Quality Act

CI – Confidence Interval

CPUE - Catch Per Unit Effort

EFI - Essential Fishery Information

MVP - Minimum Viable Population

TAC - Total Allowable Catch

WS - Withering Syndrome

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Executive Summary

The Abalone Recovery and Management Plan (ARMP) was adopted by the California Fish and Game Commission in 2005 to manage the recreational red abalone (*Haliotis rufescens*) fishery in northern California (north of San Francisco) and to guide the recovery of depleted abalone stocks elsewhere in the state. The ARMP provides a management framework based on fishery independent and fishery dependent data. Fishery independent dive surveys and two sources of fishery dependent data (creel surveys and abalone report card data combined with a systematic telephone survey) are the primary data sources used to manage the recreational red abalone fishery with management guidelines set forth in the ARMP. This report was prepared to satisfy the ARMP requirement for a triennial stock status review and is intended to be the first in a series. The report covers more than three years (2005 through 2009) because the more recent data differ greatly from earlier surveys and significantly alter management considerations for this fishery. The report also incorporates data collected before 2005 for comparisons with earlier periods and to update data presented in the ARMP.

Major findings for the northern California recreational red abalone fishery are:

(1) Correction of the Baseline Total Allowable Catch (TAC) is Warranted. The ARMP requires revising the baseline TAC with the most recent three years of catch estimates. Report card and telephone survey derived estimates from the period 2006 through 2008 are now available.

(2) Average density for index sites approaching trigger to reduce catch. The average density observed in the most recent dive surveys at the eight ARMP index sites was 0.53 abalone/m^2 which is close to the ARMP trigger of 0.50 abalone/m^2 for lowering the TAC.

(3) Evidence of Poor Recruitment. Low recruitment rates indicated by dive surveys might not be sufficient to sustain abalone populations with current levels of take. Abalone Recruitment Modules show modest recruitment rates for most of the last 10 years with only 2005 having higher than average recruitment.

(4) Very High Catch at Fort Ross Sites. High catch rates in the Fort Ross area may not be sustainable. Abalone density at Fort Ross (0.33 abalone/m^2) is near the ARMP site closure level (0.25 abalone/m^2). Recent annual catches have greatly increased in this area and represented 21% of the estimated 2008 abalone catch.

Correction of Total Allowable Catch (TAC)

The ARMP provides for making a correction in the baseline TAC using report card and telephone survey data from the three most recent catch estimates. The current baseline TAC was set at 400,000 using report card data from 2000 which did not include a telephone survey to adjust for biases from unreturned cards. The Department now uses telephone surveys to correct for biases in the data from returned report cards. Based on the estimated average annual catch from 2006 through 2008, the new baseline TAC would be 280,000 abalone. This correction in the TAC will improve the effectiveness of regulatory changes if the average abalone density continues to decline and a reduction in the TAC is needed.

Lower Abundances Observed in Fishery Independent Index Site Dive Surveys Data

Dive surveys provide data for estimating red abalone abundances (as densities) used in tracking changes in the population. The average density of eight index sites determines whether changes to the TAC should be considered. Density is critical in evaluating abalone population status because low abalone densities reduce the chance of eggs becoming fertilized and can cause recruitment failure. Surveys conducted in 2008 and 2009 had much lower abalone densities than earlier surveys and caused the average density to approach the ARMP trigger levels for reducing the TAC.

Northern California red abalone are relatively abundant but there are concerns about the future of the recreational fishery utilizing this resource. Most of the index sites have shown a decrease in abalone density recently, an indication that more abalone are taken from these sites than are being replaced by natural recruitment. Current surveys show very few small abalone and recruitment rates do not appear to be adequate to sustain current take levels in the fishery. Abalone density at Fort Ross for the 2009 dive survey (0.33 abalone/m^2) approaches the ARMP level to close a site (0.25 abalone/m^2).

Strong recruitment events are rare occurrences and the health of the current fishery probably depends largely on the recruitment event first observed in the 1989 Van Damme survey. Management of this fishery is focused on preventing further reductions in abalone density to prevent local population collapses. Maintaining current abalone abundances could prevent reductions in recruitment rates which could lead to a reduction in the sustainable level of catch. The ARMP interim management plan is designed to be conservative in managing catch between rare recruitment events. Implementation of the ARMP long term plan would feature zonal management and could take more efficient advantage of rare recruitment events. The long term plan requires more staff and resources than is currently available.

Fishery Dependent Creel and Report Card Data

Creel surveys allow the Department to estimate CPUE and incidental fishing mortality at specific catch locations, and track sizes of abalone taken at traditional high use sites. The data could be used to institute dive surveys at non-index sites when creel data indicate population declines. While these data raise concerns for some sites, no additional dive surveys are recommended at this time.

The Fort Ross area in Sonoma County continues to be the most heavily used abalone location according to report card information. Catch at this area, which includes two adjacent abalone card sites, has greatly increased recently. This area accounted for 21 percent of the 2008 total estimated abalone catch.

Updated ARMP Information

Recent analysis of data measuring the distances separating abalone within discrete aggregations (“nearest neighbor”) and aggregation sizes confirmed 0.2 abalone/m^2 (2000/hectare) as an appropriate Minimum Viable Population (MVP) level.

The withering syndrome (WS) bacterial disease which devastated some southern California abalone populations has not made a noticeable impact on abalone populations in northern California. The cooler waters in the north apparently inhibit the disease from spreading extensively but warm water conditions associated with El Niño events or warmer climate conditions could significantly increase the negative impacts of WS on northern California red abalone populations in the future.

Introduction

The Abalone Recovery and Management Plan (ARMP) was adopted by the California Fish and Game Commission (Commission) in 2005 to manage the recreational fishery in northern California and to guide the recovery of abalone stocks in the remainder of the state. The red abalone (*Haliotis rufescens*) fishery in northern California (north of San Francisco) is the only active abalone fishery in the state. Before the ARMP, the fishery was managed by bag limits, size limits, annual limits, open seasons, and gear restrictions (*i.e.*: no SCUBA or surface supplied air and no sharp tools for removing abalone). The ARMP continues the use of earlier management methods and adds safeguards based on monitoring abalone densities at eight index sites surveyed over three year periods and fishery dependent data. This report utilizes results from five years of index site survey data and fishery dependent data to evaluate the current status of northern California abalone populations. The more recent survey data are included because they significantly alter management considerations for this fishery. The report fulfills reporting requirements in the ARMP.

The three main sources of data used to manage the northern California recreational red abalone fishery are fishery independent dive surveys and two types of fishery dependent data: creel surveys and returned abalone report cards which are adjusted for bias with a telephone survey. The dive surveys provide direct information on the abundances (measured as densities) of red abalone populations at eight index sites (Figure 1) and the average density of all the index sites combined determines whether recommendations should be made to increase or reduce the Total Allowable Catch (TAC). The ARMP also provides for an adjustment to the TAC based on improved methods to estimate catch which were developed after the initial ARMP baseline TAC was set. Catch and effort are now estimated from returned abalone report cards with a telephone survey used to adjust for bias resulting from differences in fishing patterns between fishermen who return their cards and those who do not. Returned abalone report cards and the telephone survey provide data on the relative use at 56 listed abalone card locations and demographic information related to the fishery. Creel surveys are the longest time series of red abalone fishery data, and are used to monitor high use sites for changes in catch, catch per unit effort, length frequency of abalone retained, and distance traveled from access point to specific catch location. If creel data for an individual non-index site shows significant reductions in CPUE, dive surveys are subsequently conducted at the site to estimate abalone density which is then used to determine whether site closure should be considered. Abalone recruitment modules, gonad condition, stock structure and nearest neighbor studies are also reviewed as part of the Department's ongoing assessment of the resource.

Corrected TAC

The ARMP provides for making a correction in the baseline TAC using report card and telephone survey data from the three most recent catch estimates if the initial TAC exceeds current catch estimates by more than 50,000 abalone (ARMP Section 7.1.2.2). The initial TAC of 400,000 abalone was calculated using a sub-sample of report cards from a single year (2000) which did not include a telephone survey to adjust for biases from unreturned cards. Since 2002, estimates of abalone catch have been improved with the use of systematic telephone surveys. Based on the estimated average annual catch from 2006 through 2008, the new baseline TAC would be 280,000 abalone. The corrected TAC has no immediate effect on the fishery but will adjust the TAC to current levels of take

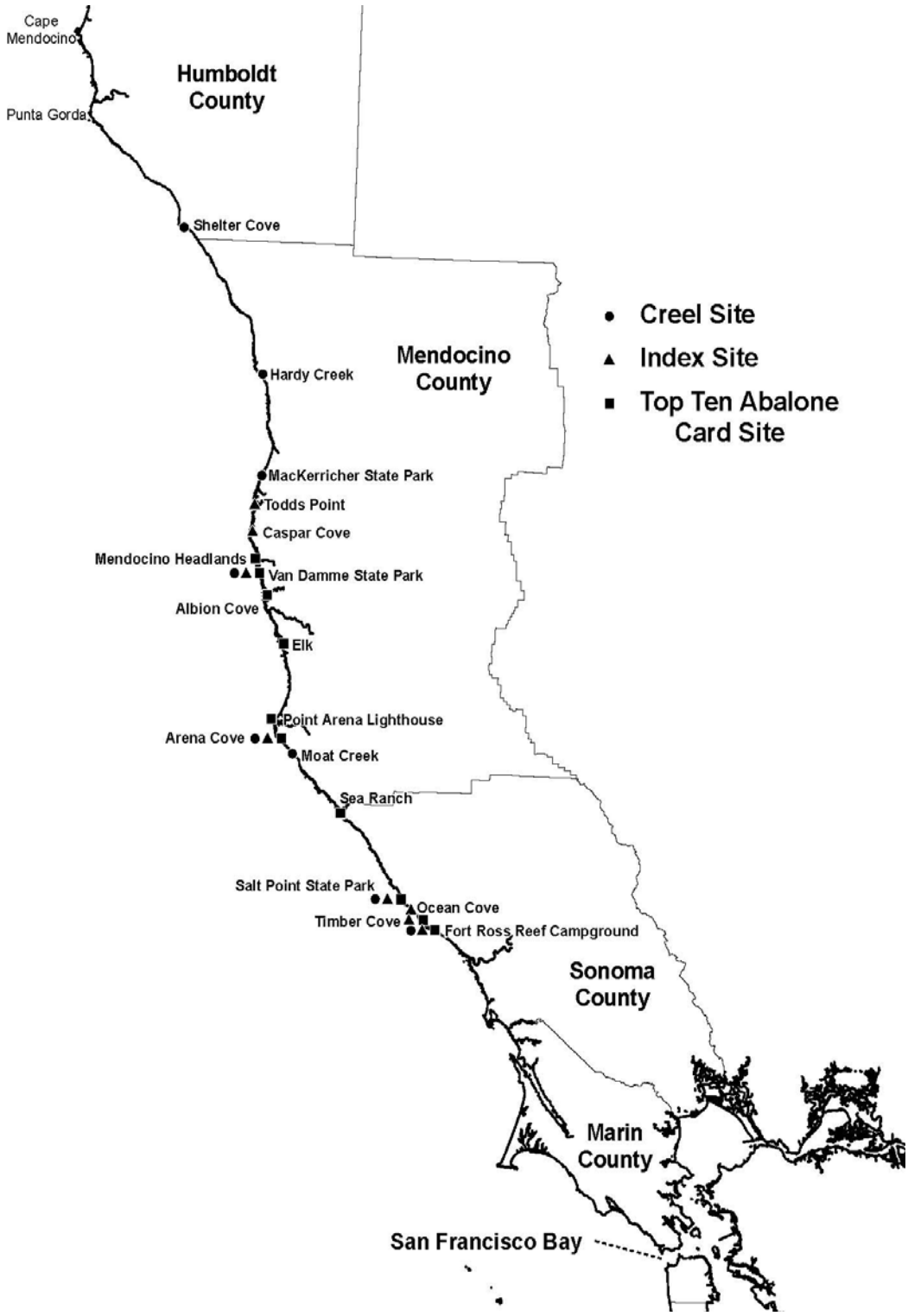


Figure 1. Creel, index, and top ten abalone card sites for the northern California recreational red abalone fishery in the ARMP.

Fishery Independent Data

Index Site Dive Surveys

The primary method of evaluating the status of red abalone populations is to compare abalone abundances from dive surveys at eight index sites (Figure 1) with criteria outlined in Section 7.1.2.2 of the ARMP (Table 1). The criteria are used to adjust the TAC and are based on abalone density and recruitment standards that correspond to recommended management actions if the criteria are reached. Density levels in the ARMP are given in abalone per hectare, however this report uses abalone per square meter (m^2) for consistency with other Department documents (10,000 abalone/hectare equals one abalone/m^2). The main criteria used to determine TAC adjustments are abalone densities over all depths, densities in deep water (28 ft to 66 ft [8.5 m to 20.1 m]), and successful recruitment (>0.45 abalone/m^2 in the 3.9 in -7.0 in [100 mm-177 mm] size class) (Table 1). In order for a decrease in the TAC to be considered, average density for all transects would have to fall below 0.50 abalone/m^2 (Table 1, shaded row). There are also criteria for increasing the TAC (Table 1). The ARMP calls for a fishery closure if the average density at the index sites were to drop below 0.30 abalone/m^2 (Table 1).

Table 1. TAC adjustment table modified from the Abalone Recovery and Management Plan with strong recruitment and density criteria (left side of table, densities in abalone per square meter) and management actions (right side of table).

CRITERIA					**ACTION**
Strong Recruitment [>0.45 abalone/m^2 in 4 to 7 inch (100-177 mm) size range]		***Density (abalone/m^2)*** (emergent surveys)			
		Deep (refuge)		All Depths	
Yes	AND	*> 0.41*	AND	*> 0.83*	1) Increase TAC by 25% (to max 500,000 ab/yr or 25% of revised TAC)
N/A		*0.33*	AND	*0.66*	2) Maintain TAC (400,000 ab/yr or revised TAC)
No	AND	*< 0.25*	OR	*< 0.50*	3) Reduce TAC by 25% increments
N/A		*N/A*		*< 0.30*	4) Close Fishery
N/A		*> 0.33*	AND	*> 0.66*	5) Reopen Closed Fishery

The dive survey protocol is to count and measure abalone along a transect line without using flashlights or disturbing the habitat (Tegner *et al*. 1989; Parker *et al*. 1988). Transects are 30 m long and one m wide on each side (60 m^2 sample area per transect). Analysis determined that 36 transects per site is an appropriate number for detecting changes in abalone density in the context of ARMP criteria and available resources.

Density

Overall density is an important measurement because it is related to successful reproduction and stock productivity. Low densities can result in the failure of abalone populations to reproduce (Shepherd and Brown, 1993). Abalone are broadcast spawners that release eggs and sperm into the water. At low abalone densities fewer eggs are produced and the eggs have less chance of being fertilized because the sperm are less concentrated.

The strong recruitment criterion in the ARMP was derived from observed densities of young abalone in the 1992 Van Damme survey during a period of high recruitment. The role of strong recruitment in the ARMP is to ensure there are adequate numbers of young abalone to replace the higher numbers of abalone taken if the TAC is increased, or to forestall a decrease in the TAC if abalone densities fall below trigger levels (Table 1). However, current recruitment levels are too low to be a factor in the latter consideration.

Surveys at the eight index sites conducted over the past three years show red abalone populations are close to levels that would trigger a TAC reduction. The average density for the eight index sites over all depths was 0.53 abalone/m^2; the average density for deep transects was 0.25 abalone/m^2; and the average density of recruits was 0.19 abalone/m^2 (Table 2). Although the ARMP provides for TAC reductions based on abalone density for deep transects, these densities fluctuate more than densities at all depths and should not be the sole factor considered for reducing the TAC.

Factors other than actual changes in density can contribute to variation in density estimates. The number and placement of transects are key factors. The number of transects relates to the statistical power of a survey to detect actual changes in density, generally the more transects surveyed, the more accurate the estimate of abundance. Transect placement is based on a stratified-random protocol. Transects are randomly set within suitable habitat and it is likely transects will be in different specific locations from survey to survey. The random location of transects increases the variation in density between years compared to a survey design which revisits the same sites, but random transects are more likely to be representative of an area and each successive random survey increases the understanding of local abalone distribution more than when the same transects are used for each survey. Randomly placed transects are an accepted protocol used for marine invertebrate surveys. To compensate for variation due to random location of transects, some high density transect locations from 2006 are planned to be re-surveyed for a special test in the coming season to verify the lower densities observed in 2009 were not a product of the random survey design. Rough weather conditions also can affect density estimates by limiting the sites surveyed to more sheltered locations.

Table 2. Recent Northern California Abalone Population Survey Densities (abalone/m^2).

Index Site	Number of Transects All Depths	Abalone Density All Depths	95% Confidence Interval	Number of Transects (Deep)	Abalone Density (Deep)	Recruitment (100 - 177 mm) Density
Todds Point 2006	34	0.43	0.19	18	0.16	0.12
Caspar Cove 2008	50	0.43	0.16	24	0.19	0.11
Van Damme 2007	28	0.69	0.36	14	0.17	0.30
Arena Cove 2007	36	0.64	0.22	19	0.45	0.23
Salt Point 2008	41	0.39	0.14	21	0.15	0.15
Ocean Cove 2007	36	0.86	0.25	19	0.42	0.39
Timber Cove 2009	35	0.43	0.14	20	0.27	0.09
Fort Ross 2009	43	0.33	0.10	22	0.17	0.10
Totals/Averages	303	0.53	0.20	157	0.25	0.19

Size Frequency – Dive Surveys

When abalone size frequency data are examined over time, it can help show the nature of changes within red abalone populations (Karpov *et al*. 1998, 2001). Size frequencies in this report are weighted by overall density to provide a more representative characterization of abalone populations than percentage-based relative size frequencies which can make low density sites appear to be similar to sites with much higher densities.

Size frequency graphs for all ARMP index sites have very similar characteristics (Figure 2). Most abalone are near the legal size limit of 7 in (178 mm) with relatively few abalone below 5.9 in (150 mm) in length or above 8.5 in (215 mm) in length. Slower growth rates as abalone increase in size produce the characteristic rise in frequency near the size limit. As abalone grow, individual year classes compress and are obscured.

The density of abalone in shallow transects is generally higher than deep transects. The peak abundance for abalone along deep transects tends to be at slightly larger sizes than shallow transects and probably is caused by the removal of larger abalone in shallow water by the fishery.

The most complete red abalone size frequency time series is from Van Damme (Figure 3). Although the series has gaps after a four-year survey period between 1989 and 1992, the data are complete enough to illustrate an important aspect of the northern California red abalone fishery. Strong recruitment events are rare occurrences (Figure 3) and the health of the current fishery probably depends largely on the recruitment event first observed in the 1989 Van Damme survey. The time series from 1989 through 1992 shows large numbers of small abalone that apparently grew into larger size classes in subsequent years. By 1999, nearly all the small abalone seen in 1989 should have reached the legal size but the large numbers of abalone just under legal size in 1999 could represent slow growing abalone. In later surveys, there has been no evidence of a large scale recruitment of small abalone similar to the one seen in 1989. Of the later surveys, only the 2003 survey shows a slightly higher abundance of small abalone, but those small abalone have not made a noticeable effect on abalone size frequencies and abundances as of the 2007 survey.

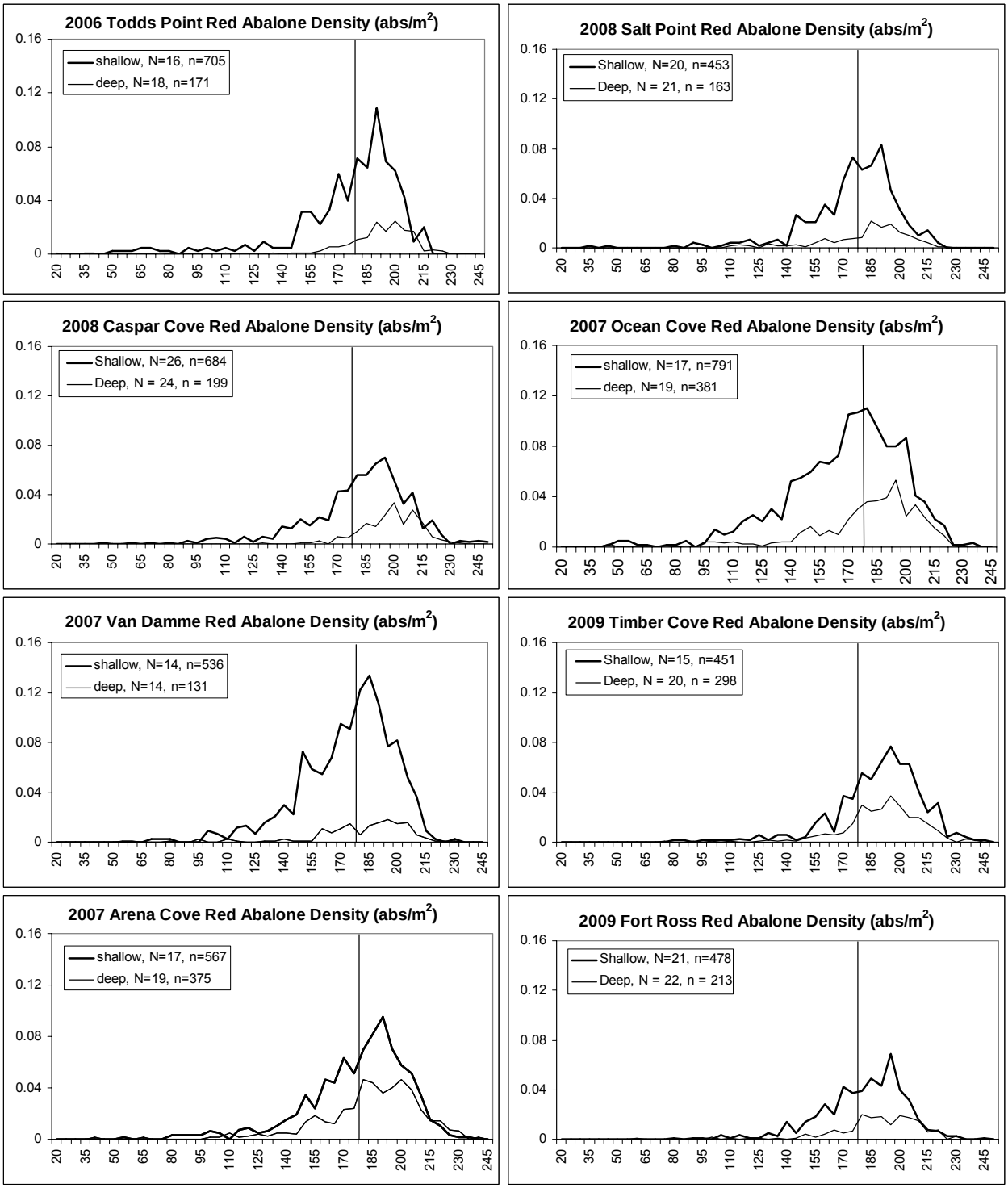


Figure 2. ARMP index site red abalone size frequency (abalone per m^2 grouped by 5 mm intervals) weighted by density (left column-Mendocino County, right column-Sonoma County, sites-north to south).

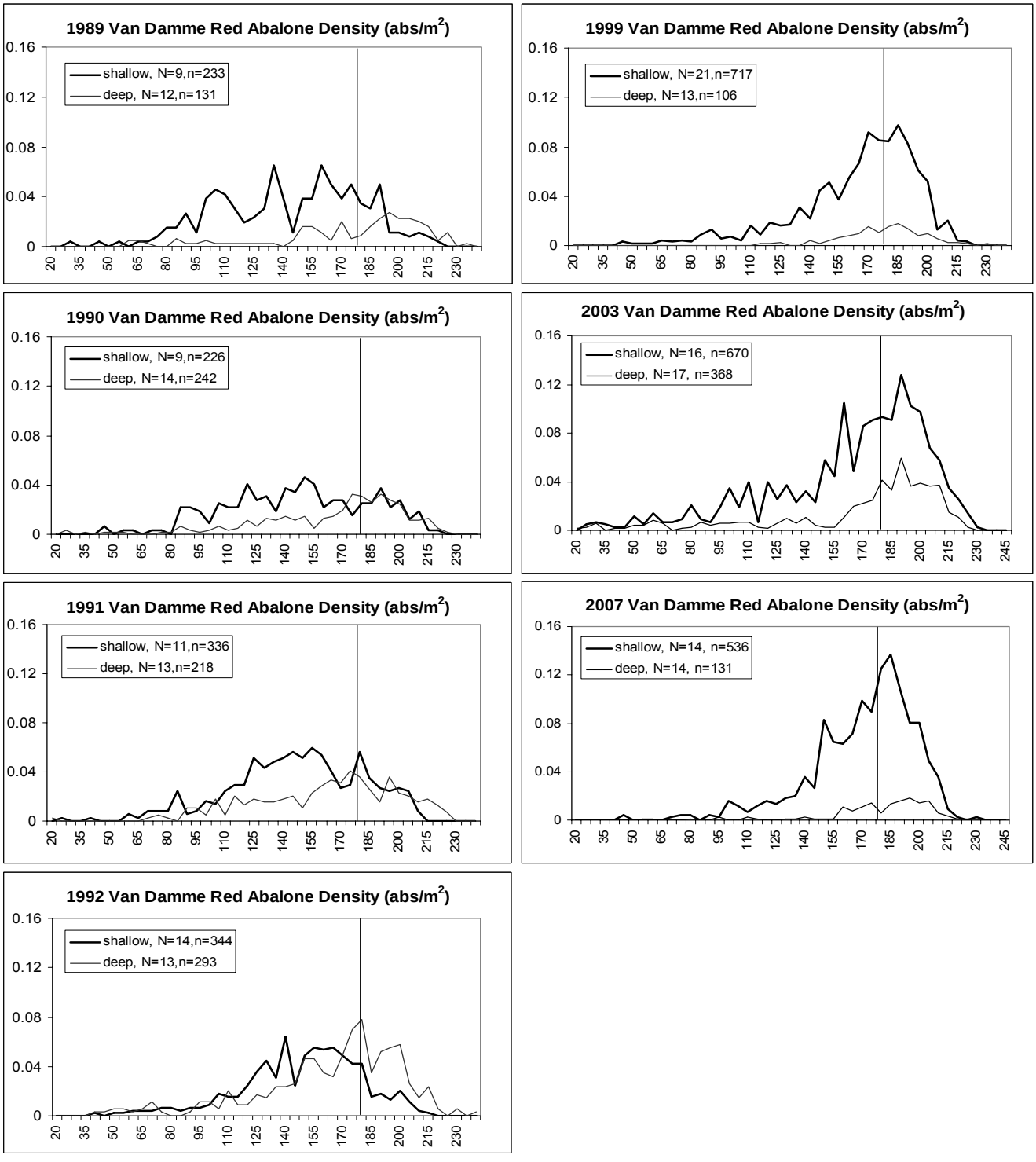


Figure 3. Red abalone size frequency (abalone per m^2 grouped by 5 mm intervals) weighted by density surveyed over 18 year time period at Van Damme. Note large number of small abalone in the 1989-1992 surveys which appear to grow over time and the relative lack of small abalone in later surveys.

Fishery Dependent Data

Abalone Report Card and Telephone Survey – 2002 to 2008

A report card for the California recreational red abalone fishery was established in 2000 which requires pickers to record catch information and return the card to the Department at season's end. An estimate of catch and effort based on returned cards alone would likely be biased due to characteristics related to those who chose to return their card versus the group that did not (Pollock *et al*. 1994). Therefore, a telephone survey was designed to estimate the catch and effort of the non-return group for each abalone season (ARMP Section 7.2.4.1). The estimate was statistically combined with counts from the returned report cards to produce an overall catch and effort estimate for the sport abalone fishery (Kalvass and Geibel 2006 and Table 3). In addition to providing catch and effort statistics for the non-return group, a number of key ratios can be developed from the telephone survey for refinement of the report card data (return group), including percentage of card purchasers who never used the card (zero effort) and those with a zero catch rate. The primary questions establish whether or not the abalone report card had been returned prior to the time of the interview, and catch and effort information.

Catch and Effort

Estimated catch stayed within a relatively narrow range from 2002 through 2006, from a low of 235,145 abalone in 2005 to a high of 264,130 in 2002, a range of 11 percent (Table 3). However, the 2007 estimated catch and effort days increased markedly. Catch per picker-year varied from a low of 7.70 abalone in 2005 to a high of 8.94 in 2007. The distribution of annual take per picker in 2007 from report card return data shows that 9 percent took the annual limit of 24 abalone. Almost five percent of pickers were not successful in taking any abalone. In 2008, estimated catch returned to levels seen in earlier years.

Catch per picker-year is calculated to estimate the average number of abalone taken per person and is probably not a useful measurement of catch per unit effort. Since the unit of effort is a year and the numbers of days and hours of effort could vary considerably, this measurement of catch and effort is not very sensitive. The creel data discussed in later sections can analyze catch per hour and would be more useful in detecting changes in catch related to effort.

Table 3. Estimated abalone catch and effort by year, 2002 - 2008.

Year	Catch	Effort Days	Cards Sold	Pickers*	Abs/Picker-Yr
2002	264,130	100,473	35,857	30,926	8.54
2003	260,027	104,516	36,769	31,647	8.22
2004	247,311	100,437	36,406	31,781	7.78
2005	235,145	93,944	35,047	30,534	7.70
2006	264,121	107,728	37,362	32,420	8.15
2007	309,449	124,252	39,789	34,632	8.94
2008	265,066	116,402	37,408	32,185	8.24

* Not everyone who purchased a card used it.

Fishing Location and Monthly Distribution

The abalone report card allows not only the estimation of catch but also analysis of catch location. The report card has over 50 northern California location codes for the abalone picker to choose from in identifying his catch site. The total catch estimate is divided into individual sites using the percent breakdown from the report card sample database. While this method allows for an estimate of catch by site code, it is biased because it relies on percentages generated only from report cards. The data allows a perspective of the amount of abalone being taken from the various sites and helps to identify sites which have higher catches.

Both the telephone survey and the report cards have consistently listed the Fort Ross area in Sonoma County as the most heavily used location (Table 4). This area consists of two adjacent sites, Fort Ross and Reef Campground, which are the closest productive sites to the San Francisco Bay Area with good ocean access. Report cards show that 13.8 percent of the abalone take came from these two sites in 2002, which equates to 37,000 abalone. The 2007 take estimate was 62,000 abalone, a 70 percent increase over the take in 2002, and 20.1 percent of the total estimated abalone catch. Abalone density in the 2009 Fort Ross survey was 0.33 abalone/m^2 and has fallen close to the ARMP level to close a site (0.25 abalone/m^2). Closure of this site could shift effort and exacerbate declining trends in abundance for a series of sites.

Table 4. Highest abalone card sites by estimated catch for 2008 and estimates for previous years.

Site	2002	2003	2004	2005	2006	2007	2008
Fort Ross + Reef Campground	37,000	37,000	37,000	33,000	43,000	62,000	56,000
Van Damme	18,000	17,000	13,000	12,000	14,000	16,000	16,000
Moat Creek	6,000	8,000	8,000	6,000	7,000	12,000	14,000
Salt Point	12,000	12,000	11,000	9,000	9,000	13,000	11,000
Sea Ranch	14,000	14,000	13,000	11,000	11,000	13,000	10,000
Mendocino Hdlnds	9,000	9,000	8,000	7,000	12,000	15,000	10,000
Arena Cove	13,000	12,000	11,000	7,000	10,000	9,000	9,000
Total Catch	264,000	262,000	248,000	235,000	263,000	309,000	265,000

Effort distribution through the season (April through November with July closed) has remained consistent between 2002 and 2007. Over 60 percent of the effort is expended before the July closure with November, the last month of the season, receiving a slight

increase in effort compared to October (Figure 4). These data could be used to examine possible effects of reducing the season.

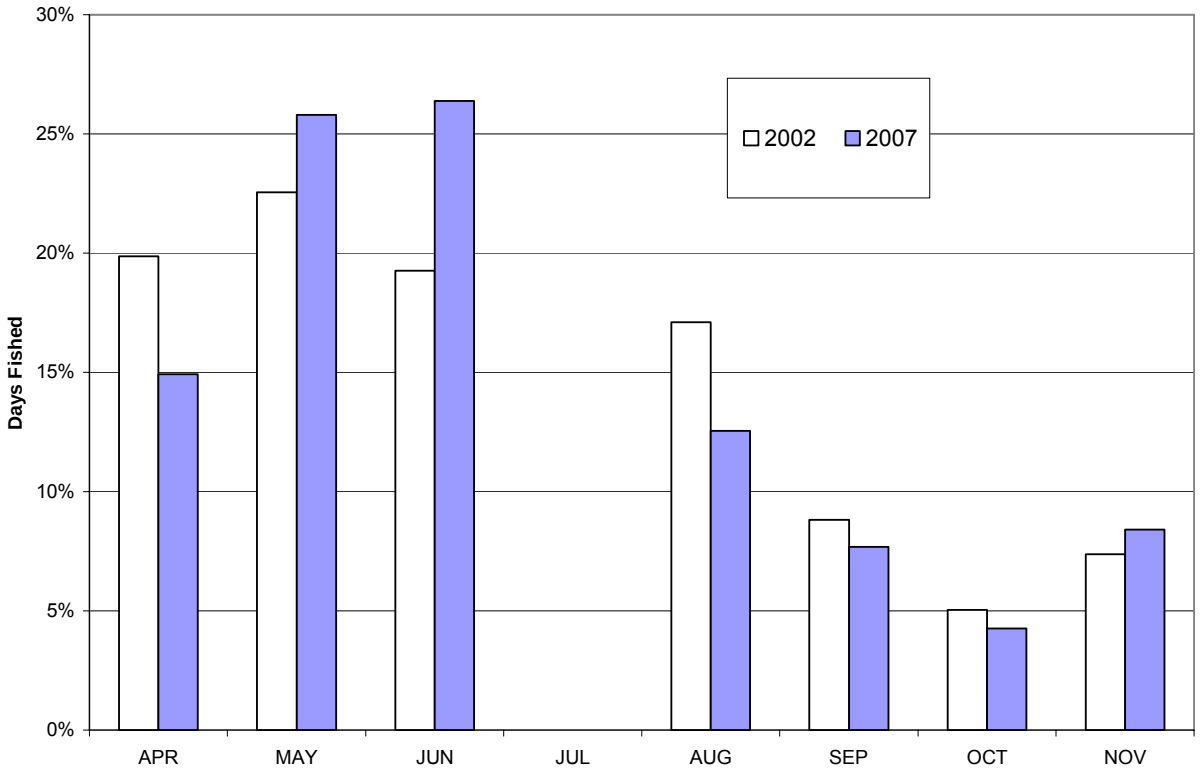


Figure 4. Sport abalone effort by month for 2002 and 2007, from report cards.

Illegal Take

One concern about the catch estimate is that it only accounts for abalone taken legally and the illegal take is not included. The most common violations consist of recreational fishers who intentionally violate regulations. Less common are commercial poachers, who may take large numbers of abalone to sell as part of illegal commercialization rings. Recreational fishers are easily contacted in the field, however, estimating the proportion of non-compliance in this fishery is difficult.

Blank (2008) used an anonymous survey of recreational fishers in Sonoma and Mendocino Counties to estimate violation rates of various abalone regulations. She calculated a 29 percent non-compliance rate with the daily take limit, 23 percent with the minimum size limit, 19 percent with licensing laws, and 15 percent with the annual take limit among the general population. While an estimate of illegal take could not be made with the data collected, this method shows promise for estimating illegal take among recreational fishers. The data indicate there is a significant number of abalone being taken which are not accounted for in total catch calculations. New regulations requiring tags on recreationally caught abalone have been added since Blank's (2008) study and are believed to have increased compliance and reduced the amount of illegal catch. Wardens believe compliance with requirements to complete abalone cards has increased since tags were required to be

placed on sport-caught abalone in 2008. The tags are easily seen from a distance and make possible violations more obvious for wardens.

Creel Surveys

Creel surveys are based upon field interviews of recreational abalone fishermen. They have been conducted in northern California since 1975 on a continuous basis in Sonoma, Mendocino, and Humboldt counties (Gotshall et. al 1974; Karpov 1992). Since 2003, creel surveys have been conducted in alternate years as specified in the ARMP (Section 7.1.2.4).

Creel surveys are important in monitoring the health of abalone populations and have allowed the Department to obtain estimates of catch per unit effort (CPUE), incidental fishing mortality, and sizes of abalone taken at traditionally high use sites along the north coast (CEQA 2001; Karpov 1992). The data provide a perspective of the fishery over a period of more than thirty years. Since 1990, data on fishing location has been collected to help determine whether localized populations are declining as indicated by increased distances traveled by fishermen from access points to take abalone. Creel data allow for the computation of take per picker-day (or take per trip), take per hour, returned abalone per picker day, and miles traveled from access point per trip. The ARMP uses creel data to trigger dive surveys when sites show signs of population declines (Table 5). If dive survey data indicate that abalone densities have fallen below the ARMP trigger level of 0.25 abalone/m^2 for a site, the site will be recommended for closure (Section 7.1.2.4 of the ARMP). The ARMP does not include provisions for catch reductions for sites which are approaching the closure density level; however, the Department could recommend mechanisms such as shortened seasons at individual sites to lower take and forestall site closure. While creel data raises concerns at some sites, no additional dive surveys are recommended at this time.

Table 5. Creel site evaluation table (ARMP Table 7-4) with survey density trigger and site closure and reopening criteria.

CRITERIA				**ACTION**
Density (abalone/m^2) - emergent			**CPUE and**	
Deep (refuge)		All Depths	**Serial Depletion**	
N/A		*N/A*	Significantly lower CPUE or increase in distance traveled	Density **surveys** to determine if closure is warranted
N/A		*< 0.25*	*N/A*	**Close** affected site and reduce base-line TAC
> 0.33	AND	*> 0.66*	*N/A*	**Reopen** closed site

Catch Per Unit Effort (CPUE)

To evaluate the current abalone population status, data were analyzed over the 2003-2007 time period and compared with data from 1989-1994 and 1995-2000 (Table 6). The

2002 regulation change from a daily bag limit of 4 to 3 has complicated CPUE comparisons between time periods and largely accounts for the reduction in number of abalone taken per trip in 2003-2007 compared to earlier time periods (Table 6).

Changes in CPUE over time can provide insight into the health of abalone populations. Data considered in this process include abalone take per trip (abs/trip or abalone per picker) and abalone per hour (abs/hour). Abalone take per hour showed a general increase with increased use of equipment. Shore pickers use the least amount of equipment, followed by shore divers with boat divers using the most. Divers from boats are more successful than shore pickers or shore divers, as would be expected since boats can access more remote, less fished areas. Fort Ross Reef Campground, Salt Point State Park, and Moat Creek all had higher take/hour averages for divers compared to shore pickers (Table 6). Shore picker CPUE was lowest at Salt Point but diver abalone/hour there was higher than most sites, which demonstrates that fishing modes can follow different trends at the same site. The low shore picker CPUE at Salt Point might be the result of the relatively steep terrain at that site which leaves less intertidal habitat accessible to shore pickers than some of the other sites with broader intertidal terraces. Abalone populations in the limited intertidal area at Salt Point could be reduced more quickly than other sites because there is less area to search and the smaller area could be searched more thoroughly in a given amount of time.

While most fishermen were able to get their bag limits in 2003-2007, take/hour is generally lower in 2003-2007 compared to the earlier time periods but the reason for the reduction is uncertain. Certainly, lower abalone abundance is a possible cause, but fishermen could also be taking more time to find larger abalone since in the 2003-2007 period, they could only take three abalone while in the previous time periods they could take four. These uncertainties make comparisons between years difficult, however take/hour declined over all modes from the earliest time period to the most recent, with the largest decrease between the 1989-1994 and 2003-2007 diver from boat mode, when take/hour dropped from 5.7 to 3.6 abalone/hour (Table 6).

Because of concern over the high take levels at Fort Ross, creel data was examined for possible problems and indications of reduced abalone populations were found for the area. Take per picker day (Figure 5) and take per hour (Figure 6) at Fort Ross declined to the lowest recorded levels and could indicate abalone are becoming less abundant and harder to find in the area. Because these measures of CPUE can be influenced by weather and tidal conditions, additional monitoring will be needed to verify these results are not the result of annual variability. These results are not definitive but are another indication of problems in the Fort Ross area.

At Salt Point State Park, catch per picker has steadily declined over the past 18 years as evidenced by the decreasing number of pickers gathering three or four abalone per trip. The decrease in catch success over time is attributed more to shore pickers than to divers (Figure 7). Salt Point is the closest major fishing site for abalone and is among the most likely sites to be affected by effort shifts from Fort Ross.

Table 6. Northern California red abalone creel survey data comparing sites, modes, and combined time periods 2003-07, 1995-2000, and 1989-94.

2003-2007															
Shore Pickers						Divers from Shore					Divers from Boats				
Site	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip
Shelter Cove	207	2.4	2.2	1.1	0.23	135	2.5	2.5	0.6	0.24	-	-	-	-	-
Hardy Creek	468	2.8	2.7	0.7	0.59	29	2.8	2.7	0.4	0.59	-	-	-	-	-
MacKerricher	305	2.4	2.2	1.0	0.26	348	2.6	2.6	0.4	0.27	-	-	-	-	-
Noyo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ChapDam	391	2.7	2.5	1.2	0.26	213	2.6	2.8	0.7	0.24	608	2.8	3.8	0.4	0.36
Point Arena	652	2.8	2.7	0.5	0.41	281	2.8	2.8	0.3	0.37	36	2.6	3.4	0.2	0.44
Moat Creek	1093	2.9	2.4	0.3	0.37	238	2.9	3.6	0.4	0.29	-	-	-	-	-
Salt Point	581	2.5	2.0	1.0	0.23	318	2.8	3.3	0.3	0.24	-	-	-	-	-
Fort Ross Reef	2032	2.8	2.3	0.6	0.31	603	2.8	3.3	0.4	0.30	-	-	-	-	-
Grand Total	5729	2.7	2.4	0.8	0.33	2165	2.7	3.0	0.4	0.32	644	2.7	3.6	0.3	0.40

1995-2000															
Shore Pickers						Divers from Shore					Divers from Boats				
Site	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip
Shelter Cove	570	3.1	2.4	1.6	0.24	288	3.4	2.9	1.2	0.24	-	-	-	-	-
Hardy Creek	429	3.5	3.0	1.0	0.59	29	3.6	3.4	0.2	0.81	-	-	-	-	-
MacKerricher	304	3.1	2.3	1.5	0.28	302	3.3	2.9	0.9	0.28	-	-	-	-	-
Noyo	19	3.9	5.0	1.3	-	18	4.0	4.2	0.6	-	49	3.4	4.1	0.4	-
ChapDam	384	3.2	2.6	1.4	0.25	274	3.1	2.8	1.3	0.32	702	3.8	4.2	0.7	0.34
Point Arena	374	3.6	3.5	1.0	0.39	257	3.5	3.7	0.4	0.35	92	3.8	5.0	0.3	-
Moat Creek	477	3.4	3.0	0.8	0.43	174	3.4	3.6	0.5	0.32	-	-	-	-	-
Salt Point	610	3.0	2.1	1.3	0.25	324	3.1	3.1	0.7	0.30	-	-	-	-	-
Fort Ross Reef	1588	3.0	2.3	1.2	0.33	645	3.3	3.1	0.7	0.33	-	-	-	-	-
Grand Total	4755	3.3	2.9	1.2	0.35	2311	3.4	3.3	0.7	0.37	843	3.8	4.6	0.5	0.34

Table 6. N. California red abalone creel survey data comparing sites, modes and combined time periods 2003-07, 1995-2000, and 1989-94 (continued).

1989-1994 Shore Pickers						Divers from Shore					Divers from Boats				
Site	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip	Trips	Abs/Trip	Abs/Hr	Ret/Trip	Miles/trip
Shelter Cove	242	2.1	1.8	2.5	0.23	203	3.1	3.4	1.4	0.24	-	-	-	-	-
Hardy Creek	631	3.1	2.7	1.3	0.65	-	-	-	-	-	-	-	-	-	-
MacKerricher	284	2.7	2.2	2.9	0.27	132	3.2	3.1	1.2	0.29	-	-	-	-	-
Noyo	-	-	-	-	-	-	-	-	-	-	355	3.4	8.0	0.3	-
ChapDam	184	2.9	2.6	3.2	0.19	739	3.0	4.4	1.7	0.32	1313	3.4	5.3	1.1	0.31
Point Arena	497	3.4	4.0	1.7	0.41	185	3.6	5.3	1.0	0.39	59	3.5	6.0	0.5	-
Moat Creek	634	3.2	3.1	2.1	0.22	299	3.6	4.1	1.7	0.17	-	-	-	-	-
Salt Point	393	3.3	2.8	1.8	0.21	197	3.3	4.3	0.8	0.22	-	-	-	-	-
Fort Ross Reef	800	3.3	3.1	2.3	0.27	401	3.6	4.6	1.3	0.28	-	-	-	-	-
Grand Total	3665	3.0	2.8	2.2	0.31	2156	3.3	4.2	1.3	0.27	1727	3.5	5.7	0.8	0.31

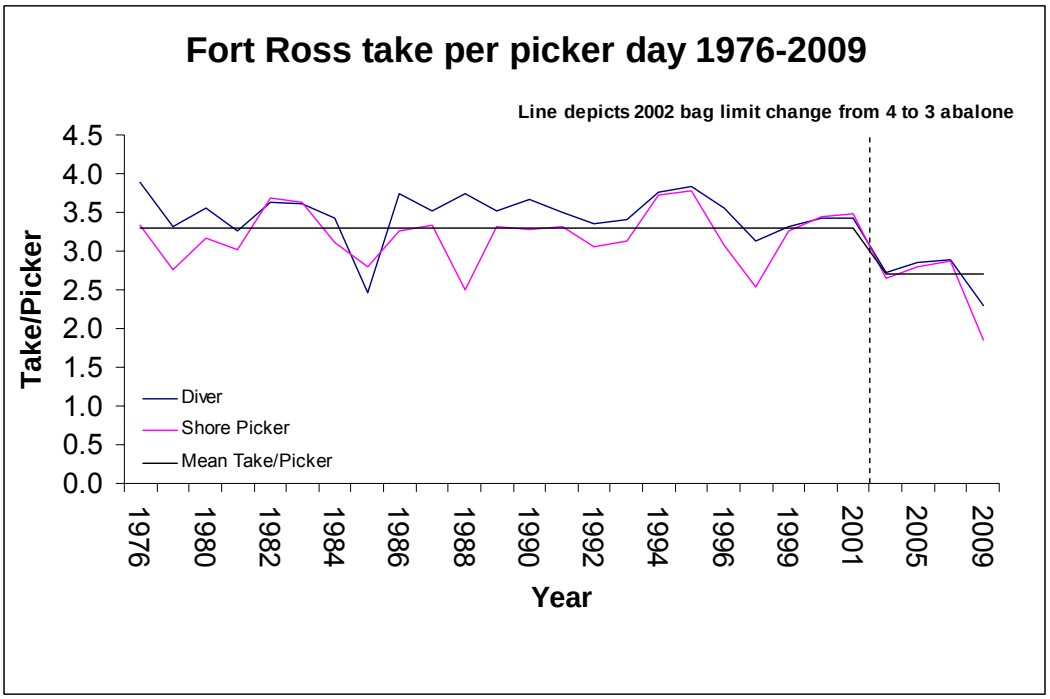


Figure 5. Take per picker day from Fort Ross creel surveys. Dashed line depicts the 2002 daily bag limit change from 4 to 3 abalone.

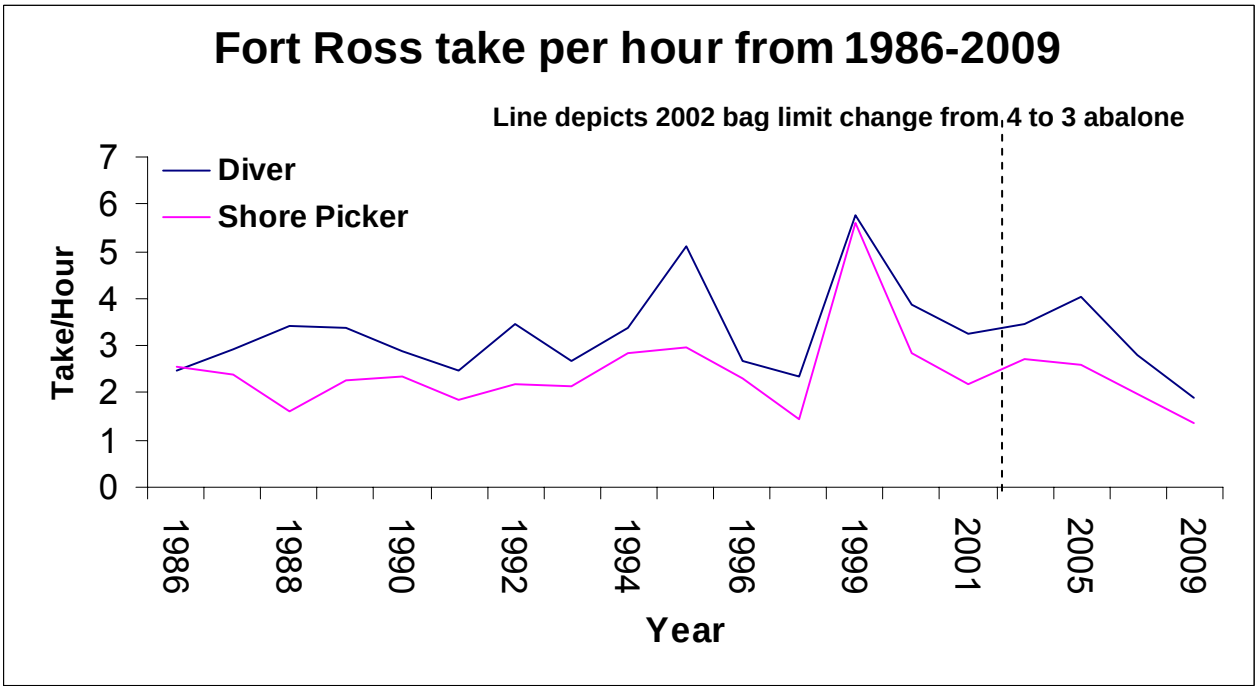
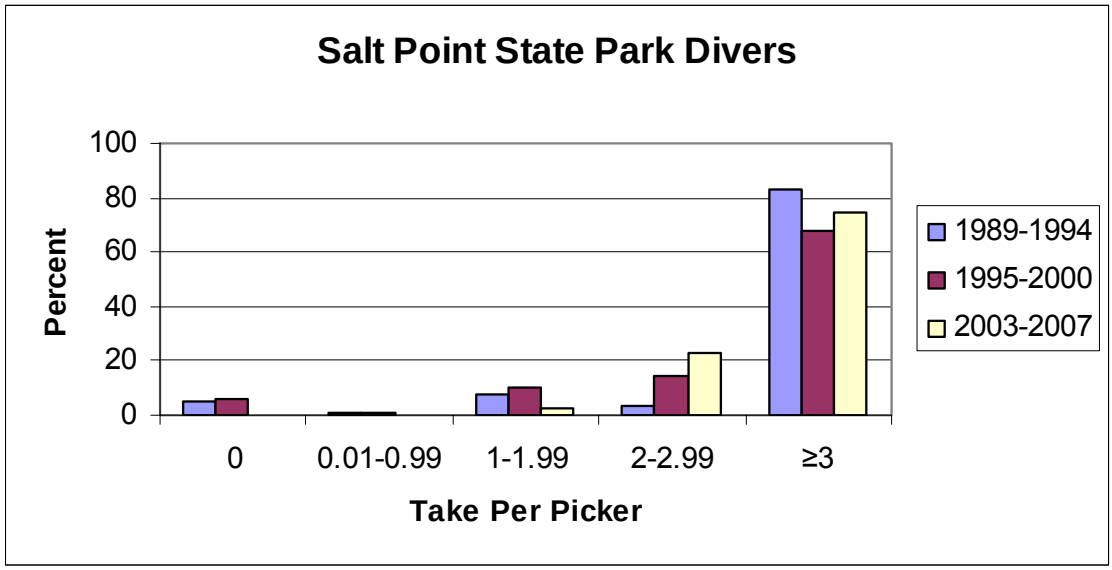


Figure 6. Take-per-picker-hour from Fort Ross creel surveys. Dashed line depicts the 2002 daily bag limit change from 4 to 3 abalone.



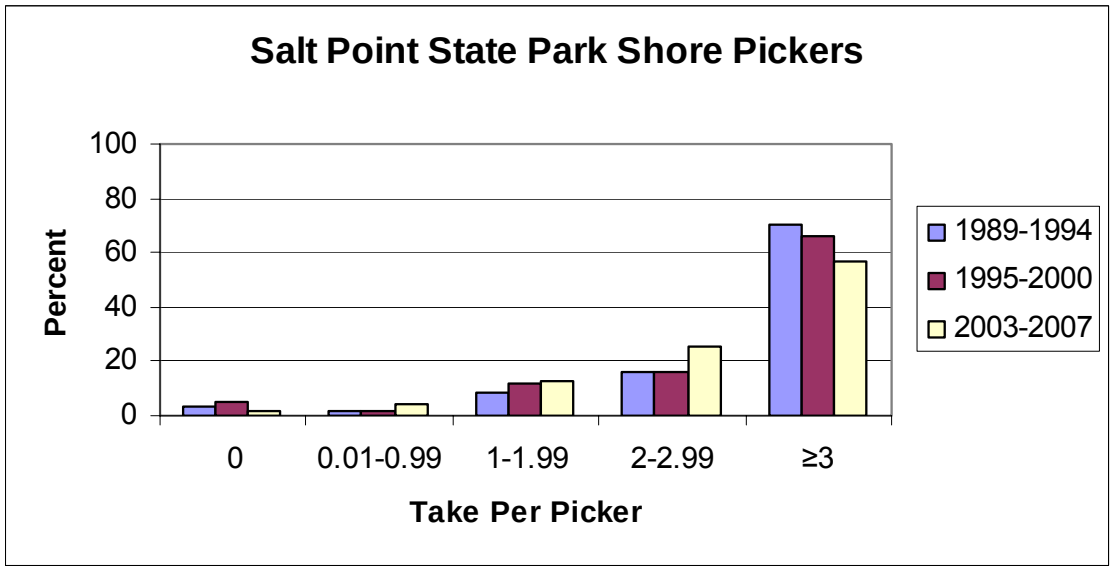


Figure 7. Creel survey percent take at Salt Point State Park for divers and shore pickers comparing 1989-1994, 1995-2000, and 2003-2007.

Distance Traveled

Distance traveled from access point to harvest location was compared between the three time periods to help delineate trends in abalone availability. The furthest distance traveled occurred at Moat Creek, with 2003-2007 shore pickers traveling up to 2.0 nm. This distance may be evidence of serial decline occurring at this site, but the data is inconclusive due to the small sample size and low percentage of pickers interviewed traveling this

distance. However, a higher percentage of the shore pickers intercepted traveled over 1.0 nm during 2003-2007 compared with 1990-1994.

Distance traveled appears to have stabilized overall; this may be due in part to the changes in bag and annual limits in 2002 which were designed to reduce the total take of abalone. Other explanations for the apparent stabilization could be that the maximum distances people are willing to travel have been reached. There has not been a dramatic increase in distance traveled at any of the creel sites when comparing 1995-2000 data with 2003-2007 data.

Size Frequency – Creel Survey

Size frequency data from creel survey sites were combined into four major areas due to their close proximity or to increase sample sizes for more reliable analysis: Shelter Cove to MacKerricher, Chapman to Van Damme, Arena Cove to Moat Creek, and Salt Point to Fort Ross Reef Campground. With the exception of the Shelter Cove to MacKerricher area, the sites combined are relatively close to each other and probably share similar environmental characteristics. These data were compared over the years 1975 to 2007. At each area divers generally harvested larger abalone than shore pickers.

Updated ARMP Information

Annual Red Abalone Juvenile Recruitment Index

An annual red abalone juvenile recruitment index was established using standardized abalone recruitment modules (ARMs) which are surveyed for juvenile abalone annually. ARMs are made of concrete cinder blocks cut lengthwise, stacked inside a cage enclosure (Davis 1995). Twelve ARMs were deployed at Van Damme State Marine Conservation Area in 2000 and surveyed every year since (Rogers-Bennett *et al*. 2004a).

All species of abalone found in the ARMs are identified and measured. The average number of juvenile red abalone [<2.0 inches (50 mm)] per ARM is recorded as the annual juvenile red abalone recruitment index (Figure 8). The peak occurred in 2005 and corresponded to a period when upwelling was weak and delayed along the coast.

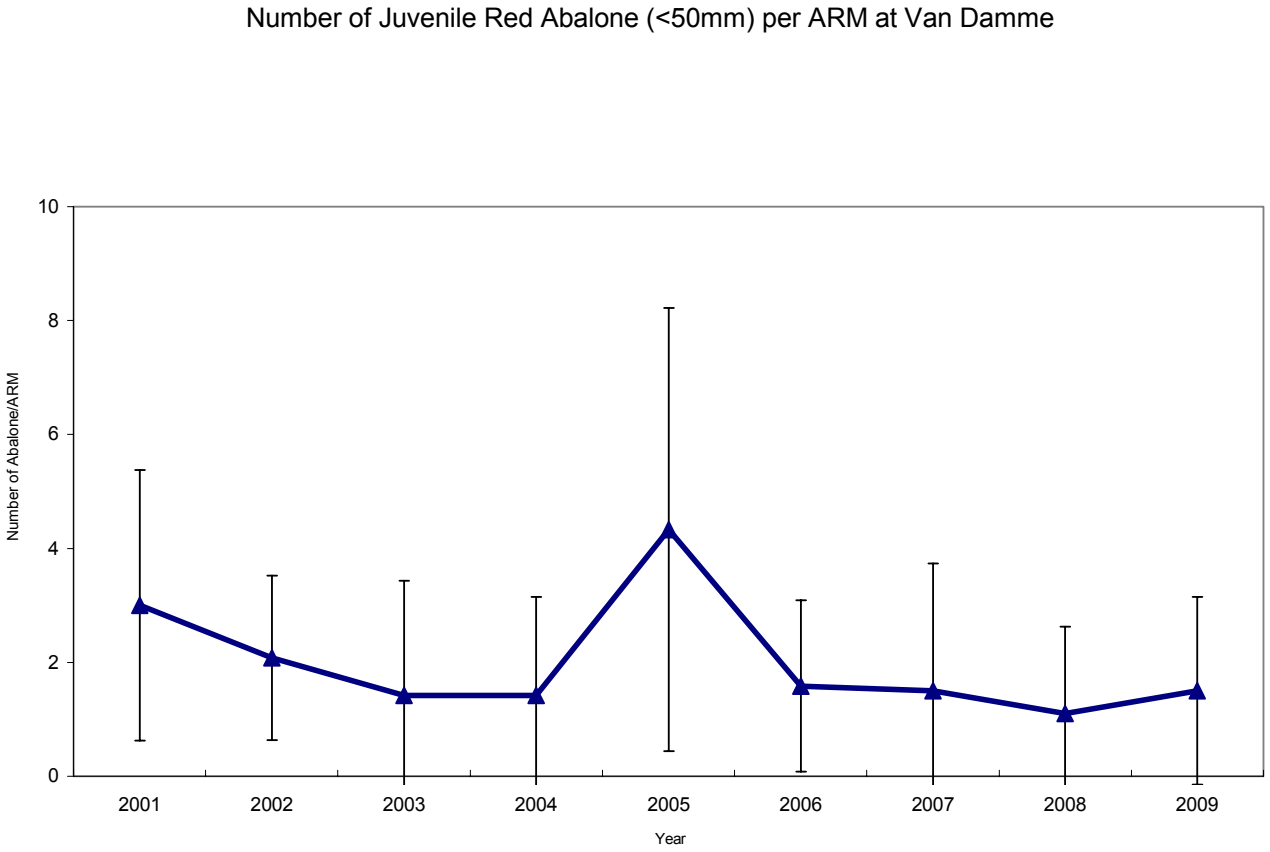


Figure 8. Number of juvenile abalone (<50mm) found per ARM (standard deviation shown as vertical lines) at Van Damme.

Aggregation Characteristics

Button (2008) examined nearest neighbor and degree of aggregation in abalone to determine a minimum viable population (MVP) level. She measured the distance between the closest abalone to a random point and its nearest neighbor. Aggregation sizes were quantified by counting the number of abalone within 2.5 m from the abalone closest to the random point (Babcock and Keesing 1999, Button 2008). Density was determined by counting all emergent abalone along transects at the study sites.

Abalone at all sites are highly aggregated (Button 2008). The average distances between nearest neighbors and the average aggregation sizes in the populations are strongly correlated with density. The average nearest neighbor distance increases dramatically at densities below ~2,000 abalone/ha (0.2 abalone/m^2). Similarly, the average aggregation size is less than four at densities close to 2,000/ha. In populations with equal numbers of females and males, the probability that an aggregation will contain both sexes decreases rapidly in aggregations of less than four and could negatively impact the reproductive potential of such aggregations (Button 2008). These results indicate the 2,000 abalone/ha (0.2 abalone/m^2) MVP threshold in the ARMP is suitable (Button 2008).

Disease – Withering Syndrome (WS)

Northern California red abalone populations appear to be unaffected by the bacterium which causes WS, the disease which devastated black abalone (*H. cracherodii*) in central and southern California. Besides the WS bacterium, there are numerous causes for abalone to have shrunken feet including lack of food. Abalone infected with the bacterium do not necessarily develop shrunken feet. The bacterium and abalone with WS signs have been found as far north on the mainland as San Mateo County and the bacterium was present in 16 percent of subtidal red abalone collected from the Farallon Islands in 2007. Samples from seven abalone creel sites and samples of visibly shrunken abalone submitted by recreational fishers from sites in Sonoma, Mendocino, and Humboldt counties have all been negative for the bacterium. The bacterium was found in a small number of red abalone collected from Crescent City and Van Damme State Beach but no infected abalone from those sites showed signs of the disease. The water temperature in northern California appears to be cool enough to prevent infected abalone from developing signs of the disease under most environmental conditions. However, an El Niño simulation study suggests that infected red abalone populations will have much higher mortality due to the disease during a severe El Niño event. Warmer climatic conditions could also increase mortality due to WS.

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