MARINE MAMMAL COMMISSION

Photo courtesy of the National Park Service

MARICULTURE AND HARBOR SEALS IN DRAKES ESTERO, CALIFORNIA

A Report by the Marine Mammal Commission

22 November 2011

EXECUTIVE SUMMARY

In 2012 the Secretary of the Interior will determine whether to renew a Reservation of Use and Occupancy and a Special Use Permit issued to Drakes Bay Oyster Company for operations in Drakes Estero, an estuary on the West Coast just north of San Francisco, or convert the estuary to full wilderness status. The Secretary's determination is a matter of policy. Science, however, has a role in informing the Secretary about the potential consequences of his decision for resources within the estuary.

In 2009 the Marine Mammal Commission agreed to review the science pertaining to whether mariculture activities in Drakes Estero have affected or are affecting Pacific harbor seals (*Phoca vitulina richardsi*). The seals use the estuary for resting, breeding, pupping, and rearing their pups. The Commission was assisted in the first stage of its review by a panel of scientists with expertise in mariculture and in harbor seal health and ecology. The review objectives were to (1) evaluate the best available scientific information pertaining to harbor seals and mariculture effects; (2) evaluate the strengths and weaknesses of those data, (3) identify information gaps, and (4) recommend research and management activities to reduce scientific uncertainty and ensure the protection of harbor seals and their habitat. The Commission also agreed to review the Park Service's management of the harbor seal population.

The two proximate concerns regarding mariculture activities are that they might disturb seals or displace them from the habitat that they would otherwise use absent such disturbance. The broader concern, more difficult to measure, is that disturbance and displacement could reduce the seals' fitness—a measure of their ability to survive and reproduce.

The main data types available for the review include counts of seals within Drakes Estero and surrounding colonies, observations of disturbance events collected during those counts, and oyster harvest records kept by Johnson Oyster Company and its successor, Drakes Bay Oyster Company. Other useful or potentially useful documentation include photographs taken by automated cameras and videos taken during camera maintenance, observations of harbor seal mortality within the estuary, and aerial photographs of the estuary that were used by the National Park Service to assess the spatial extent (acreage) of mariculture activities in years dating back to 1993.

The review focused on three analyses conducted by the Park Service. The first was a preliminary analysis presented orally to the Marin County Board of Supervisors in May 2007. That analysis suggested that mariculture activities caused a large (80 percent) decline of harbor seal mothers and pups at one of the haulout sites (oyster bar, or OB) compared to previous observations at that site. Those results were based on counts conducted before 4 May 2007 and at the end of May the Park Service revised its estimate downward to a 55 to 60 percent decline. The Commission agrees that the number of seals using that site declined substantially in 2007. However, it also notes that the comparison was based on data from 2004, when the number of seals using the site was the highest on record. Given the natural variability of counts at that site, the Commission does not believe that the 2004 data constitute the appropriate basis for estimating the expected number of seals in 2007. The Commission also does not believe that the existing information is sufficient to determine the factor(s) that caused the change in seal numbers at the site.

The Park Service's second analysis was published as Becker et al. (2009) and is comprised of two parts. The first part examined the annual disturbance rate (i.e., reported disturbances per survey) as a function of the total annual oyster harvest. After examining individual disturbance records, the Commission concludes that, from time to time, mariculture activities have disturbed the seals. However, the data used in the analysis are not sufficient to support firm conclusions regarding the rate and significance of such disturbance.

The second part of Becker et al. (2009) analyzed factors that might explain harbor seal haulout patterns within the estuary during the seals' reproductive period. Importantly, this analysis shifted emphasis from individual disturbance records to use of the annual oyster harvest level as a proxy for mariculture activity (i.e., including the presence of boats, human activities, and mariculture materials). The results indicated that El Niño-southern oscillation (ENSO) events and annual oyster harvest levels best explain the seals' haulout patterns at the upper estuary haulout sites. The panel convened by the Commission in the early stages of this review raised strong concerns about this analysis and the use of annual oyster harvest levels as a proxy for mariculture effort. Their concerns were based on the fact that mariculture activity has varied by ownership and management, growing method, location within the estuary, and season and, therefore, may not be related to annual harvest level.

The Park Service responded to various criticisms of the Becker et al. (2009) paper by revising and expanding the analyses and publishing the results as Becker et al. (2011). This paper consists of three main parts. The first, not controversial, examines the haulout patterns of seal mothers and pups based on site isolation from land-based sources of disturbance.

The second part of Becker et al. (2011) is a reanalysis of harbor seal habitat use within Drakes Estero. The reanalysis examines whether seal haulout patterns in the upper (near mariculture) versus lower (away from mariculture) estuary are related to ENSO events, oyster harvest level, the spring (March–May) pooled disturbance rate (disturbances/number of surveys) in either the upper or lower estero, or the pooled maximum annual seal counts of all other Point Reyes area colonies (regional population size). The Park Service used two types of statistical analysis and incorporated new data dating back to 1982. As with Becker et al. (2009) the results suggest that ENSO events and mariculture harvest levels best explain the seals' use of haulout sites within Drakes Estero. The paper suggests that mariculture may have caused about an 8 ± 2 percent decline in harbor seal use of the upper estuary sites.

The third part of Becker et al. (2011) investigates harbor seal use of Drakes Estero versus neighboring colonies within the Point Reyes area as a function of multiple possible explanatory variables, including year (as a linear trend), the portion of Drakes Estero seals using subsite A (which was effectively lost to the seals between 2004 and 2007), the maximum annual seal count at Double Point (which experienced a rapid decline in 2003 because of a marauding elephant seal), annual spring human-related disturbance rate (all sources), years since the last ENSO event, regional annual maximum seal count (less seals at Drakes Estero), annual oyster harvest, and annual oyster harvest converted to a (high/low) binary variable. The Park Service also supported its contention that annual oyster harvest is a reasonable proxy for mariculture effort by analyzing relationships between annual harvest levels and the frequency of boats in the estuary, seasonal harvest patterns, and the acreage devoted to mariculture annually as estimated from aerial photographs of the estuary taken

since 1993. The results indicate that the 2003 event at Double Point, ENSO events, annual oyster harvest, and the loss of subsite A all may have influenced the distribution of seals between Drakes Estero and the neighboring colonies during the period in question.

The findings of Becker et al. (2011) have been challenged on a number of grounds, and the last phase of the Commission's review examined in detail the statistical methods used by the Park Service. The Commission structured this statistical review to allow the conservation organizations (National Parks Conservation Association and Save Our Seashore), Drakes Bay Oyster Company, and the Commission each to choose a statistician to review the methods. The statistician representing the conservation organization found that Becker et al. (2011) uses appropriate statistical methods and provides support for an inverse correlation between annual oyster harvest levels and the use of upper estuary haulout sites by harbor seals. The scientist chosen by Drakes Bay Oyster Company completed a set of analyses that he believed countered the results of Becker et al. (2011). He pointed toward the elephant seal event at Double Point in 2003 and the total number of seals in the area as the dominant factors explaining harbor seal haulout patterns both regionally and within Drakes Estero. However, his analyses are difficult to evaluate because his statistical models are confounded by built-in dependencies that are inconsistent with the statistical procedures he used. The third statistician, chosen by the Commission, found the statistical methods in Becker et al. (2011) to be generally appropriate but also made several suggestions for improving them. The Park Service concurred with those suggestions and conducted several additional analyses, reported in preliminary form in this report.

The Marine Mammal Commission believes that the data supporting the above analyses are scant and have been stretched to their limit. Nevertheless, the analyses in Becker et al. (2011) provide some support for the conclusion that harbor seal habitat-use patterns and mariculture activities in Drakes Estero are at least correlated. However, the data and analyses are not sufficient to demonstrate a causal relationship. Additional, carefully guided study would be required to determine if the apparent relationship is one of cause and effect.

To meet its objectives, the Commission describes in this report a number of shortcomings in the data used in the above analyses. Improvements are needed in the procedures used to collect disturbance data and to characterize mariculture activities and effort in the upper estuary. Photographs taken between 2007 and 2010 warrants further review to assess their usefulness for characterizing the rates and consequences of disturbance. Also, studies are needed to characterize harbor seal haulout patterns in the absence of disturbance, and to assess the biological significance of disturbance when it occurs.

Whether and to what extent the above shortcomings are addressed will depend, in part, on the decision by the Secretary of the Interior. If the Secretary determines that the estuary should be converted to full wilderness status, then the Park Service should continue to study the seals to determine if and how they may change in abundance or alter their habitat-use patterns. If the Secretary decides to renew the Reservation of Use and Occupancy and a Special Use Permit issued to Drakes Bay Oyster Company, then the Commission believes that he also should require the Park Service to implement an adaptive management approach that, if done well, should address the various weaknesses and gaps in the available data.

The Commission would be pleased to advise the Secretary in either case.

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1.0 INTRODUCTION

Drakes Estero is an estuary in Point Reyes National Seashore, which is located on the Pacific coast 25 miles north of San Francisco (Figures 1 and 2). The National Park Service is the primary manager of the Seashore but other federal and state agencies have management responsibilities related to certain activities and resources within the estuary. The estuary provides resting and pupping habitat for harbor seals (*Phoca vitulina richardsi*)[1] (Figure 3) and, since the 1930s, has been the site of mariculture operations focused primarily on growing oysters.

Figure 1. Drake's Estero, an estuary on the West Coast just north of San Francisco (photo courtesy of Robert Campbell)

For the past several years, the estuary has been at the center of two closely related issues. The first pertains to whether and, if so, to what extent mariculture operations are adversely affecting the estuary, including its use by harbor seals. The second pertains to whether the Secretary of the Interior should renew a Reservation of Use and Occupancy and a Special Use Permit issued to Drakes Bay Oyster Company for operation in the estuary beyond 2012 or convert the estuary to wilderness status. The first of these issues is a matter of science and the second a matter of policy. The National Park Service has released a draft environmental impact statement that discusses both issues.

The present report by the Marine Mammal Commission addresses the first issue only, and only as it pertains to potential mariculture effects on harbor seals. Other human activities in the estuary affect harbor seals, and those activities also warrant review and appropriate management. In fact, the terms of reference for this review (Appendix A) indicate that the Commission's original intent was to conduct a broader review. However, as the review proceeded, it became clear that the primary question, strongly contended, is whether mariculture has affected or is affecting the seals. The Commission therefore sharpened the focus of its review on the potential effects of mariculture on harbor seals.

The Park Service introduced the Marine Mammal Commission to this matter in May 2007, just prior to a related hearing of the Marin County Board of Supervisors. For the next several years the Park Service, a representative of the Drakes Bay Oyster Company, and

[1] This report uses the term "seals" to mean harbor seals, unless otherwise noted.

others independently kept Commission staff abreast of related developments. In May 2009 the National Research Council of the National Academies of Science released a report entitled "Shellfish Mariculture in Drakes Estero, Point Reyes National Seashore, California" (National Research Council 2009). With regard to harbor seals, the report states—

> None of the scientific research projects within Drakes Estero was designed specifically to assess whether the oyster farm operations were impacting the local harbor seal population, and this constrains attempts to draw definitive conclusions about potential impacts. Analyses of monitoring data found a correlation between seal counts and years since the last ENSO [El Niño-Southern Oscillation] event and oyster harvest levels at two haulout sites within the upper estuary (Becker et al., 2009), but this cannot be used to infer cause and effect. Consequently, research that has been conducted within Drakes Estero cannot be used either to directly demonstrate any effects of the oyster farm on harbor seals or to demonstrate the absence of potential effects.

The report also indicated that the findings to date "highlight the need for a more detailed assessment of the extent to which different disturbance sources may impact harbor seals both on land and in the water."

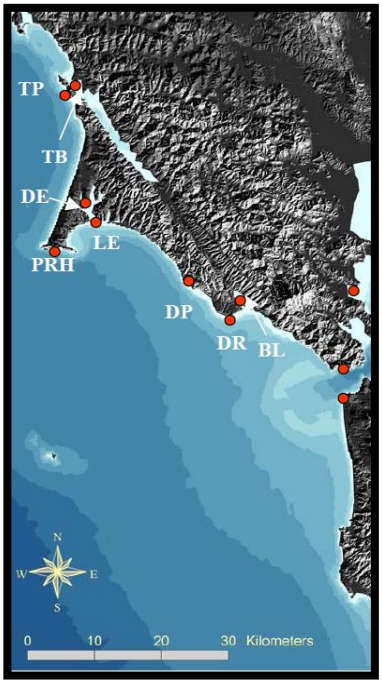


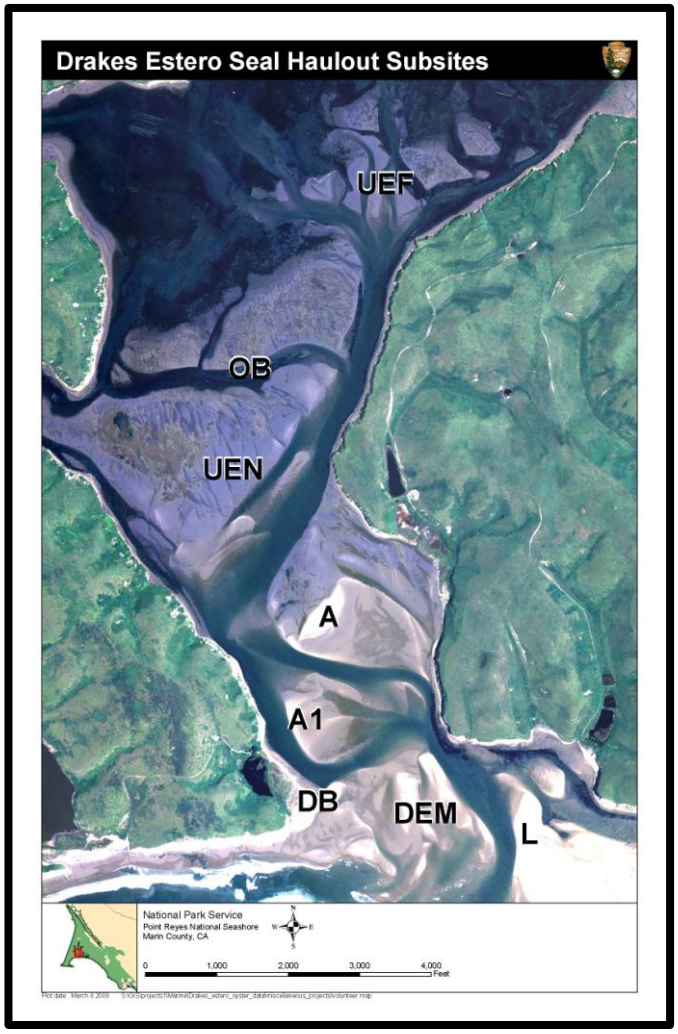
Figure 2. Harbor seal haulout sites near the Point Reyes area. TP = Tomales Point, TB = Tomales Bay, DE = Drakes Estero, PRH = Point Reyes Headland, LE = Limantour Estero (treated as part of Drakes Estero in this report), DP = Double Point, DR = Duxbury Reef, and BL = Bolinas Lagoon (from Allen et al. 2004)

In June 2009 the National Parks Conservation Association and the Sierra Club wrote the Marine Mammal Commission to request its involvement in this issue. Their letter emphasized the importance of applying the precautionary principle in this case. The precautionary principle states that, in the face of uncertainty about potential human impacts on a resource, management should err on the side of resource protection.

In accordance with the Marine Mammal Protection Act, the Commission does comment and make recommendations on matters of policy. However, in this case, the Commission agreed to conduct an independent, solely science-based review of the potential effects of mariculture on the use of the estuary by harbor seals, but without taking a position on how precautionary the decision process should be. It did so with the aim of providing an objective assessment of the available scientific information to inform the Secretary of the Interior as he decides the future of the estuary.

1.1 BACKGROUND

Harbor seals: Pacific harbor seals inhabit nearshore and estuarine areas from Baja California to Alaska. They do not migrate extensively but, on occasion, may travel 300 to 500 km to find food (Herder 1986). The seals haul out year-round to rest, reproduce, and molt on sandbars, rocky outcrops, and offshore islands along the coast. The location and timing of their haulout patterns vary with a range of factors, including their reproductive condition, time of day, tide, current direction, weather, season, year, presence of predators and prey, and human activities (Allen et al. 1984, Yochem et al. 1987, Suryan and Harvey 1999, Thompson et al. 2001, Grigg et al. 2004, Hayward et al. 2005, Seuront and Prinzivalli 2005). Their foraging excursions tend to be relatively short (hours) and they consume a variety of mid-water and bottom-associated prey.



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The California population of harbor seals was decimated prior to enactment of the Marine Mammal Protection Act, but has been recovering since the Act was passed in 1972. The National Marine Fisheries Service's most recent estimate of abundance is about 34,000 (Carretta et al. 2006), although that estimate is based on data collected in 2004 and is becoming outdated. About 80 percent of the California population occurs along the mainland (the remainder in the vicinity of the Channel Islands), and about 20 percent of the mainland population occurs in the Point Reyes area (Lowry et al. 2005). The number of seals hauled out in Drakes Estero is greatest during the spring/summer reproductive and molting seasons and, to date, the maximum count within the estuary has been about 1,600 seals (National Park Service 2004, Becker et al. 2011).

Mariculture: The state of California began issuing licenses to grow shellfish in the estuary in the 1930s. The Johnson Oyster Company operated in the estuary from the 1950s to 2005, when it sold its operation to the Drakes Bay Oyster Company. Several methods have been

used to grow oysters. One method involves suspending spat-laden u-shaped bars over wooden racks dispersed through the upper parts of the estuary. The oysters are left to grow for up to 18 months before they are harvested. A second method involves placing bags of spat-laden shell fragments on tidal sandbars. This method generally requires more tending: after the oysters have reached a certain size, workers turn the bags over periodically to facilitate symmetrical growth. The Drakes Bay Oyster Company uses those two methods. A third method, used by the Johnson Oyster Company, was to tie bags of oysters to stakes secured to the estuary bottom. In addition to the above, Johnson Oyster Company is reported to have secured bars with attached oysters in the later stages of growth on tidal flats using a method referred to as a cluster culture. The use of these methods has varied over time, has not been well documented, and is a matter of some contention, as will be described later in the report.

1.2 REVIEW OBJECTIVES AND METHODS

To evaluate the available scientific data on harbor seal/mariculture interactions in the estuary the Commission established review objectives, enlisted the support of an expert scientific panel, and convened several meetings of the parties to review and discuss those data.

Objectives: To conduct its review, the Commission indicated that it would (1) evaluate the best available scientific information pertaining to harbor seals and mariculture effects; (2) evaluate the strengths and weaknesses of those data, (3) identify information gaps, and (4) recommend research and management activities to reduce scientific uncertainty and ensure the protection of harbor seals and their habitat. The Commission also agreed to review the Park Service's management of the harbor seal population.

Panel: The Commission convened a panel of experts to assist with its review (Table 1). It selected the members based on their knowledge and experience with harbor seals, mariculture, and/or veterinary medicine. It asked them to participate in their own professional capacity rather than representing their agencies. Panel members participated in the Commission's review only through the initial meeting in February 2010 and by completing individual reports based on that meeting.

Meetings: The Commission initially organized its review around a 21 to 24 February 2010 meeting at the National Park Service Headquarters within the Point Reyes National Seashore (see Appendix B for the meeting agenda and list of participants). The meeting was broad in scope and included presentations by the parties involved in the issue, discussion among the

Table 1. Panel members that assisted the Marine Mammal Commission in its review of the potential effects of oyster mariculture on harbor seals in Drakes Estero

Name	Affiliation
Peter Boveng	National Marine Fisheries Service, National Marine Mammal Laboratory
Sean Hayes	National Marine Fisheries Service, Southwest Fisheries Science Center
Steven Jeffries	Washington Department of Fisheries and Wildlife
Brian Kingzett	Vancouver Island University
Robert Small	Alaska Department of Fish and Game
Michael Walsh	University of Florida

parties and panel members, and a one-day field trip to visit the estuary. The estuary trip allowed the panel to become familiar with (1) the location where Park Service volunteers collected information on harbor seals and various sources of disturbance, (2) the sites and methods used to grow oysters, and (3) the sites where harbor seals haul out under current conditions in the estuary.

The discussion at the February meeting covered all of the planned agenda except specific disturbance data records in the Park Service's volunteer database that indicated disturbance of harbor seals. A smaller group, not including the panel, met on 7 June 2010 to complete that discussion. The second meeting involved representatives of the Park Service, Drakes Bay Oyster Company, Dr. Corey Goodman[2], and the Marine Mammal Commission staff only.[3]

On 27 August 2010 the Commission's Executive Director met with representatives of the Drakes Bay Oyster Company and Dr. Goodman to review selected photographs that had been taken by Park Service cameras in the estuary beginning in 2007.

In July, August, and September of 2011 the Commission arranged for a detailed review of the statistical methods used in the second of two papers (Becker et al. 2011) produced by the Park Service regarding potential mariculture effects on the seals. The review was conducted by (1) Dr. Goodman, who was supported in his review by two statisticians; (2) Dr. Dominique Richard, an independent consultant; and (3) Dr. John Harwood, from the University of St. Andrews, Scotland.

The Park Service's three main presentations regarding potential mariculture effects on harbor seals have been in the form of an oral report to the Marin County Board of Supervisors (8 May 2007) and in the two scientific publications: Becker et al. (2009) and Becker et al. (2011). The following sections review the major types of available data and then focus individually on the Park Service's presentation to the Marin County Board of Supervisors and the findings and criticisms of the two publications.

2.0 REVIEW OF SCIENTIFIC DATA

The Commission considered six sources of data pertaining to potential harbor seal disturbance by mariculture activities, including—

(1) Periodic counts by Park Service staff and volunteers of harbor seals hauled out in or near the estuary and in the Point Reyes area (Adams et al. 2009, Appendix C);
(2) Volunteer and Park Service staff records of harbor seal disturbance observed during visits to the estuary to count seals;

[2] Dr. Goodman participated at the request of Mr. Steve Kinsey of the Marin County Board of Supervisors.
[3] The Commission recorded the proceedings of the two meetings and interested parties can obtain copies by contacting the Commission.

(3) Photographs of selected areas in the estuary taken by automated cameras each minute during daylight hours beginning in 2007 (available at http://www.nps.gov/pore/parkmgmt/planning_reading_room_photographs_videos.htm), logs from reviews of the photographs (Appendix D), and supplemental observations and videos by a Park Service volunteer who helped maintain the cameras (Appendix E);

(4) Oyster production records from the California Department of Fish and Game and the California Department of Public Health;

(5) Observations of harbor seal mortality within or near the estuary; and

(6) Aerial photographs, taken between 1993 and 2009, that provide some evidence of the presence or absence of oyster bags on certain sandbars in the estuary and, when present, their placement.

2.1 PERIODIC COUNTS

The status of harbor seals considered in this report can be described at five scales: the full California population, the combined Point Reyes colonies, the Drake Estero population, the seals at specific haulout sites within the estuary, and individual seals. A brief review of harbor seals at those scales provides a necessary context for evaluating potential interactions with mariculture in the estuary.

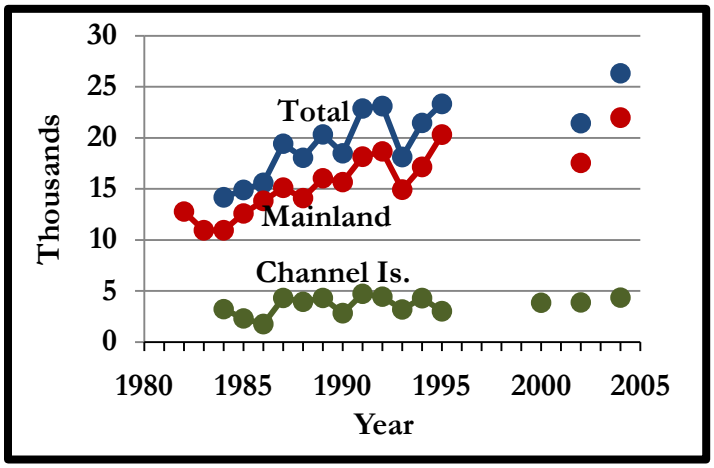


Figure 4. Counts of the California stock of harbor seals from the 1980s to the present (data courtesy of M. Lowry of the Southwest Fisheries Science Center, National Marine Fisheries Service). The total population estimate of 34,000 seals in 2004 is based on these counts corrected for seals not observed during the counts (Carretta et al. 2006)

California population: The National Oceanic and Atmospheric Administration's 2005 population assessment report (Carretta et al. 2006) provides the most up-to-date summary of the California population. The statewide population estimate is based primarily on aerial surveys. The report indicates that the population numbered about 34,000 seals (statewide) in 2004 (Figure 4). The report also states that—

> [n]et production rates appeared to be decreasing from 1982 to 1994.... Although earlier analyses were equivocal (Hanan 1996) and there has been no formal determination that the California stock has reached OSP (Optimal Sustainable Population level as defined by the MMPA [Marine Mammal Protection Act]), the decrease in population growth rate has occurred at the same time as a decrease in human-caused mortality and may indicate that the population is approaching its environmental carrying capacity.

The California population undoubtedly has been recovering from decimation prior to passage of the Marine Mammal Protection Act. Whether it is near carrying capacity depends

on how that term is defined. If it is intended to mean the maximum level a population could maintain over time under current conditions then, indeed, the population may be approaching a current carrying capacity. However, the Commission interprets the Act to mean the maximum level a population could maintain over time under natural conditions. In that case, it is not clear that the population is approaching its natural carrying capacity. The distinction is necessary because human activities can alter the conditions that determine carrying capacity. If human activities reduce harbor seal breeding habitat—as is contended—the reduction might artificially lower the effective carrying capacity. Alternatively, human activities also could increase carrying capacity if, for example, they reduced predators on harbors seals (e.g., sharks, killer whales). Thus, determining if a population is at its natural environmental carrying capacity requires an evaluation of whether (1) the population has reached the maximum size it can maintain over time under the prevailing conditions, and (2) prevailing conditions are reasonably consistent with natural conditions. Until both topics have been addressed, all that can be said for the California population of harbor seals is that its numbers have increased substantially over the past four decades, and that the rate of increase appears to be slowing.

Point Reyes colonies: In the Point Reyes area harbor seals are counted using ground surveys based the San Francisco Bay Area Network pinniped monitoring protocol (Adams et al. 2009). The seals aggregate into colonies at Tomales Bay, Tomales Point, Point Reyes Headlands, Drakes Estero, Double Point, Duxbury Reef, Bolinas Lagoon, and Point Bonita (Figure 1, Adams et al. 2009). A major ENSO affected the entire Eastern Pacific in 1998. In 2003, a male elephant seal at Double Point is known to have killed a minimum of 40 harbor seals and disrupted the remainder of the colony. Annual means of maximum daily seal counts for the eight colonies from 1997 to 2010 are graphed in Figure 5. A large ENSO

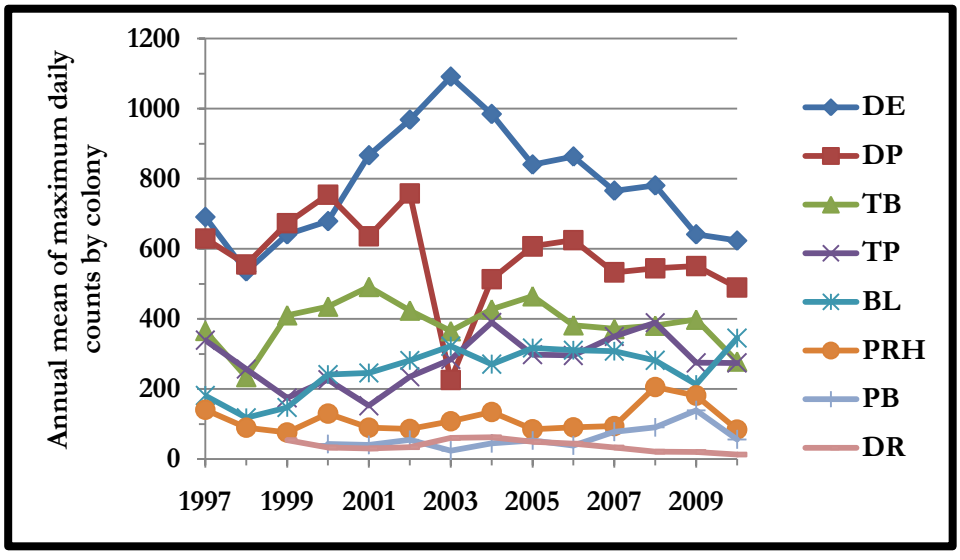


Figure 5. Annual mean of maximum daily counts (adults and pups) by colony and during the full year (left axis), and total of those counts (right axis). Colonies are Drake's Estero (DE), Double Point (DP), Tomales Bay (TB), Tomales Point (TP), Bolinas Lagoon (BL), Point Reyes Headland (PRH), Point Bonita (PB), and Duxbury Reef (DR) (data from National Park Service)

event might have reset the regional ecosystem in 1998. The year 2003 seems to have been a breakpoint in the trajectories of the three largest colonies (Drakes Estero, Double Point, and less markedly Tomales Bay) but each of these three responded differently. At Drakes Estero a consistent increasing trend from 1998 to 2003 reversed to a fairly consistent decreasing trend from 2003 to 2010, where the increase from 1998 to 2003 was roughly a doubling and the decrease from 2003 to 2010 was roughly a halving that returned the population almost to its 1998 numbers. At Double Point a slight and uneven increasing trend from 1998 to 2002 was interrupted by an abrupt drop by two-thirds in 2003, coincident with the elephant seal disturbance, followed by recovery to near pre-disturbance levels by 2006 and then a slight decline to 2010 when the colony was slightly below its 1998 numbers. At Tomales Bay harbor seal numbers increased modestly from 1998 to 2001 followed by a slight decrease from 2001 to 2003, reversing to a slight increase from 2003 to 2005, and then followed by an uneven decrease from 2005 to 2010. Of the five smaller colonies, two showed a slight long term increase from 1998 to 2010 (Tomales Point and Bolinas Lagoon), one showed a declining trend to near extinction (Duxbury Reef), and two showed no long-term trend (Point Bonita and Point Reyes Headland), with none of the five showing any particular change in 2003.

Drakes Estero population: The annual mean number of harbor seals at Drakes Estero increased rapidly from 1998 to 2003 and then declined steadily from 2003 to 2010 (Figure 5). The increased mean number of seals from 2002 to 2003 may reflect some movement of seals from Double Point into Drakes Estero coincident with the elephant seal disturbance, but the Drakes Estero increase from 1998 to 2002 does not appear to be connected to events at Double Point. In addition, the magnitude of the Drakes Estero increase from 2002 to 2003, roughly 150 animals, could simply be a continuation of the 1998 to 2002 increase. The increase prior to 2003 has not been explained and may reflect a combination of actual population growth and annual variation in counts. The decline of seals at Drakes Estero after 2003 is nearly monotonic (i.e., population counts decreased almost every year) and appears to reflect the movement or loss of roughly 500 seals relative to 2003. The cause(s) for that decline also is (are) not clear. A hypothesized return to Double Point of seals driven out by the event of 2003 cannot have been a major contributor to the Drakes Estero post-2003 decline because the total increase at Drakes Estero from 2002 to 2003 was roughly 150 seals. The extent to which the movement of seals between Double Point and Drakes Estero explains the dynamics of seals at Drakes Estero will be discussed later in this report.

Within Drakes Estero, the most dramatic known event was the loss of the channel separating sandbar A (or the sandbar on which haulout A occurred) from the mainland after 2004. This was the largest haulout site in the estuary until that time, and the loss of the channel clearly prompted a redistribution of seals within the estuary. How long it took for the seals to adapt to the loss of haulout A is not clear, but the number of seals using haulout site A peaked in 2003 and then declined to virtually zero by 2007 (Figures 6 to 8). The 2003 to 2010 loss from site A (roughly 250 non-pups and 80 pups totaling about 330 individuals) constitutes a good portion of the total 2003-2010 decline (roughly 500 individuals) from Drakes Estero overall, if the loss from site A did not redistribute within Drakes Estero. The 2003-2010 loss of roughly 100 individuals from site OB (oyster bar) makes up most of the remainder of the decline.

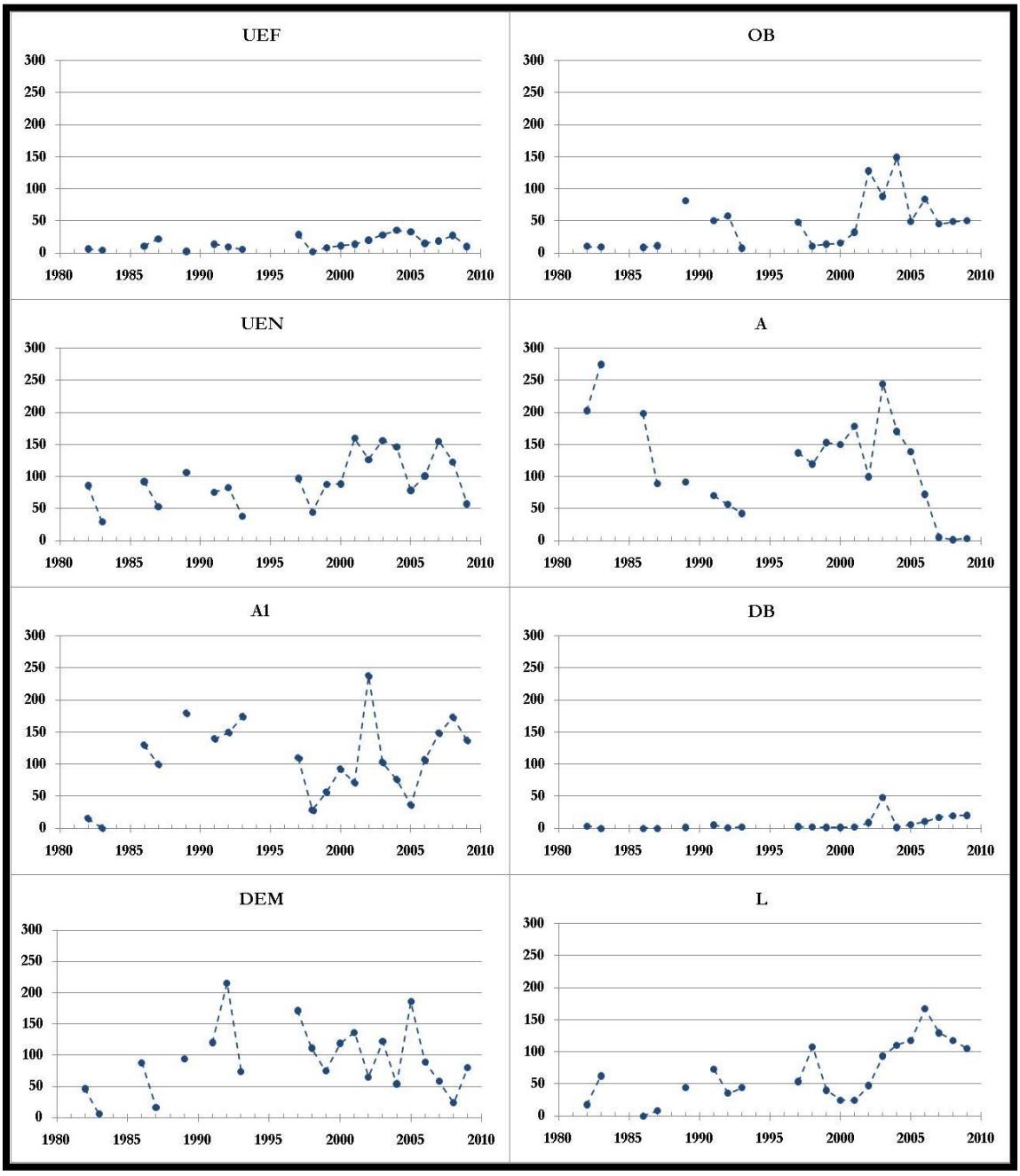


Figure 6. Annual mean of maximum daily counts of non-pup seals (i.e., seals larger than pups) during the period from 15 April to 15 May of each year. The haulout sites UEF, OB, and UEN are closest to mariculture activity (data from National Park Service)

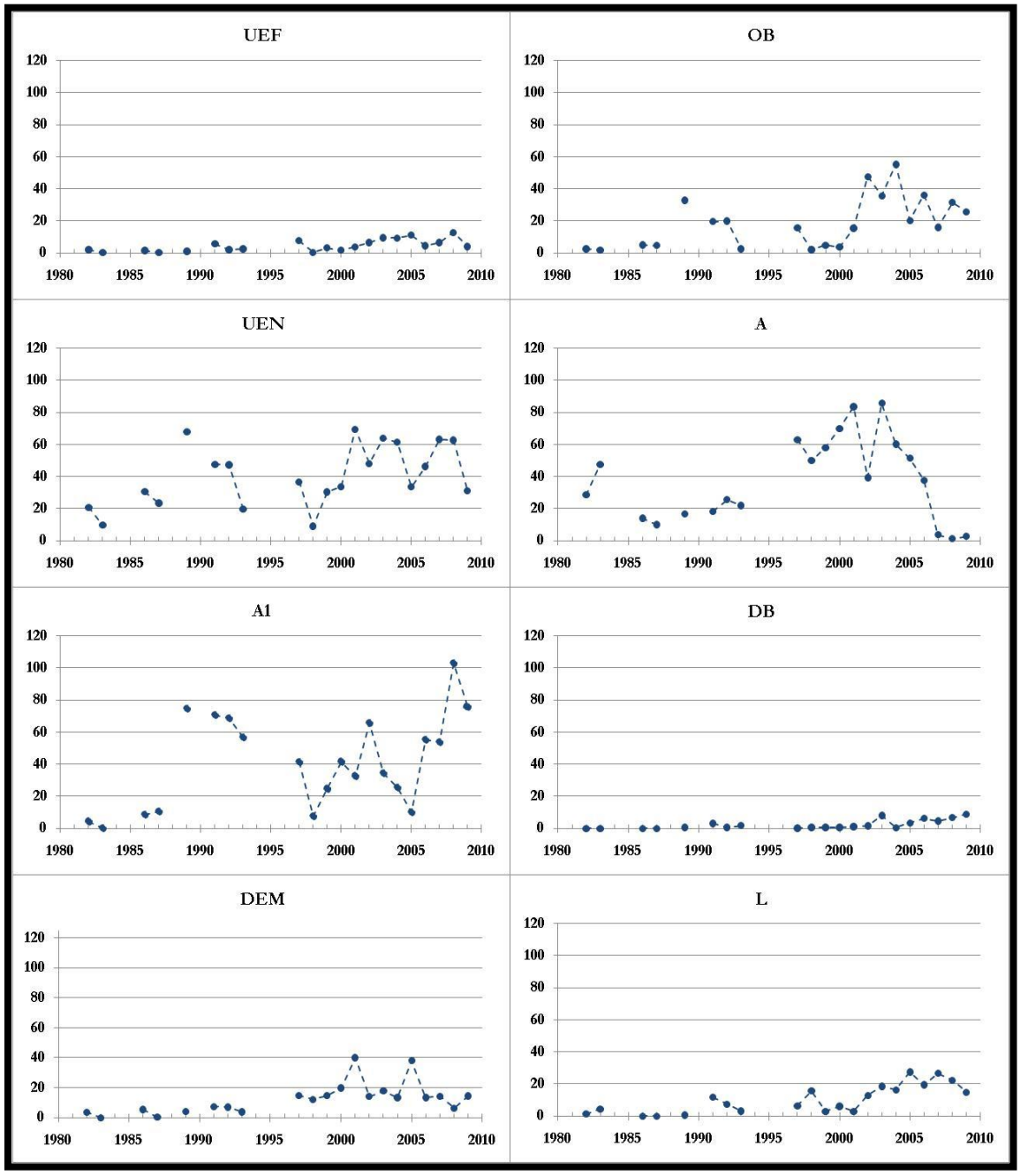


Figure 7. Annual mean of maximum daily counts of seal pups during the period from 15 April to 15 May of each year. The haulout sites UEF, OB, and UEN are closest to mariculture activity (data from National Park Service)

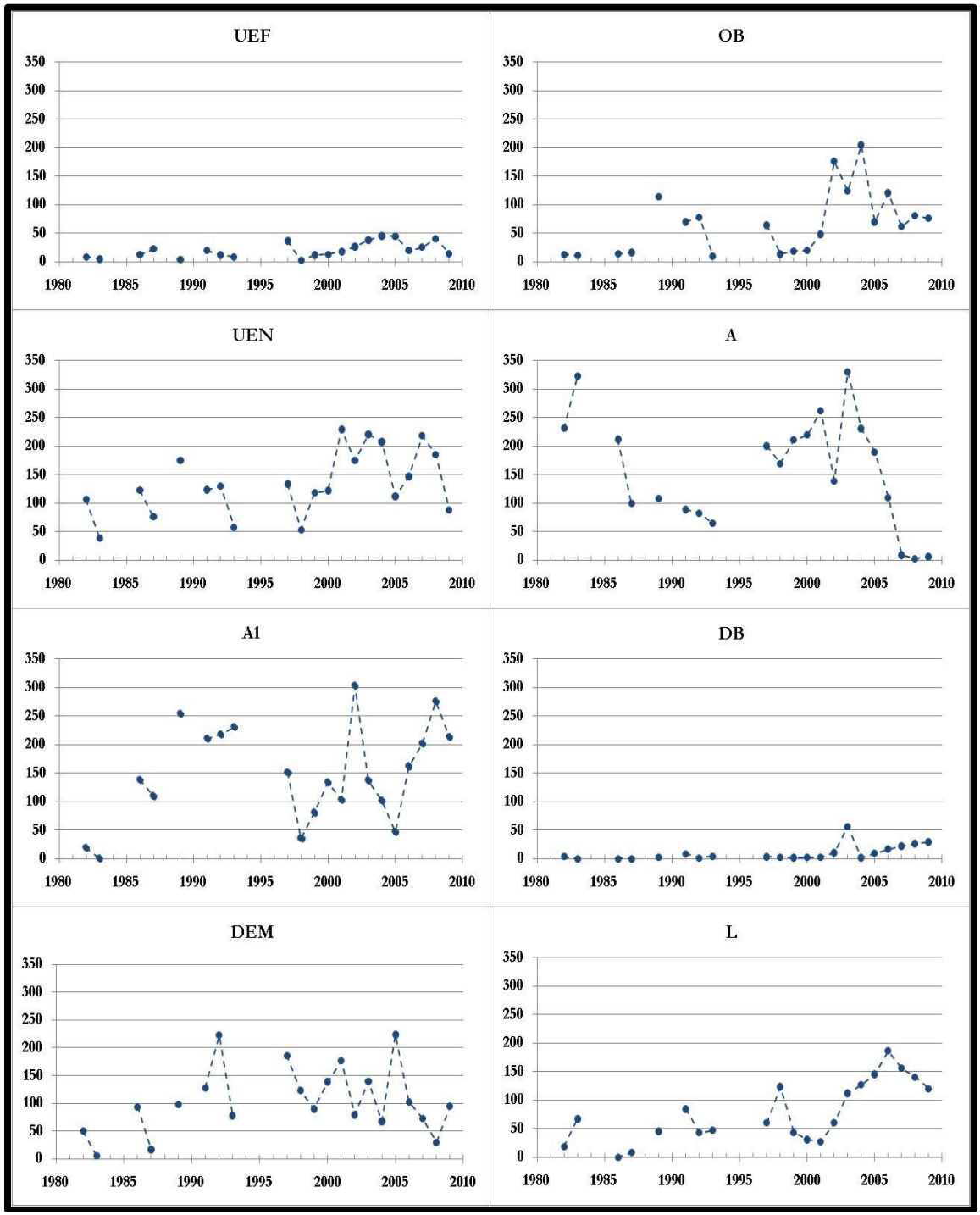


Figure 8. Annual mean of maximum daily counts of seal pups and non-pups combined during the period from 15 April to 15 May of each year. The haulout sites UEF, OB, and UEN are closest to mariculture activity (data from National Park Service)

In addition, other unknown factors (e.g., changes in oceanographic conditions as well as human-caused disturbance) also might have affected the seals' selection of haulout habitat and the amount of time they used that habitat. It is worth noting here—in advance of more detailed discussion of the potential effects of mariculture—that haulout site OB is close to mariculture activities, whereas site A is not. It also is worth noting here—in advance of more detailed discussion of the time trajectory of oyster harvest estimates—that the period from 1998 to 2003, when the Drakes Estero population was steadily increasing, overlaps with a period of historically low oyster harvests, 1999 to 2005 with the lowest estimate in 2000, and that the harvest was generally high and trending upward during the period from 2006 to 2009, during which time the Drakes Estero population was declining fairly consistently (Table 4).

Drakes Estero haulouts: Within the estuary, harbor seals generally use seven main haulout sites: upper estero far (UEF), oyster bar (OB), upper estero near (UEN), A, A1, Drakes Estero mouth (DEM), and Limantour Spit (L). Counts of seals (i.e., non-pups, pups, and total) at these sites in the peak of the reproductive period (defined here as 15 April to 15 May) suggest at least five main patterns (Figures 6 to 8).

(1) The seals use certain sites more than others for hauling out and reproduction.

Absent any disturbance, preference for the various sites could be reasonably inferred from the seals' haulout patterns. The basis for their site selection is generally thought to be related to protection from rough nearshore conditions (e.g., storms, high waves, strong nearshore currents), water depth (i.e., the seals are thought to prefer areas with quick access to relatively deep water), and avoidance of predators (i.e., the seals choose sites not easily accessible to land-based predators). Whether the observed haulout patterns reflect undisturbed conditions clearly is an important consideration in this report.

(2) The counts at each site, except haulout A, generally increased from the early 1980s to the present.

The increasing trend at each site is consistent with the overall growth of the California population. The high counts at haulout site A in the early 1980s suggest that it was a preferred site at that time. As the population grew, seals shifted their haulout patterns to include other sites in the estuary. By the end of the 1980s, UEN and OB also had become important haulout sites during the reproductive period.

(3) Counts at any given site tend to be highly variable among years, seasons, and days.

The amount of variability by year, season, or day is an important consideration in any evaluation of human-induced changes in haulout patterns, and will be considered below in section 3.1 on the observed decline at haulout site OB between 2004 and 2007. Variability in the mean counts reflects real differences in the way seals use the estuary on an annual, seasonal, and daily basis, as well as measurement (i.e., counting) error, which is an inherent element of virtually all survey designs. Measurement error should be relatively small in the estuary because the seals tend to (a) haulout along

the shoreline, arranging themselves almost linearly, (b) vary in size and pelage patterns, which facilitates recognition of individuals, and (c) remain stationary for relatively long periods, making them easier to count. In addition, the survey site is elevated above the estuary, which enhances the counters' view of the estuary and seals. At the same time, measurement error is likely to be larger for more distant sites. At a greater distance, the observer's viewing angle is reduced, individual seals are more difficult to distinguish, and poor sighting conditions (e.g., weather) are more likely to obscure the observer's view.

(4) Events or conditions outside the estuary may influence counts within the estuary.

As just noted, the marauding adult male elephant seal at Double Point in 2003 likely caused some seals to move from Double Point to other sites including Drakes Estero. Such movements may explain some of the increased counts at some haulout sites in Drakes Estero (e.g., A, A1, OB) in that year. Oceanic and ecological conditions in the nearshore environment also may influence counts within the estuary. For example, seals may adjust their haulout patterns depending on weather and wave conditions, availability of prey, or encounters with predators.

(5) Events or conditions within the estuary may influence counts within the estuary.

As also just noted, in 2003 counts at haulout site A rose to their second highest level in the past three decades. Thereafter, the number of seals at that site declined sharply until 2007, when virtually no seals used the site. The decline almost certainly reflects the loss of the channel that had previously separated site A (or the sandbar on which it occurred) from the land, although it also may reflect the return of some seals to Double Point. The loss of the channel increased the vulnerability of seals using that site to disturbance by various sources (e.g., hikers, coyotes). The seals that used haulout site A when it was isolated by the channel either shifted to other sites within Drakes Estero (e.g., A1, L; Figure 6-8) or moved to sites outside of Drakes Estero (e.g., Point Reyes Headland, Figure 5) when the channel disappeared.

Individual seals: Individual seals are the basic units of the above population groupings. The status of an individual seal is best measured in term of its fitness. Fitness is a measure of a seal's ability to survive and reproduce and is determined by a number of factors, including the quality of the seal's habitat. For example, an adult female's selection of pupping habitat may determine whether her pup survives.

Disturbance and displacement are the two main mechanisms by which oyster farming might adversely affect individual harbor seals. Other types of effect (e.g., introduction of contaminants or disease) may be possible, but are unlikely, and the entire debate regarding potential interaction between mariculture and harbor seals in Drakes Estero has focused on disturbance and displacement or some combination of the two. Specifically, are mariculture operations disturbing or displacing seals to the extent that they have altered their behavior or use of estuary habitat for resting, molting, or reproduction?

Marine mammal scientists have a number of tools for studying the effects of disturbance and displacement, including observations and counts of seals, various tags and telemetry devices, and experimental manipulation of the seals or their environment. The scientific literature contains various reports of disturbance or displacement of harbor seals and other marine mammals by human activities (e.g., Gerrodette and Gilmartin 1990, Suryan and Harvey 1999, Bejder et al. 2006).

Practically speaking, disturbance can only be detected if an activity causes a seal to change its behavior. A seal may detect an activity using its visual, acoustic, or, possibly, olfactory senses. The sensory cue is an important consideration in the study of disturbance, but is difficult to determine because the seals live in both air and water and likely can detect both visual and acoustic stimuli over some distance (e.g., hundreds of meters). Although vision may be the primary sense for a seal hauled out on land, sound can travel efficiently through air and harbor seals on land likely depend on both senses to detect what they perceive to be potential threats. When in the water, they may depend primarily on sound to detect and assess more distant threats and vision to detect and assess closer threats. Sound levels have not been assessed in the estuary and the sound fields are likely to be complex given the shallow and variable bathymetry of the estuary and the substantial changes in water depth with the rising and falling tides. Depending on the circumstances, observers monitoring seals over relatively long distances may be more likely to detect potential sources of disturbance using vision rather than hearing, which could affect the way that they perceive or report a disturbance event.

A disturbed seal may exhibit a continuum of responses. It may raise its head (i.e., a head alert), flush (i.e., changing its position on land, which usually means moving toward the water), flush into the water but remain near the site, flush and leave the site temporarily, or flush and abandon the site permanently.

The significance of a head alert can be difficult to assess. In fact, it may be difficult to distinguish a seal's natural movements from an actual alert. For example, a seal may raise its head as it attempts to find a comfortable position. In other cases, a seal may look up to evaluate an object sighted or heard, quickly reassure itself that the object presents no threat, and then simply return to its resting mode. Whether such a response constitutes a meaningful disturbance is questionable. In some cases, however, head alerts could be indicative of a significant effect on a seal. When seals are hauled out on land, they exhibit a degree of vigilance to possible threats. The level of vigilance varies from seal to seal depending on a variety of factors (age, sex, physiological condition [e.g., just gave birth], and history [e.g., has had recent encounters with humans or some other threat]. More vigilant seals expend additional energy and may be more likely to respond to a perceived threat (e.g., abandon a haulout site). For such seals, head alerts may be indicative of a high level of vigilance with the associated consequences. In such cases, it may not be appropriate to dismiss head alerts as being of no biological significance. Finally, when a seal first perceives an object to be a threat, it may move toward the water or enter the water depending on the nature and imminence of the perceived threat. The seals generally appear more confident in the water, where they are more mobile and the water provides a three-dimensional medium in which they are more able to avoid a perceived threat.

Displacement may follow an immediately preceding disturbance event, but does not necessarily require such disturbance. A seal may avoid an otherwise preferred haulout site based on experience or the presence of an object perceived to be a possible threat. The propensity for displacement is uncertain, dependent on a range of variables, and difficult to predict.

2.2 OBSERVATIONS OF DISTURBANCE COLLECTED BY PARK SERVICE STAFF AND VOLUNTEERS

The Point Reyes Bird Observatory conducted seal counts in the estuary beginning in 1982 and continuing intermittently until 1996. Since 1996 Park Service staff and volunteers have counted the seals to assess their abundance and trends (Adams et al. 2009). The counts are considered to be comparable as they followed similar methods and involved some of the same personnel. One or two staff/volunteers count the seals from a location on the western side of the estuary using a spotting scope, binoculars, or the naked eye. As a secondary function, they also document disturbance events, recording their date, time, site, disturbance source, response type, and comments. In reviewing the disturbance records, readers should keep in mind six important points.

First, the seals may be disturbed by a number of different sources. At the Commission's February 2010 meeting, Park Service staff summarized disturbance incidents for all sources over the past decade. The summary included a chart of disturbance events recorded during March, April, or May from 2000 to 2009 (Figure 9). The chart indicates that motorboat-related disturbances are a small portion of all disturbances recorded in the database. Although this report focuses on the effects of mariculture, it is important to keep in mind that the seals are subject to disturbance by multiple activities and any analysis of the effects of mariculture on the seals may be confounded by the effects of those other activities.

Second, the surveys cover only a portion of time when disturbances might occur. Therefore, they constitute only a sample of the actual disturbances. As a sample, they also may be a biased indicator of all disturbances. For example, if surveys tend to occur more on weekends, then they may be positively biased toward sources of disturbance that also are more common on weekends and negatively biased to those activities that tend to occur during the week.

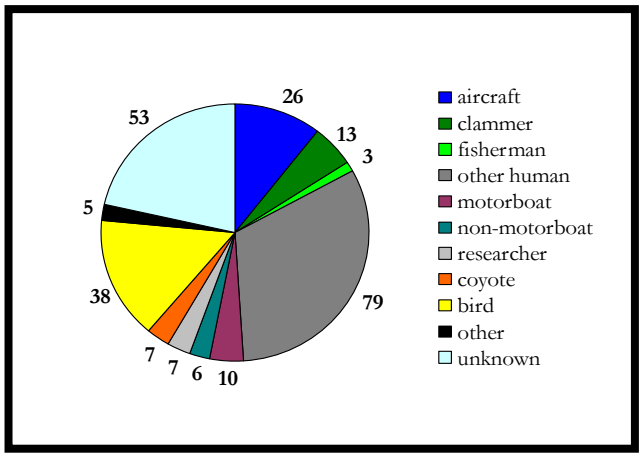


Figure 9. Relative frequencies of various sources of disturbance of harbor seals in Drake's Estero, as documented by Park Service staff and volunteers during population counts in the months of March, April, and May from 2000 to 2009 (data from National Park Service)

Third, characterizing a disturbance is not a simple matter. First, the observer must be able to recognize a seal's behavior as different from

that expected under undisturbed conditions. Although the distinction may be obvious in most circumstances, it may not be clear in others (e.g., did a seal move toward the water to initiate a foraging trip or to avoid a perceived threat). The observer also must attempt to determine the source of the disturbance and, here, too, the source may be obvious in some cases but not in others (e.g., two potential sources are present or none are apparent).

Fourth, in the case of Drakes Estero, the observer also must decide if the information is sufficient to link the disturbance to mariculture. In some cases that link may be clear (e.g., the occupants of a boat load or unload oyster bags). In others, the relationship may not be clear (e.g., persons are observed in a boat or on a tidal flat, but their activities are not clearly related to oyster bags or equipment). Absent evidence to the contrary, the Park Service assumes that virtually all motorboats in the estuary are related to mariculture. Becker et al. (2011) justified this assumption as follows—

> No motorized boats are allowed within the estuary except for those from a commercial shellfish operation which currently makes approximately 1500 motorboat trips per year into the estuary (but not all trips are near seal haulout sites). Other than at the oyster processing facility, there is nowhere in the estuary to launch a trailered motorboat. The nearest port available to launch a small boat is over 29 km away over open ocean, and the harbor seal monitoring programme …which conducts surveys at the mouth of the estuary has not observed any motor boats entering or leaving via the mouth of the estuary during more than 400 surveys over 21 years. With special permission and regulation, research and rescue boats may enter the estuary in rare instances (generally less than three times per year).

The Park Service acknowledges occasional violations of this assumption. Indeed, several disturbance reports refer to boats that do not appear to be mariculture related (e.g., a zodiac, a "blue-yellow" boat).

Fifth—and this is a matter of some contention—the Commission is not yet convinced by the available data that all reported mariculture-related incidents since 2005 are necessarily related to Drakes Bay Oyster Company. For example, under certain circumstances (discussed below) the Park Service has attributed a disturbance to mariculture when the Drakes Bay Oyster Company has asserted that it could not have been involved and has electronic records (e.g., time/date stamped time cards) to support its assertion. One interpretation of such disagreement is that one of the parties is mistaken. A second interpretation is that a disturbance did occur, did involve oyster bags (i.e., mariculture), but was caused by someone other than employees of Drakes Bay Oyster Company. That is, the possibility that on occasion other boats are in the estuary may explain strongly held but conflicting interpretations of several reported disturbances. The available data are not sufficient to determine with full confidence just how often motorboats unrelated to mariculture are in the estuary, but this is a problem that could be easily investigated and, at least for the future, easily remedied.

Table 2. Disturbances noted by Park Service staff and volunteers during harbor seal counts. HA = head alerts, F = flush (i.e., move toward water), FW = flush into water

Record	Date	Time	Site	Source	Response	Database comments
1	03/03/1982	12:15	A	Powerboat	HA,FW[a]	Information insufficient to attribute to Johnson's Oyster Company
2	03/03/1982	12:23	UEN	Powerboat	HA,FW[a]	Information insufficient to attribute to Johnson's Oyster Company
3	04/30/1982	11:05	UEN	Powerboat	HA,FW[a]	Information insufficient to attribute to Johnson's Oyster Company
4	04/07/1996	12:00	UEF	Motorboat	HA	Alarm, no flushes
5[b]	04/07/1996	12:30	UEN	Powerboat	HA	Head lifts
6[b]	05/04/1996	09:45	UEF	Boat	HA	Boat close, veered away; five people in boat
7	08/17/1996	15:05	A	Motorboat	HA	Head lifts only
8	08/17/1996	15:35	DM	Gray motorboat	HA	Head lifts only
9	06/29/1999	11:03	A	Boat	HA,FW	Motor boat anchored, pulled up net, boat left after seals rehauled
10[b,c]	05/08/2003	13:40	A	Oyster boat	FW	Boat came from the oyster farm
11[b,c]	05/08/2003	13:40	UEN	Oyster boat	HA	Boat came from the oyster farm
12[b]	07/17/2003	10:06	UEN	Oyster boat	HA	
Transition from Johnson Oyster Company to Drakes Bay Oyster Company						
13[b,c]	05/06/2006	14:05	UEF	Motor boat	FW	Blue yellow oyster related? zipped through the channel and headed direction of Johnson's
14[b,c]	04/26/2007	15:50	OB	Oyster boat	FW	Oyster boat and two people, see trip report
15[b,c]	04/26/2007	15:50	UEN	Oyster boat	HA	Oyster boat and two people, see trip report
16[b,c]	04/26/2007	16:10	OB	Oyster boat	HA	Oyster boat and two people
17[b,c]	04/26/2007	16:55	UEN	Oyster boat	FW	Oyster boat and two people
18[b,c]	04/26/2007	16:55	OB	Oyster boat	FW	Oyster boat and two people
19[b,c]	04/29/2007	12:50	UEN	Oyster boat	F	Mom and pup flushed when boat accelerated toward bull point from north end of OB after throwing out bags
20[b,c]	04/29/2007	13:40	UEN	Oyster boat	FW	Boat returned, threw more bags out and left
21[b,c]	05/08/2007	08:45	UEN	Oyster boat	FW	Directional path of boat described on form
22[b,c]	05/08/2007	08:45	OB	Oyster boat	FW	Directional path of boat described on form
23[b,c]	05/08/2007	08:45	UEF	Oyster boat	FW	Directional path of boat described on form
24[b,c]	03/14/2008	12:33	UEN	Oyster boat	FW	Engine noise oyster boat grayish, beat up, 1 man and 2 children
25	12/10/2008	15:15	OB	Motor boat	HA	Boat noise from the boat that picked up the 3 clammers from OB. Observer took photos.
26	06/03/2009	15:45	OB	Motor boat	FW	Small inflated rubber boat

[a] The Park Service's database includes a "Y" value under "Response" but the field notes clearly describe the seals' responses, so the response values have been changed in accordance with the field notes

[b] Used in Becker et al. (2009)

[c] Used in Becker et al. (2011)

Sixth, the Park Service analyses of potential effects distinguish between discrete, short-term disturbance events and long-term disturbance from the presence of boats and equipment related to mariculture and the activities of mariculture workers.

Park Service staff, representatives of the Drakes Bay Oyster Company, Dr. Corey Goodman, and Commission staff reviewed the disturbance data records in Table 2 at the Commission's 7 June 2010 meeting. Representatives of the Drakes Bay Oyster Company did not contest the pre-2005 disturbance records, as the Company was not involved in those events.

A review of these disturbance data records is necessary and useful not only because it helps characterize incidents of purported disturbance, but also because it reveals the limitations of and uncertainties associated with the data. For that reason, the following point-by-point review is intended to help identify means for improving the collection of data and reducing those sources of uncertainty.
The Commission's assessment of the disturbance records is as follows.

Records 1-3: The first two of these records were collected at 12:15 and 12:23[4] on 3 March 1982 (Wednesday) and the third at 11:05 on 30 April 1982 (Friday). The Park Service has determined that the information for all three records is not sufficient to attribute them to the Johnson Oyster Company because the observers did not provide sufficient information to distinguish oyster-related activities from clamming.

Records 4 and 5: Both of these records occurred at about the same time (12:00 to 12:30) on 7 April 1996 (Sunday). They were documented by two different observers who attributed them to a motorboat and a powerboat (likely the same boat). Both observers noted seal responses as head alerts (also referred to as head lifts or alarms). Record 4 indicates the boat, with one man onboard, came from the northwest finger of the estero, went between estero far (UEF) and estero mid, then past estero mid (OB?) and near (UEN), and finally stopped between UEN and A. The boat stopped at a buoy and the man onboard pulled up a net. Record 5, documented by the other observer, noted head lifts at estero near (UEN) and site A. This observer also noted that sighting conditions were compromised by fog. At the Commission's 7 June meeting, the participants generally agreed that, based on the location (between UEN and A) and activity (pulling up a net) the reported disturbance likely involved water quality sampling.[5] The California Department of Public Health requires mariculture operators to conduct water quality sampling to ensure that the oysters do not pose a risk to public health. Thus, such sampling is a component of mariculture activity.

Record 6: A single observer collected this record at 09:45 on 4 May 1996 (Saturday). The observer noted a boat that picked up people at OB, came close to estero far (UEF) and then veered away, going "around to other side" [presumably the other side of the estuary], away from UEF. The observer documented head lifts only by seals on UEF. The Commission

[4] Times in 24-hour format.
[5] Sampling involves collection and analysis of mussels for biotoxins.

does not consider the information sufficient to confirm whether the disturbance was or was not related to mariculture.

Records 7 and 8: A single observer collected these two records at 15:05 and 15:35 on 17 August 1996 (Saturday). The 15:05 record refers to a motorboat with two people, apparently near haulout site A, and the second record identifies a gray motorboat with two adults and two children, in the same vicinity, but recorded in the Park Service's database as DM (Drakes Mouth). In both cases, the activities resulted in head lifts only. Given the location, the Commission suspects this activity was related to water quality sampling, but the evidence is not sufficient to confirm that was the case or whether the disturbance was or was not related to mariculture.

Record 9: This record was collected at 11:03 on 29 June 1999 (Tuesday). It involved a motorboat near haulout site A. The person onboard anchored the boat and then pulled up some type of net. The activities resulted in head alerts and flushed nine seals into the water. The seals hauled out again before the boat left. Based on the location and activity, the Commission suspects this activity was related to water quality sampling, but the evidence is not sufficient to confirm that was the case or whether the disturbance was or was not related to mariculture.

Records 10 and 11: A single observer collected these records between 13:15 and 14:15 on 8 May 2003 (Thursday). They involved the same boat, which the observer described as a 15' runabout with two people on board. The boat resulted in head alerts at UEM (OB?) and the flushing of 54 or possibly 64 seals into the water from site A. The record indicates that 71 seals were at the site prior to the disturbance, 7 remained on shore after the disturbance, and 54 flushed. Two simple explanations for the mathematical inconsistency would be that either 17 remained on the site after the disturbance, or 64 were flushed into the water. The observer thought that the boat was from the oyster farm because "seals at DE and A outside of 7 [were] not disturbed." The Commission does not consider this information sufficient to confirm whether the disturbance was or was not related to mariculture.

Record 12: A single observer collected this record at 10:06 on 17 July 2003 (Thursday). He was counting seals when he noted "boat engine noise" and "oystermen." He also noted seal head alerts, which he attributed to the boat moving to the edge of site UEN. The observer did not provide the basis for concluding that the persons involved were "oystermen" and, again, the Commission does not consider this information sufficient to confirm whether the disturbance was or was not related to mariculture activities.

Observers collected records 13 through 26 after Drakes Bay Oyster Company began its operations in the estuary. These records were discussed at the Commission's 7 June meeting and most remain contentious.

Record 13: Two observers working together collected this record at 14:05 on 6 May 2006 (Saturday). They observed a blue-yellow motorboat, "oyster related?" that "zipped through the channel and headed [in the] direction of Johnson's." The observers documented the flushing of 24 seals into the water from haulout site UEF. None had hauled back onto UEF

after 30 minutes. In the Commission's view, the question mark after the words "oyster related" appropriately reflects uncertainty regarding the source of the disturbance.

In the Commission's 7 June 2010 meeting Drakes Bay Oyster Company indicated that (1) its workers would have no reason to be in the main channel, which is closed during the pupping season, (2) that it generally does not work on Saturdays, (3) the Company does not own a blue and yellow boat and did not own one at the time of the observation, (4) and that poor sighting conditions and the distances involved confound the description of this disturbance. The Park Service acknowledged uncertainty regarding the source of the disturbance and adjusted the comment field for this entry to read "possibly oyster-related." However, the Company contends that this disturbance did not occur.

The Commission must question the Company's reasoning and conclusion on this point, particularly given the information in the record, which was collected by two observers. The Company can assert that it was not involved in the disturbance but, if that is the case, then it is not clear how it also could dispute that the disturbance occurred at all, unless it assumes responsibility for, or is somehow informed of, all boat activities in the estuary. As noted elsewhere in this report, an alternative explanation would be that, from time to time, boats unrelated to the Company enter the estuary and cause disturbance. Consistent with this hypothesis, the occupants of such boats may appear to conduct activities related to mariculture, although they are not affiliated with the Company. Therefore, the Commission sees no basis for questioning that this disturbance occurred, although it agrees that the information is not sufficient to determine whether it was or was not related to mariculture.

Records 14 through 18: These records all pertain to the period from 15:50 to 16:55 on 26 April 2007 (Thursday). The observer, a Park Service scientist, documented disturbances that she attributed to an oyster boat (white and about 20 ft long) with two people. The boat was first sighted with men poling the boat westward through the lateral channel (at the east end of the OB haulout site). Once half way through the channel they used the engine, and when two-thirds of the way through the channel they landed on the OB side near oyster bags. The two men, one in a green slicker and another in yellow slicker pants, checked bags and added an additional 30 bags. The men returned to the boat, left by moving eastward back through the channel and finally continued into Home Bay. The scientist estimated that about 90 seals were disturbed by the boat and about 14 of them, including 7 pups, flushed into the water.

Drakes Bay Oyster Company disputes these disturbance records. The Company stated that (1) all its employees had clocked out by 16:47 on that day based on computerized, certified payroll records and electronic time/date-stamped time cards; (2) it has a white boat, but the boat was out of the water and inoperable on that day, (3) the description of the men poling their boat through the eastern end of the lateral channel is not consistent with the distribution of eel grass in the channel as evident in Park Service and California Department of Fish and Game maps and images of the estuary; (4) its workers do not use the lateral or main channel during the pupping season; (5) they do not pole through eel grass, but rather lift the drive unit, motor slowly, and clear the propeller often; and (6) the timing of the events described by the scientist is inconsistent with the times that it would take to complete the actions described. The Commission considers the information sufficient to document a

disturbance related to mariculture, but does not conclude that it was related to Drakes Bay Oyster Company.

Records 19 and 20: These records both pertain to the period from 12:50 to 13:40 on 29 April 2007 (Sunday). Two observers working together noted two disturbance events. The first occurred at 12:50, when a mother-pup pair on UEN flushed as "[a] boat accelerated toward Bull Point from N[orth] end of OB channel after throwing out bags." The second occurred 50 minutes later when, presumably, the same boat "returned, threw more bags, [and] left again." This time the activity flushed two seals into the water, also from UEN.

Drakes Bay Oyster Company also disputes these disturbance records. It asserts that (1) its workers do not usually work on Sundays and that 29 April 2007 was not an exception (the Company referenced its electronically stamped time cards and other records to support its claim), (2) they would not make two trips 50 minutes apart to place bags at the same location, (3) the round trip required to go from OB back to the Company's shoreside facility, reload bags, and return to OB would require more than 50 minutes, (4) such a trip would require staff at the shoreside facility to prepare bags for planting, and (5) OB was underwater at the time of the recorded disturbances and no harbor seals could have been hauled out. The Park Service and some members of the conservation community argue that, on occasion, the Company has worked on Sundays, that the trip would not take that long and also that multiple trips could be made if the bags were taken from a barge anchored in the estuary, and that seals do haul out on the tidal flats as long as the water is not so deep that the seals become buoyant. At the Commission's 7 June 2010 meeting the Park Service agreed to add a comment to its database stating that "DBOC disputes the presence of a DBOC boat at the time and location of disturbance event." The Commission considers the available information sufficient to document that harbor seals were disturbed by activities related to mariculture, but not to ascribe the disturbance to Drakes Bay Oyster Company.

Records 21 through 23: These records all pertain to observations at 08:45 on 8 May 2007 (Tuesday). The single observer noted a boat at 08:40 before she was onsite. She observed that the boat "traveled slowly and hugged land. Then he nosed and headed boat 100-150 ft maybe toward UEN then left east side approach in channel—never landed—just looking at sandbar/seals." The observer's records indicate that 34, 6 plus, and 5 plus seals were flushed into the water from UEN, OB, and UEF, respectively.

Drakes Bay Oyster Company did not question the presence of the observed boat, noting that a boat did travel to the sentinel mussel buoy located in the main channel, across from UEN, to collect a sample for marine biotoxin analysis. It did not agree that the passage of the boat caused a disturbance. It also questioned how the observer could have made all of the recorded counts plus keep track of the amount of disturbance at the site under the reported sighting conditions (extreme heat and "Blur-heat conditions on estero sites") in the period of time noted on the data sheet (from 08:45 to 09:08), and at the distances involved (reported by the Company as up to 2200 meters). The Company also questioned how a single disturbance could have occurred at all three sites at 08:45. Finally, the Company argued that the boat driver's behavior would have been inexplicable given the fact that it was pupping season (the most critical time to avoid disturbance) and the driver was well aware of

the Park Service's concerns regarding mariculture in the estuary and the need to avoid disturbance.

The questions raised by Drakes Bay Oyster Company do not rule out the possibility of this disturbance. Photographs taken on this day indicate that, at least from the location of an automated camera on the east side of the estuary, sighting conditions were limited at 8:30 but cleared in the following minutes. It also is possible to make the counts recorded in the observer's data sheet because counters often count quickly to avoid losing their place and complete the counts with the minimum amount of seal movement. In addition, seals at all three sites could have been disturbed at the same time if the disturbance was caused by sound or a combination of sight and sound from the boat. Finally, the Commission does not doubt that the boat driver would be trying to avoid disturbance. However, disturbance is a function not only of the activity involved, but also the sensitivity of the seals and it is possible that the seals were disturbed despite every good intention on the part of the boat driver. In general, the photographs reveal the wake of a boat and changes in seal activity, but the chain of events requires some interpretation and the Commission therefore considers the evidence equivocal; that is, the evidence cannot be used to confirm or refute a disturbance with complete confidence. This record is discussed further in section 2.3 on photographs.

Record 24: An observer collected this record at 12:33 on 14 March 2008 (Friday). The observer's comments were "Engine noise, oyster boat, grayish, beat up, 1 man + 2 children or @ least 1 child in red, other in blue hood jacket, hard to tell." The observer documented head alerts, flushing, and four seals flushing into the water. The seals had not hauled out again at 12:55. The observer did not provide a basis for assuming the boat was an "oyster boat."

Drakes Bay Oyster Company acknowledges that this might have been one of its boats, but it disputes the timing of the event, whether a disturbance actually occurred, and the presence of children in the boat. Snapshots of the boat activity related to this reported disturbance were taken by an automated camera. The resulting photographs reveal the arrival and departure of the boat and activity on the tidal flats, but cannot be used to confirm or refute a disturbance because the seals that were reported as disturbed were outside the frame of the photographs. This event is discussed further in section 2.3 on photographs.

Record 25: A single observer collected this record at 15:15 on 10 December 2008 (Wednesday). She noted that 11 seals alerted ("HA" or head alerts) and that their response indicated that the seals "may have heard M.B. [motorboat], grey boat to pick up 3 clammers." The observer referenced "Lunny men" on the data sheet, but the Park Service changed this record to simply indicate "motorboat" in their records. The Commission concurs that the information is not sufficient to determine whether the disturbance was or was not related to mariculture or the Drakes Bay Oyster Company.

Drakes Bay Oyster Company was not aware of this record before the Commission's 7 June 2010 meeting. It did not comment on the record because the disturbance was attributed to a "motorboat" only.

Record 26: Two observers working together documented this disturbance at 15:45 on 3 June 2009 (Wednesday). A small inflated rubber boat flushed 11 seals off OB into the water. The observers attributed the disturbance to a motorboat and the Park Service later confirmed that it was not related to the Drakes Bay Oyster Company.

Disturbance records summary: The above records were collected by a total of 13 different observers working singly or in pairs. Of the 12 records collected before 2005, 5 appear to have caused seals to enter the water (records 1, 2, 3, 9, and 10); the remaining 7 records involved head alerts only. None of the 12 records before 2005 can be attributed with complete confidence to oyster operations. Confidence may be highest for those observations that appear to be related to water quality sampling (records 4, 5, and 9, and possibly records 7 and 8). Otherwise, the records appear to make inferences regarding the activity involved based largely on the presence and direction of an observed boat and the assumption that virtually all boats in the estuary were related to mariculture. Although such an assumption may be correct in some or even most cases, the Commission questions whether it is correct in all cases.

The 14 records collected since 2005 pertain to 8 incidents of purported disturbance (i.e., in some cases, multiple disturbances can be attributed to a single incident such as a single boat trip into the estuary). Of those 8 incidents, the Park Service and Drakes Bay Oyster Company—

- agree that the Company was not involved in the 3 June 2009 incident;
- agree that the Company's boat was present during the reported 8 May 2007 incident, but do not agree that the boat disturbed seals; and
- differ in their interpretations of the incidents on 6 May 2006, 26 April 2007, 29 April 2007 (two incidents), 14 March 2008, and 10 December 2008.

With regard to the last point, the Park Service considers the evidence to be sufficient to determine that the incidents were related to mariculture, although the involvement of Drakes Bay Oyster Company is at least implicit in the above-cited explanation in Becker et al. (2011). The Drakes Bay Oyster Company has argued that it was not involved in those incidents (except 14 March 2008) and that its records support its view.

The 8 May 2007 and 14 March 2008 incidents are discussed further in the following section on photographs.

For perspective, questions about which of these events resulted from mariculture activities do not diminish their value as evidence of disturbance generally.

2.3 PHOTOGRAPHS AND VIDEOS

From 2007 to 2010 the Park Service took about 281,000 pictures in the estuary. It used one or two automated cameras positioned on the eastern side of the estuary near the confluence of the lateral and main channels. The cameras were intended to document activities in the

Table 3. Periods when two automated cameras took pictures in Drakes Estero

Year	View	Beginning Date	Ending Date
2007	OB	5 May	19 June
2008	UEF	6 March	23 June
2008	OB	13 March	19 June
2009	OB	17 April	4 Aug
2010	UEF	12 February	6 June

estuary, including disturbances, and were aimed at the UEF, OB, or the lateral channel. They were set to take a picture each minute during daylight hours, but they did not always operate continuously for various reasons (e.g., depleted batteries). With exceptions, they took photographs during the following periods (Table 3).The photographs provide some information regarding the incidents on 8 May 2007 and 14 March 2008.

8 May 2007: The photographs taken prior to, during, and after the purported incident on 8 May 2007[6] are of limited use for describing in detail the positions and movements of seals at the time a boat passed to and from a station used for water quality testing. Their resolution is insufficient for describing seal movements in detail, they provide only instantaneous snapshots of seal position, and they are compromised by hazy viewing conditions up until about 8:40—approximately the time that the boat passes. They do not show the boat used on that day to collect the water quality samples from a station lower in the estuary and they also do not show two of the sites (UEN, UEF) where disturbance was reported and may show only a portion of the seals on the third site (OB). They do show the boat's wake, making it possible to determine when it approached, passed, and departed the area of concern.

When viewed individually, the information in the photographs is difficult to interpret. When viewed as a series covering the moments before, during, and after the boat's passage, the results indicate that the seals' activity level increases as the boat approaches and passes, then decreases again. The photographs also show some seals hauling out during that period. It is feasible that the seals were reluctant to enter the water because they perceived that doing so would increase their exposure to a threat. However, that is generally not the reaction that one would expect. The timing and passage of the boat and the change in seal activity level are consistent with the observer's record, but the photographic evidence of disturbance requires interpolation of what occurred in the periods between pictures. For that reason, the Commission considers the photographs to be equivocal—that is, not sufficient to describe, with full confidence, what actually happened throughout the period in question.

[6] The photographs are available at http://www.nps.gov/pore/readingroom/Photos/2007/05_May/08/AM/. See photographs 2007-05-08 08-30-15 AM T.JPG to 2007-05-08 09-00-15 AM T.JPG.

14 March 2008: The 14 March 2008 photographs[7] from the westward facing camera show (1) a boat heading eastward in the lateral channel at 12:41, (2) the boat landed on the south side of the lateral channel by 12:42, (3) at least two people moving about the site until 12:46, (4) the boat pushed off by 12:48, (5) the boat heading westward in the lateral channel at 12:49, and (6) the boat was out of camera view by 12:50. Photographs from the northwestward facing camera show the boat's approach and departure. The photographs do not provide definitive evidence of who was in the boat, or what they were doing on the UEN site. The observer's record and the photographs are inconsistent with regard to the timing of this event: the observer's record indicated 12:30 whereas the photograph indicated the boat approached UEN and landed at 12:41 to 12:42. Nonetheless, the evidence is otherwise clear that the boat approached and landed at UEN at about the reported time. After the boat landed the people were active in an area near oyster bags, suggesting that the activity was related to mariculture. The photographs do not provide a basis for concluding that the activities were or were not related to Drakes Bay Oyster Company. The photographs also do not show any seals, including those that were recorded as having been disturbed by the incident. Therefore, it is not possible to confirm or refute the reported disturbance based on the photographs.

Park Service logs of photographs: The Park Service arranged for several volunteers to review the majority of photographs taken between 14 March and 22 May 2008 (from one camera) and between 6 March and 21 May 2008 (from the other camera). The logs compiled by those volunteers comprise about 365 entries, virtually all including a date, time, and comment (Appendix D). The comments generally describe the presence, location, and direction of a boat or the presence of people on one of the haulout sites (primarily OB). Two series of notes indicate the presence of a zodiak and one series indicates the presence of a kayak that causes seals to flush into the water. One note is marked with an asterisk (3 April at 14:08) and the words "possible seal flush (1)" were noted in the comment section at the same time that a motorboat was started and left the lateral channel. Taken together, the photographs reveal boats in the estuary and in the western portion of the lateral channel and the presence of people on haulout sites, but they do not provide direct evidence of disturbance by the boats or people.

A volunteer also reviewed the photographs taken between 17 April and 1 August 2009. The resulting log (Appendix D) begins with the statement, "No activity seen from 4-17 to 4-30." The log then provides times and observations from 28 days, generally with multiple observations per day. The log documents five disturbances, four caused by kayaks and one of unknown source. The reviewer noted kayakers present on 6 occasions. In contrast, she noted a boat present on 15 occasions when seals were present but she did not record any disturbance.

[7] The photographs are available at http://www.nps.gov/pore/readingroom/Photos/2008/OB/03-17-08/. See photographs IMG_0028.JPG to IMG_0038.JPG.

Additional observations by a volunteer: The Park Service also enlisted the help of a volunteer to maintain the cameras from 5 March to 5 June 2008 (approximately the same period covered in the notes just described). During maintenance, the volunteer kept a database of observations from the site where the cameras were placed (Appendix E). The records included a field for "disturbance." Of the 337 entries in that field, 319 were "N," 11 were "Y," and 7 were "Unk." All the records marked "Y" in the disturbance field gave a date and start and end times. In most cases they included a boat route (letter/number code) and indicated that the boat was traveling either up or down the estuary. The observer documented her observations on harbor seal disturbance data sheets and took 43 videos of the estuary.

The records compiled in the volunteer's database do not provide sufficient information to characterize the nature and extent of the reported disturbances. However, the volunteer's more detailed data sheets provide additional information[8]. Those records indicate the source to be a boat or motorboat in almost all cases. In one case (27 May 2008) she attributed the disturbance to "oyster farmers talked loudly." The responses were head alerts except in three cases (10 April 2008, 15 May 2008, 27 May 2008) that resulted in seal flushes into the water.

Almost all of the 43 videos were scans of the estuary. Two of the videos show a boat. A video recorded on 19 March 2008 panned between seals resting on water-covered tidal flats and a boat operating to the north of them. The video does not provide compelling evidence of disturbance.

In contrast, on 15 May 2008 the volunteer observed harbor seals resting on OB. She reported witnessing an incident that caused some of the seals to flush into the water. She videotaped the seals at the water's edge and in the water, and she also videotaped the boat moving northward at some distance from the seals. Importantly, this disturbance of seals also was documented by photographs. The photographs are available at http://www.nps.gov/pore/ readingroom/Photos/2008/OB/05-15-08/, are labeled IMG_1596.jpg through IMG_1696.jpg, and provide snapshots from 2:00 pm to 2:10 pm on that date. The snapshots show—

2:00	a boat parked on the south side of the lateral channel and seals resting on haulout OB
2:01	the same scene, but a worker now visible to the left of the boat
2:02	the same scene, but the worker no longer visible
2:03	the boat just starting to pull back from where it was parked
2:04	the boat moving west in the lateral channel creating a visible wake, a seal on the far left raising its head
2:05	the boat appears to have crossed the lateral channel and parked at OB
2:06	the boat has backed away from OB

[8] The data sheets are available on the Point Reyes National Seashore Web site at http://www.nps.gov/pore/ parkmgmt/planning_reading_room_upper _drakes_seal_oyster.htm.

2:07 the boat has left the area photographed and is moving up the west channel, seals in the water and flushing on land
2:08-2:10 seals appear to be returning to a resting state

The combination of video and still photography provides convincing evidence of seal disturbance that likely was caused by the sound of the boat as it left OB and moved up the west channel (a distance of hundreds of meters).

The utility of the photographs: One of the many points of contention regarding the above described photographs is whether they provide a useful basis for confirming or refuting occurrences of disturbance. The Commission believes that they should be evaluated more closely. That being said, any further evaluation should address not only the question of whether they do or do not reveal disturbances, but also the question of whether they are or are not likely to reveal disturbances if they occurred. This latter question is similar to the question of statistical power; i.e., the ability of a statistical test to detect a significant effect if such an effect occurs. The same type of question needs to be asked as part of any fuller evaluation of the photographs. The 8 May 2007 and 14 March 2008 incidents described above indicate that the photographs may not be as useful as originally intended, whereas the 15 May 2008 suggests they may provide valuable information if such events are detected during review of the photographs. A fuller examination of the photographs is necessary to form a conclusion with a reasonable level of confidence.

2.4 OYSTER HARVEST RECORDS

Harvest records (Table 4) are central to the Park Service's analyses of mariculture effects on harbor seals. The Park Service has been accused of using only its own data in these analyses, and this dataset refutes that accusation. The California Department of Fish and Game compiles the records based on tax forms collected from mariculture operators. The annual records are numbers of oysters converted to total weight. Becker et al. (2009) graphed the numbers and Becker et al. (2011) listed them in a table (their Table A1).

Becker et al. (2009, 2011) used harvest weights as a proxy for mariculture effort and the propensity for long-term disturbance resulting from boat activity, human activity, and the presence of equipment (i.e., bags, lines, and stakes). As noted earlier, they differentiated this type of disturbance from that which is short-lived and may result from such events as a kayaker passing a haulout, a hiker walking along the shore, or an aircraft flying overhead. As discussed below (sections 3.2 and 3.3), the translation of mariculture effort into potential disturbance is complicated and lies at the heart of questions about any potential cause-and-effect relationships between the harvest and propensity for disturbance of the seals.

2.5 OBSERVATIONS OF INCREASED HARBOR SEAL MORTALITY WITHIN OR NEAR THE ESTUARY

In 1997 and 2000, respectively, scientists documented 91 and 25 dead adult harbor seals in the Point Reyes region (Allen et al. 2004) but were unable to determine the cause of death. In 2008 a volunteer reported a number of fresh pup carcasses on the spit at the mouth of the estuary. Staff from The Marine Mammal Center (Sausalito, California) responded,

Table 4. Estimates of oyster harvest levels (lbs) in Drakes Estero by year and source

Year	Harvest records	Park Service source(s) of inference
1982	360,004	Harvest data
1983	440,139	Harvest data
1986	437,043	Harvest data
1987	634,869	Harvest data, oblique image of bags
1989	549,953	Harvest data
1991	442,745	Harvest data
1992	606,484	Harvest data
1993	662,388	Aerial image of bags
1997	476,791	Harvest data
1998	292,188	Harvest data, higher than 2005
1999	125,749	Slightly higher than 2000-2004, declining
2000	34,094	Lower than 2002-2004
2001	65,676	Aerial image of absence of bags
2002	78,064	DTP, pers. obs., harvest data
2003	118,643	Aerial image of absence of bags
2004	96,754	DTP, pers. obs., harvest data
2005	138,958	Aerial image of bags, increasing harvest
2006	291,538	Increasing harvest, bags in '05
2007	468,000	Aerial image of bags
2008	438,000	Aerial image of bags
2009	458,000	Aerial image of bags

located six scavenged pup carcasses, and recovered four of them for post mortem examination. By the end of the 2008 breeding season, the number of dead pups observed totaled 35, of which 16 were examined. All were recently deceased, with varying degrees of scavenging, all but two were in good body condition (blubber depth 9-13mm), and one included milk in its stomach (indicating that it had nursed recently). Histology revealed peracute trauma in all cases and only one instance of infection (umbilical). Microbiology and analyses of blubber contaminants were unremarkable and a test for influenza was negative. Absent compelling findings and additional information on pup mortality rates in the estuary, the above information is not sufficient to form conclusions regarding the number of dead pups observed in 2008. Cause of death remains undetermined in all cases (adults and pups) observed in 1997, 2000, and 2008.

2.6 AERIAL OBSERVATIONS OF THE ESTUARY

Becker et al. (2011) used aerial images of the estuary to support their use of total annual harvests as a proxy for mariculture effort. The images, taken at different resolutions, provide evidence pertaining to the presence or absence of oyster bags and other materials on the tidal flats on which haulouts UEN, OB, and UEF are located. The images are of varying quality and provide clear evidence of mariculture material in some cases but limited or poor evidence in others. The images are discussed in detail in section 3.3.

3.0 NATIONAL PARK SERVICE ANALYSES OF THE SCIENTIFIC DATA

As noted earlier, the Park Service made a presentation to the Marin County Board of Supervisors on 8 May 2007, describing its concern regarding potential displacement of seals from certain haulouts. Park Service scientists then published their initial analyses of the potential effects of mariculture on harbor seals in Becker et al. (2009). To address various uncertainties and criticisms related to that paper, they subsequently published Becker et al. (2011). The following sections describe and evaluate these three analyses in chronological order.

3.1 THE APPARENT DECLINE IN SEAL COUNTS AT HAULOUT OB

On 8 May 2007 the Park Service reported that the number of seals at one of the haulout sites had declined by 80 percent over the preceding two years. They attributed the decline to the influence of mariculture activities at or near that site. At the Commission's February 2010 meeting, the Park Service identified the site as OB, explained that the changes observed were based on a comparison between April-May 2004 versus April-3 May 2007, described how the Service came to its conclusion, and provided revised estimates (55 to 60 percent decline) based on data that included the full month of May 2007. The data underlying the Park Service's concerns are illustrated in Figure 10. The Commission's evaluation of these observations and the Park Service's assessment of them is as follows.

(1) Substantially fewer seals used site OB in 2007 than in 2004. This statement is true whether used to describe the pup, non-pup, or total counts through 3 May 2007 or through the remainder of the 2007 reproductive season.

(2) The apparent decline should not be interpreted simply on the basis of a comparison between 2004 and 2007, because estimates from single years are subject to natural environmental noise as well as measurement error. A more robust sense of decline in the OB population may be obtained from the definite trend from 2002 to 2009 (Figures 6 to 8). The inclusion of this larger dataset in the analysis allows the noise to better average out. Evidence of a decline over this interval is convincing.

(3) The available information is not sufficient to identify mariculture as the cause of the reduction in seals using OB from 2004 to 2007. The Park Service attributed the decline to mariculture, asserting that the seals were displaced from the site because of oyster bags being close to or on seal haulout areas. However, the Park Service did not provide data illustrating the closeness of the bags and seals at that time. In addition, variation in the number of seals using OB over the past decade could reflect the influence of natural physical or biological/ecological factors either outside the estuary (e.g., changes in nearshore conditions, prey availability, the distribution of seals following disruption of the Double Point colony by a male elephant seal) or inside the estuary (e.g., changes in tidal patterns, redistribution of seals related to the influx of seals in 2002 and 2003 followed by some redistribution of those seals). That being said, the available information also is not sufficient to rule out the possibility that mariculture activities altered harbor seal haulout patterns in that area. In fact, multiple factors may have contributed to the observed pattern. Absent better

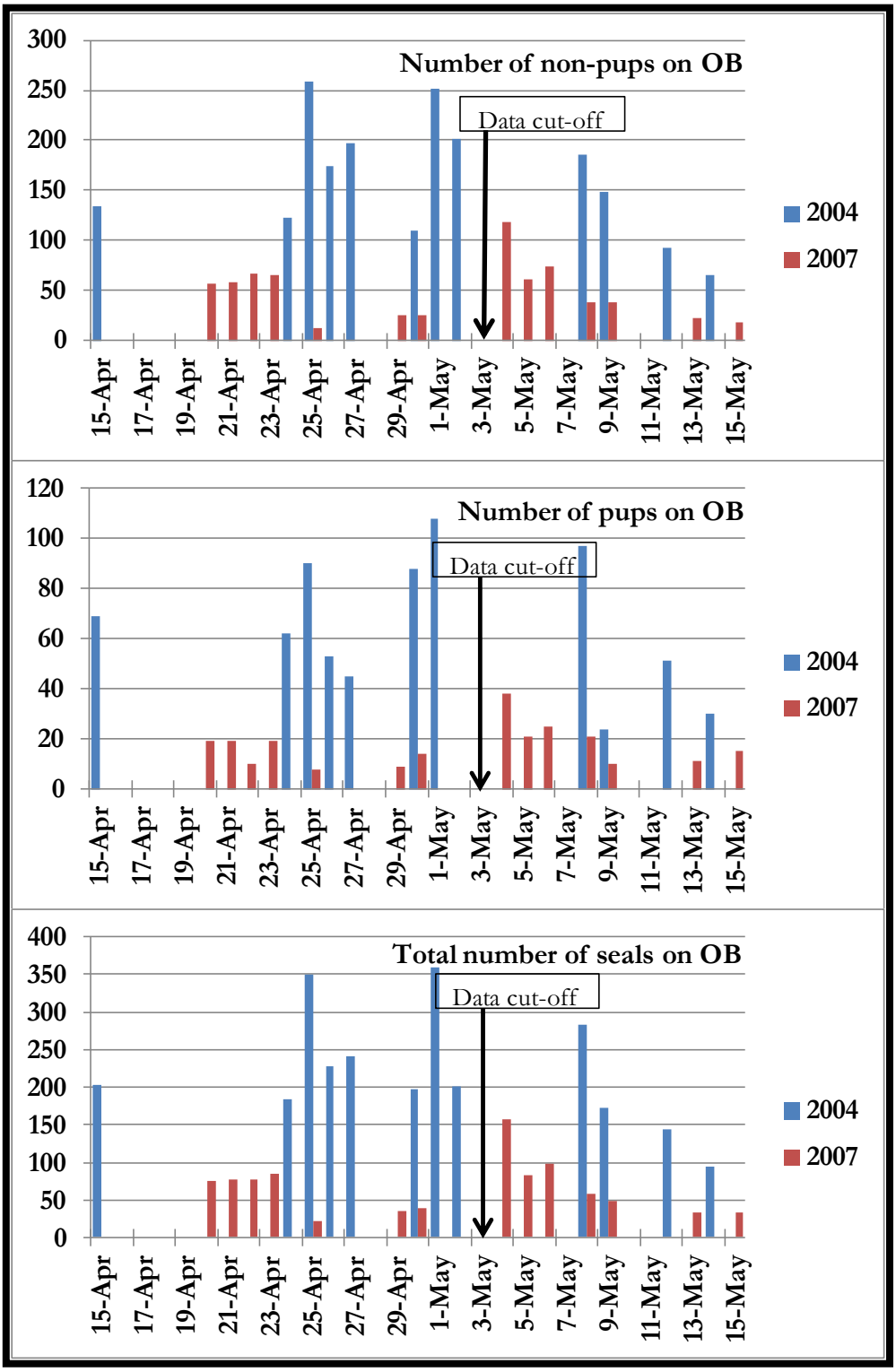


Figure 10. Counts of non-pups, pups, and total number of seals illustrating how the National Park Service concluded that the number of seals using haulout site OB had declined by 80 percent

information, the cause of the decline in seal numbers using OB in the period from 2004 to 2007 (or 2004 to 2009 or 2010) cannot be attributed conclusively to any specific cause, although mariculture remains a possible factor.

3.2 BECKER ET AL. (2009)

The Becker et al. (2009) paper consists of two main components. The first is a correlation analysis of mariculture-related disturbances as a function of the annual oyster harvest. The second is a more complex analysis examining possible relationships between seal use of OB and UEN haulout sites during the reproductive season and four potential explanatory (i.e., independent) variables: annual harvest amounts, year as a linear trend, years since an El Niño-southern oscillation (ENSO) event, and density dependence.

Correlation analysis of disturbance rate versus harvest size: The first analysis in Becker et al. (2009) was to assess whether the rate of disturbance incidents observed by volunteers during their counts increased with the total oyster harvest from the estuary (their Figure 2B, reproduced here as Figure 11). The hypothesis is that the rate of disturbance would be higher for larger harvests because they require more activity in the estuary (boating activity, human activity, and presence of bags, lines, and stakes). If the results of the analysis support the hypothesis, then they lend credibility to the use of annual mariculture harvests as a proxy for levels of activity levels that may cause disturbance. If the results do not support the hypothesis, then they lend support to the conclusion that annual harvests are not a good proxy for activity level and the potential for disturbance. The disturbance records used to examine this potential relationship are listed in Table 5 and are graphed in Figure 2B of Becker et al. (2009).

For this analysis, the Park Service combined observed disturbances if they occurred at the exact same time. That is a reasonable approach as such disturbances were not independent of each other. The Service also subsequently indicated that three of the records in 1996 should be excluded from the analysis because they did not result in disturbance. If those records are removed, then the number of reported disturbance events included in the analysis decreases from 16 to 13. Of those, three cannot be reliably linked to mariculture, one is known to be related to water quality sampling, and another three are thought to be related to water sampling. If water quality sampling is required on a regular basis

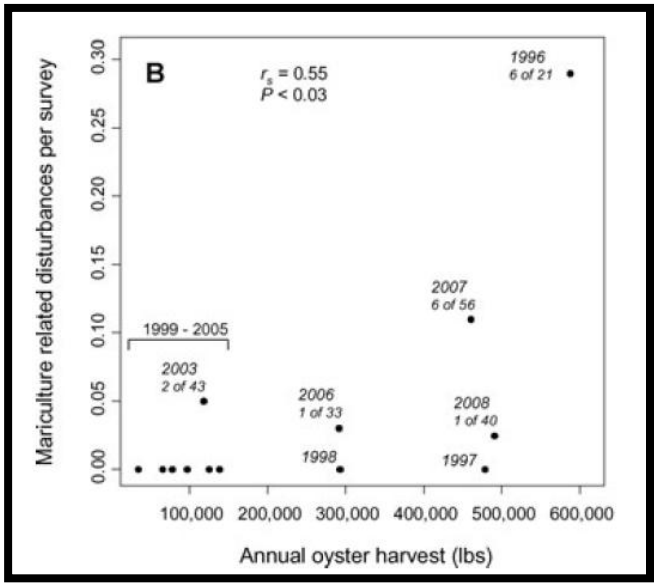


Figure 11. A reproduction of Figure 2B from Becker et al. (2009) illustrating their analysis of disturbance rate (disturbances observed per survey) as a function of annual oyster harvest

Table 5. Disturbances used in Becker et al. (2009) to assess the rate of disturbance (per survey) as a function of size of the mariculture harvest. The Park Service has indicated that the entries in the shaded rows should be removed from the analysis because they did not result in a disturbance

Date	Time	Site	Response	Oyster-related	Removed because
04/07/1996	12:26	UEF	None	---	No disturbance
04/07/1996	12:26	OB	None	---	No disturbance
04/07/1996	12:26	A	Head alerts	Water sampling?	
04/07/1996	12:30	UEN	Head alerts	Water sampling?	
05/04/1996	9:30	OB	None	---	No disturbance
05/04/1996	09:45	UEF	Head alerts	Unknown	
05/08/2003	13:40	A	Flushed into water	Water sampling?	
		UEN	Head alerts		
07/17/2003	10:06	UEN	Head alerts	Unknown	
Transition from the Johnson Oyster Company to the Drakes Bay Oyster Company					
05/06/2006	14:05	UEF	Flushed into water	Unknown	
04/26/2007	15:50	OB	Flushed into water	Yes	
		UEN	Head alerts		
04/26/2007	16:10	OB	Head alerts	Yes	
04/26/2007	16:55	UEN	Flushed into water	Yes	
		OB	Flushed into water		
04/29/2007	12:50	UEN	Flushed	Yes	
04/29/2007	13:40	UEN	Flushed into water	Yes	
05/08/2007	08:45	UEN	Flushed into water	Water sampling	
		OB	Flushed into water		
		UEF	Flushed into water		
03/14/2008	12:33	UEN	Flushed into water	Yes	

irrespective of harvest amounts, then any tendency of such sampling to cause disturbance should not vary as a function of harvest size. Assuming that to be the case, water quality sampling should not be modeled as a function of total harvest, but rather as a constant irrespective of total harvest.

If one excludes (1) the three records identified by the Park Service as not causing a disturbance and (2) the three records that cannot be attributed with sufficient confidence to mariculture, then that leaves ten disturbance events. Three of those ten were attributed to the same boat within a span of about one hour. Thus, aside from the disturbance caused by that boat, the analysis rests on seven additional disturbance events over a period of 13 years. The Commission does not consider these results to be a strong basis for forming conclusions about the frequency of disturbance based on annual mariculture harvests.

Multivariate analysis of haulout patterns in the upper estuary: The second major component of the Becker et al. (2009) paper is a multivariate analysis of several factors that might explain harbor seal haulout patterns. Under ideal conditions, this analysis would be based on clear and reliable descriptions of (1) the nature, frequency, duration, and location of mariculture activities, and (2) the responses of the seals and the significance of those responses. Absent such information regarding mariculture activities and effort, the analysts

used the total annual harvest, measured in weight, as a proxy. To assess the potential impact of disturbance and displacement, they used the number of seals at haulouts UEN, OB, and UEF during the seals' reproductive season. They graphed annual harvest and the number of adult and pup seals hauled out at OB in their Figure 2A, included here as Figure 12.

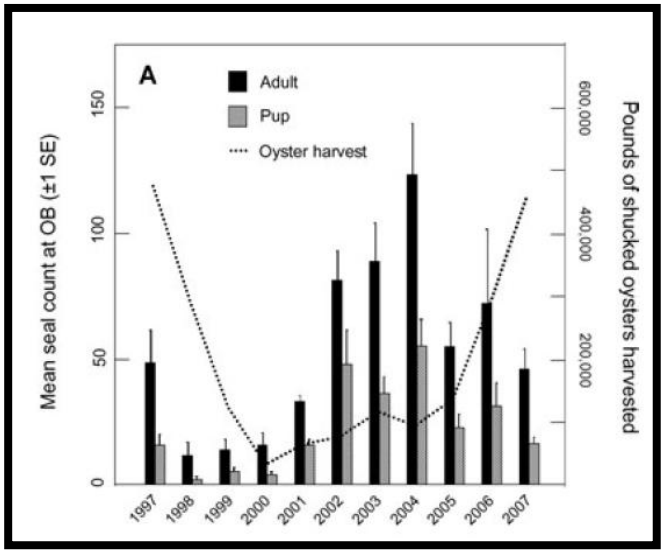


Figure 12. The relationship between total annual oyster harvest and harbor seal haulout patterns at site OB, as depicted in Becker et al. (2009)

The multivariate analysis found that a combination of years since the last ENSO and mariculture best explained the observed haulout patterns. They also found that the statistical relationship between the two independent variables (years since El Niño and mariculture) and the dependent variable (haulout patterns on OB) explained about 37 percent of the variation in haulout pattern and that the probability of explaining that variation if there were no real relationship was less than 5 percent. The key question is whether the apparent relationship is real or spurious—that is, do the findings of this analysis in Becker et al. (2009) indicate a cause-and-effect relationship between mariculture activities and seal haulout patterns or is the apparent relationship random, coincidental, or due to some factor or set of factors not considered in the analysis.

Answering that question requires, in part, filling in the details of how mariculture effort is or may be related to the disturbance rate. Much of the discussion at the Commission's February 2010 meeting focused on this point. The reluctance to accept the total harvest as a reliable indicator of disturbance rate was based on the fact that, as practiced over the past several decades, oyster harvesting practices in the estuary have varied as a function of management, growing method, location, and season, and the total harvest weight does not reflect such detail.

Management has changed in at least two ways. First, a 1992 management agreement between the Johnson Oyster Company and various federal and state agencies restricted the activities of the oyster company (the Johnson Oyster Company until 2005 and then the Drakes Bay Oyster Company), particularly with regard to presence in the main and lateral channels of the estuary during the seal reproductive season. Management also varied within the Johnson Oyster Company and then with the transition to the Drakes Bay Oyster Company.

Growing methods also have changed, and the potential for disturbance appears to change significantly with the growing method because of the amount of tending required for the different methods. Oysters on the racks do not appear to require as much tending as oysters in bags linked together by line and staked to the tidal flats. Oyster growing methods have

varied over time and, importantly, that variation has not been documented adequately, confounding assessment of mariculture effort.

Location is a critical consideration for a number of reasons. With few exceptions, oyster racks are confined to the upper estuary and are farther away from seal haulout areas. How far is "far enough" is a critical but unanswered question. When the Commission's panel visited the estuary during the February meeting, the OB area where the seals were hauled out was hundreds of meters from the areas where bags were placed on the southwestern edge of the lateral channel. Although the panel observed no disturbance as a result of their presence (and that of the boats carrying them), it was not possible to tell whether the separation was so great that the risk of disturbance was very low, or whether the seals chose to maintain such a separation because of their sensitivity to disturbance. This issue is further complicated by the fact that the estuary is highly dynamic and the rising and falling tides change substantially the areas available to seals for hauling out. So the proximity of oyster operations and seal haulout sites is a central issue requiring further characterization.

Season also is a critical factor. The Park Service's analysis focused on the reproductive period because of its importance to the status of the harbor seal population. As just noted, the 1992 agreement posed restrictions on mariculture during the reproductive period. Activities during that period also change as a function of weather (particularly rain) and, in later years, they also have changed in response to the controversy surrounding mariculture in the estuary (K. Lunny, pers. comm.).

Absent a clear description of all these factors, the Commission's panel was not convinced that the total annual harvest is a reliable indicator of the nature and extent of disturbance from mariculture activities. The panel members believed that, without the necessary details on mariculture effort and disturbance, they could not conclude with scientific rigor that mariculture activities cause disturbance leading to displacement of seals from haulout areas in the upper estuary.

Comments from the Commission's panel following the February 2010 meeting: The claim of an 80 percent decline at haulout site OB from 2004 to 2007 and the Becker et al. (2009) paper were the two main topics at the Commission's February 2010 meeting, although the panel also had a draft of the paper that subsequently was published and is now referred to as Becker et al. (2011). As noted earlier, the Commission did not retain the panel for review beyond their reports based on the February 2010 meeting. Their individual reports are included here as Appendix F and the main points of their reviews are summarized as follows.

- Mariculture is not incompatible with a healthy seal population, as is evident in other areas along the West Coast.
- Depending on how mariculture is conducted, the potential effects of mariculture on harbor seals in Drakes Estero could vary from biologically negligible to biologically significant. At any given moment, a seal's responses to human activities will depend on a range of factors such as distance from those activities, previous experience with those activities, the response(s) of other seals, etc.

- Biologically significant effects would be realized through changes in reproduction, survival, and dispersal.
- The Park Service should clearly articulate what its objectives and thresholds are in this case.
- The Park Service's papers provide sufficient evidence to suggest a potential for disturbance effects, but not sufficient evidence to confirm that is the case. The evidence that exists is based on correlation and is not sufficient to conclude causation.
- The disturbance dataset suffers from a number of shortcomings, including the potential for observer error; nonetheless, the data still have some utility and the data collection approach could and should be improved.
- The Park Service needs a better measure of mariculture effort, although the existing measures are not without some value that should improve over time.
- Better measures of mariculture effort would incorporate clear spatial and temporal components.
- A range of other factors, both natural and human-related, may affect the dynamics of this population and they should be investigated to the extent possible.
- Estuaries are dynamic and haulout sites available to seals will change over time as channels, shoals and sand bars come and go entirely due to natural forces such as sedimentation, water inputs, currents, tidal flow and storms independent of disturbance.
- Existing information is not sufficient to judge a safe distance between mariculture activities and the seals, although that could be evaluated using an appropriate scientific design.
- Any evaluation of trends should take into account the factors driving them and their variability.
- Cooperative, adaptive management provides the best means for investigating many of the uncertainties associated with this issue.
- Such an approach would depend on effective communication and cooperation for purposes of sharing information, education, and training.
- An adaptive management approach should be guided, at least in part, by scientists with expertise in behavior or behavioral ecology.

Other criticisms of Becker et al. (2009): Other critics raised additional objections to the 2009 paper. The criticisms, and the Park Service's response to them, are listed in Table 6.

3.3 BECKER ET AL. (2011)

As is clear from Table 6, the Park Service's main response to criticisms of Becker et al. (2009) was to revise its analyses and publish the new results in Becker et al. (2011). The revised analyses examined the effects of mariculture and other factors on harbor seal habitat use patterns at three scales—subsite (haulout), colony (Drakes Estero), and regional (Point Reyes).

Table 6. Criticisms of Becker et al. (2009) and resulting changes in Becker et al (2011)

Criticism	Park Service response
Used incorrect harvest value for 2007	Used the data available at the time of submission and updated that value for the 2011 paper
Did not include 2008 harvest estimate	Included 2008 and 2009 data points in the 2011 paper
Included controversial disturbance data	Ran the analyses both with and without the contested data points
Selectively used disturbance data (2000 to 2007)	Used disturbance data from 1982-1983 and 1997-2009 (1996 excluded because no seal count data for 1996)
Should not have used a one-year time lag because oysters are only on sandbars for a short time	Removed time lag in 2011 paper
Did not account for harbor seal population size within the estuary and in surrounding areas	Included lower estuary population size in 2009 paper and regional population size in 2011 paper
Did not follow quality assurance/quality control protocols for disturbance data	Did follow those protocols, which are for count data, not disturbance data
Ignored disturbances from other sources and focused on mariculture use	2011 paper explicitly tests for effects of disturbance from all anthropogenic sources; in that analysis the authors pooled all sources of disturbance
Did not analyze the entire estuary population as a single unit	Analyzed in 2011 paper
Ignored potential impacts of 1992 boating agreement	Analyzed in 2011 paper
Should find additional years of data for seal count analyses	2011 paper increased the dataset to 21 years for areas within Drakes Estero and to 15 years for the region, based on availability of data
Annual oyster harvest is a poor metric of mariculture activity	(1) Conducted several additional analyses regarding the spatial and temporal relationship between mariculture harvest and effort (i.e., boat observations, seasonal versus annual harvests), (2) attempted to infer level of effort based on aerial photographs, (3) tested categorical and continuous variables in 2011 paper, and (4) requested a meeting with Drakes Bay Oyster Company to discuss a better approach, scheduled a meeting that was subsequently postponed by the Company, and then made a second unsuccessful attempt to set up a meeting.

Analysis and results at the subsite scale: This analysis was aimed at determining if the spring disturbance rate (all sources) affected the haulout patterns of seal mothers with pups. The authors concluded that such disturbance did not have a significant effect on spatial use, but rather spatial use was pre-determined by general sandbar isolation (i.e., whether the sandbar was connected to land and therefore accessible to certain sources of disturbance such as hikers, horseback riders, and predators).

The finding that mother-pup pairs appear to prefer haulout sites isolated from disturbance is not surprising. Females invest substantial resources in reproduction. If disturbance poses a threat to them or their pups (such as might be the case when coyotes have greater access to haulout sites), natural selection should favor an adjustment in haulout patterns if alternative sites are available and provide conditions more suitable to successful rearing of pups.

However, in the Commission's view, isolation and short-term disturbance are not independent factors. Rather, they are almost certainly closely linked. Although isolation occurs as a result of the physical features of the environment (in this case, a channel), its ecological significance undoubtedly is related to avoidance of disturbance. Indeed, it is hard to make an argument that, by itself, physical isolation is an important factor. The most reasonable interpretation of this finding is that the analysis did not reveal a significant effect of short-term disturbance beyond that involving seals switching from haulout site A to other sites.

The above finding has not been controversial, although it points to the significance of the haulout sites in the middle and upper estuary (i.e., UEN, OB, and UEF) to mother-pup pairs. The results of this subsite analysis will not be considered further in this report.

Analyses and results at the colony scale: The primary question at the colony scale is whether mariculture activity displaces mothers and pups away from haulout sites UEN, OB, and UEF. The Park Service tested this hypothesis by evaluating potential relationships between the proportion of total seals or pups within the estuary at these sites and four main explanatory variables: mariculture effort as represented by annual harvest levels, years since the most recent ENSO event (modeled as *log (years since ENSO+1)*), disturbance rate (*disturbances by all sources/number of surveys*), and the pooled maximum annual seal counts of all other Point Reyes harbor seal colonies (i.e., regional population size).

The Park Service used two types of statistical models for conducting these tests. It first used generalized linear mixed models for an initial round of testing based on the 15 years for which regional counts are available (1982, 1983, 1997-2009). (Recall that Becker et al. (2009) was criticized because the analyses therein did not take into account regional population patterns.) It used generalized linear mixed models because they allow calculation of the Akaike Information Criterion (AIC), which serves as a measure for judging the relative fit of different combinations of explanatory variables. The AIC approach is intended to seek the best fit to the data by balancing the amount of variation explained versus the number of variables required to explain it. Adding more explanatory variables to a statistical model generally improves the correspondence between predicted and actual values of the dependent variable, but this can involve fitting to the noise as well as fitting to the signal and, at some point, the addition of those variables actually reduces the genuine predictive or

explanatory power—a phenomenon referred to as "overfitting." The Park Service used likelihood ratio tests and the AIC to avoid overfitting, accepting an additional explanatory variable only if the probability of the observed improvement in goodness of fit was less than P=0.05 under the null model. It also used explanatory variables that it considered beforehand to be plausible as factors that might exert a causal influence on seal distribution and tested combinations of explanatory variables only if they were not highly correlated.

The Service then used generalized estimating equations with the 21-year dataset (1982, 1983, 1986, 1987, 1989, 1991-1993, 1997-2009) for evaluating the effects of mariculture and time since ENSO (without the disturbance and regional explanatory variables). Generalized estimating equations allow for some autocorrelation within the dependent variable. In this case, the dependent variable is derived from maximum daily counts, which generally do exhibit within-season autocorrelation.

The Park Service also used two additional explanatory variables derived from the initial set of four. It used annual oyster harvest in a binary (high/low) form to address criticisms regarding the use of annual oyster harvest amounts as a proxy for mariculture (i.e., each year was ranked as either high harvest or low harvest), and it divided disturbances into those occurring in the upper versus lower parts of the estuary. Finally, the Park Service tested the effect of the 1992 management agreement by adding another binary explanatory variable (i.e., before 1992 agreement, after 1992 agreement) for that purpose.

The Park Service's results again suggest that a combination of time since ENSO effects and mariculture activities provide the best explanation for the haulout patterns in the upper estuary (i.e., at UEN, OB, and UEF haulouts). The combination of the two explanatory variables (time since ENSO plus mariculture) was significantly better—in a statistical sense—than the use of time since ENSO alone. The results suggest that the 1992 agreement did not have a significant effect on seal use of the UEN, OB, and UEF haulouts. The results also indicated that, after removing the effects of time since ENSO, mariculture may cause a reduction of 8 ± 2 percent in the number of seals using these sites.

Analyses and results at the regional scale: To evaluate the proportion of seals hauling out in Drakes Estero versus other Point Reyes colonies, the Park Service considered a variety of possible explanatory variables. They included, including year as a linear trend, portion of seals using haulout site A (to assess the influence of changes occurring at site A after 2003), the number of seals at Double Point (to assess the influence of a marauding elephant seal in 2003), the spring disturbance rate in the estuary, years since the last ENSO event, the total annual maximum count (minus Drakes Estero) in the region, total annual mariculture harvest, and total annual mariculture harvest treated as a binary variable (again, high or low). Here, too, the Park Service was responding to criticisms that it had not included other potentially relevant factors.

For these analyses the Park Service used binomial generalized linear models to "model the probability that any random seal was found in Drakes Estero (success) versus somewhere else in Point Reyes (failure)." It again avoided combining correlated explanatory variables by rejecting those combinations with a variance inflation factor (a measure of multi-collinearity) exceeding 3 (a relatively conservative limit). It also used an AIC adjusted for possible over-

dispersion (variance greater than expected for a binomial variable) and for small sample size—hence, QAICc. In addition, it used bootstrapping to estimate standard errors for the oyster harvest variable. One of the advantages of using AIC, or an adjusted form of it, is that the best models can be weighted and combined in a process referred to as model averaging to produce an estimate of the most likely combination of variables. Finally, the Park Service repeated parts of its analysis using a Bayesian approach on a subset of the best performing regional models. The use of this alternative approach provided a means for checking and validating results from the binomial generalized linear models.

The results from these tests indicated that combinations of Double Point, subsite A, and oyster harvest (in binary or continuous form) produced the best predictors of seal use of Drakes Estero versus other colonies in the Point Reyes area. The results, judged on the basis of QAICc values, all produced r^2 values of 0.46 to 0.63. By themselves, year, Double Point (maximum annual count per year), human-related spring disturbance rate (all sources), and years since ENSO were poor predictors of seal use of Drakes Estero. The results for high/low oyster alone were statistically significant with r^2 values of 0.26 and 0.29 for pups and total seals, respectively. After removing the effects of Double Point and subsite A, the results again suggested that high oyster harvest years resulted in a reduction of about 7 ± 2 percent of pups and 5 ± 2 percent of total seals in Drakes Estero. The alternative Bayesian approach produced similar results.

4.0 CRITICISMS OF BECKER ET AL. (2011)

Becker et al. (2011) has become the primary focus of the debate over potential mariculture effects on seals in the estuary. This report considers criticisms of the Park Service's analyses under four headings. They involve allegations that the Park Service (1) unreasonably continued to use annual oyster harvest as a proxy for mariculture effort, (2) failed to demonstrate that seals and mariculture overlap, (3) used data selectively, and (4) failed to acknowledge alternative models and results.

4.1 USE OF ANNUAL OYSTER HARVEST AS A PROXY FOR MARICULTURE EFFORT

If all other things are equal, it generally stands to reason that if mariculture activities have any propensity for disturbing seals, and if increasing annual harvests require increasing effort near seal haulouts, then increasing annual harvests will lead to an increasing chance of disturbance. Becker et al. (2009) followed this reasoning and—as noted earlier—was criticized by many, including the Commission's panel, largely because all other things may not be equal. That is, effort may vary as a function of management, growing method, location, and season, as was noted earlier in this report.

In response to this criticism, Becker et al. (2011) completed several additional analyses to assess how much effort might have varied as a function of annual harvest. The key question for these analyses was whether effort in the vicinity of UEN, OB, and UEF generally followed the high/low/high pattern evident in the California Department of Fish and Game's annual harvest records for the late 1990s to the late 2000s (see Table 4). Briefly, those analyses are as follows.

First, Becker et al. (2011) examined the sighting rate of motorboats in the estuary (i.e., sightings per survey) during the period from March to May each year from 1996 to 2009. The results (Figure 13) indicated a statistically significant relationship with more boats sighted per survey in years with higher oyster harvest.

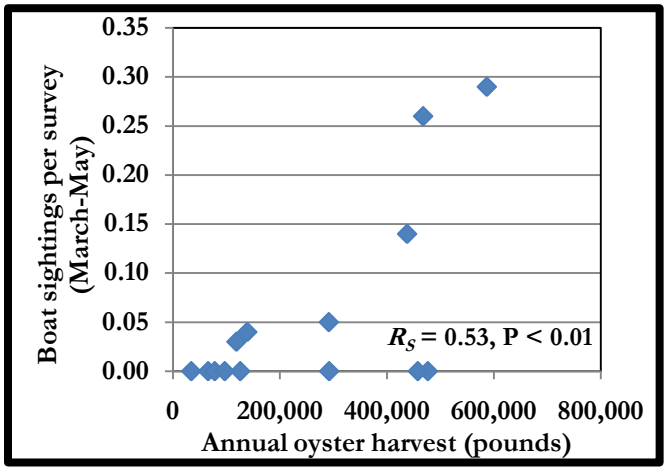


Figure 13. Graph depicting the boat sighting rate per survey (March through May) versus the annual oyster harvest in pounds

Second, Becker et al. (2011) examined the temporal relationship between annual harvest and harvest during the seal reproductive period (March-May). Their results (Figure 14) revealed a statistically significant relationship, indicating that the annual spring harvest was a relatively constant fraction of the total annual harvest.

Third, the Park Service responded to concerns about using the reported, specific harvest weights by converting them to binary form in which each harvest is treated as either high or low (analyses were duplicated to test the 2005 harvest level as both high and low).

Fourth, Becker et al. (2011) estimated the acreage of mariculture materials or equipment in certain years between 1993 and 2009 using aerial photographs available from several sources. The Commission's interpretation of the photographs analyzed for Becker et al. (2011) (Appendix G) is as follows.

1993 This photograph from Google Earth reveals clear lines of oyster materials on UEN, OB, and UEF in a year with a high harvest.

1994 This photograph was on the National Park Service server and reveals clear lines of oyster materials on OB and UEF in a year with a high harvest.

2001 This photograph from the Digital Airborne Acquisition System does not reveal clear evidence of mariculture material in a year with low harvest.

2003 This photograph from Google Earth is not particularly clear, but does not reveal evidence of mariculture material in a year with low harvest.

2004 This photograph from Google Earth is not particularly clear, but does not reveal evidence of mariculture material in a year with low harvest.

2005 This photograph from the National Agriculture Imagery Program does reveal some mariculture material on OB, perhaps more than estimated in a year with low harvest.

2007 No photographs were available and mariculture acreage was estimated based on a land survey (Brown and Becker Trip Report, 13 March 2007).

2008 This photograph from Pacific Aerial Surveys reveals mariculture material on UEN, OB, and UEF in a year with a high harvest.

2009 This photograph from Pacific Aerial Surveys (procured for the Park Service) reveals mariculture material on UEN, OB, and UEF in a year with a high harvest.

The photographs from years 1993, 1994, 2008, and 2009 all provide clear evidence of mariculture activities on the tidal flats where haulouts UEN, OB, and UEF occur in years with high harvests. The years in question include 2001 to 2005, when the total annual harvest dropped from a mean of about 400,000 pounds throughout much of the 1990s (1990 to 1998) and from 2006 to 2009, to a mean of about 90,000 to 100,000 pounds from 1999 to 2005. Thus, the high/low pattern is clear in the harvest amounts and the question is whether that pattern applies to the activity level around UEN, OB, and UEF haulouts.

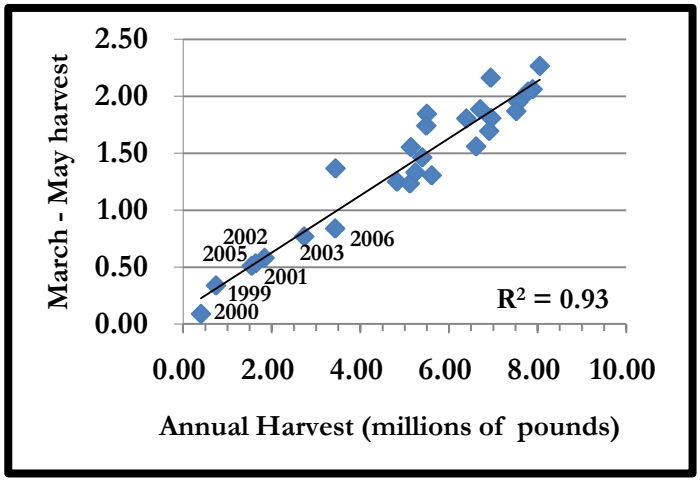


Figure 14. Graph depicting the March-May harvest versus total annual harvest

The Park Service assessed the above photographs and illustrated the results in Figure 4 of Becker et al. (2011) (reproduced here as Figure 15). The figure depicts a statistically significant relationship between acres of mariculture equipment and annual oyster harvest. After the publication of Becker et al. (2011) the Park Service identified some additional photographs from the California Department of Fish and Game pertaining to mariculture activities on UEN, OB, and UEF (Appendix H). Those photographs reveal striations on OB in 2003, 2004, and 2005, and on UEF in 2005. Drakes Bay Oyster Company interprets those lines on OB as rows of cluster cultures; that is, clusters of bars taken from the oyster racks in the estuary and placed on the tidal flats where the attached and nearly grown oysters can mature before harvesting. However, they appear to overlap exactly between 2003 and 2005 and an alternative explanation is that they are marks that have persisted from previous activities. As discussed below, incomplete records from the California Department of Public Health and Drakes Bay Oyster Company indicate some harvesting from bed 17 (tidal flat on which haulout UEN is located) but do not show any harvesting from bed #20 (tidal flat on which haulout OB is located). Thus, the amount of oyster activity in 2003 and 2004 remains in question.

Critics also have questioned the estimated acreage for 2007, which exceeds that in any other year during the period in question. The estimated acreage in 2007 is from a survey rather than an aerial photograph, and the trip report for the survey includes a discrepancy in the estimated total acreage. The range for the acreage used would appear to extend from 10 to 22 acres, but the actual amount is not certain. Despite these uncertainties, the relationship depicted in Figure 4 of Becker et al. (2011) is likely to remain statistically significant even if the total acreage for 2007 was lowered to 10 acres and if all of bed #20 were used for cluster groups because of the limited size of the area (less than five acres).

Critics also have indicated that records from the California Department of Public Health demonstrate that the Johnson Oyster Company harvested from both beds 17 (west UEN) and 20 (west OB) from 2000 to 2004. They have further asserted that those are the only beds that the company was allowed to use when it rained. However, as just noted, the limited California Department of Health records (Appendix I) sent to the Commission by Dr. Corey Goodman do not provide a record of harvesting from bed 20 during the period from 2000 to 2004. They show harvests from bed 17 in 10 of 30 records from 24 November 2001 to 25 January 2002, 2 of 15 records in January 2003, 2 of 48 records from 28 February to 5 May 2003, and 6 of 40 records from 17 November 2003 to 29 January 2004. In addition, they show that on days with rain the Johnson Oyster Company harvested from beds 4, 7, 8, 9, 17, 22, and 38, indicating that the company was not restricted to beds 17 and 20 when it rained.

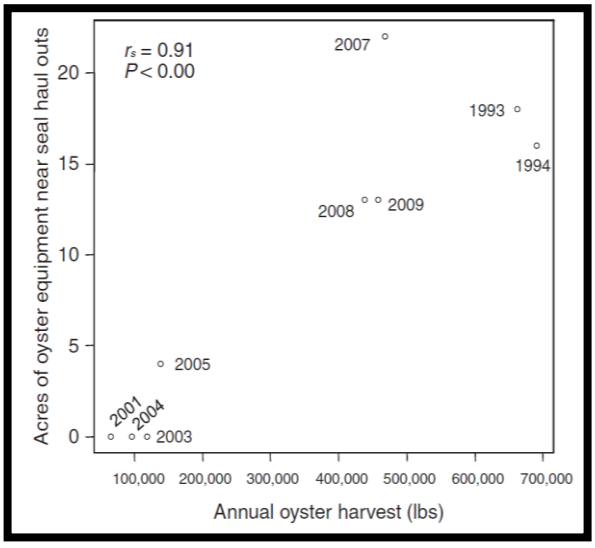


Figure 15. Graph from Becker et al. (their Figure 4) depicting their estimate of annual oyster acreage versus total annual harvest in pounds

Critics also have asserted that other records from the Johnson Oyster Company and Drakes Bay Oyster Company confirm harvesting from beds 17 and 20 in 2000-2004. However, the only records provided to the Commission do not substantiate that claim with actual data. The Commission has been provided with two signed statements from former employees of the Johnson Oyster Company and harvest records from Drakes Bay Oyster Company. However, Park Service staff who conducted research at a site overlooking the estuary during the summer of 2003 also will provide signed statements indicating that little harvesting occurred in 2003. The records from Drakes Bay Oyster Company do not include harvest amounts from 2000-2004, indicate nine harvests from bed 17 between 1 March and 31 May 2005, and do not indicate any harvests from bed 20 during that period.

Finally, after its June 2010 meeting the Commission urged Park Service staff to meet with Drakes Bay Oyster Company to develop a better method for characterizing mariculture effort. Critics of the Park Service have accused its staff of failing to ask for the data pertaining to harvest amounts. However, this statement appears to be an incomplete description of communications between Park Service staff and Drakes Bay Oyster Company. By both telephone and email (Appendix J) Park Service staff did attempt, unsuccessfully, to set up a meeting to discuss mariculture effort as well as seek comments on Becker et al. (2010)—an earlier draft of Becker et al. (2011).

Although harvesting details remain unclear—largely because of inadequate recordkeeping—the Park Service appears to have made a good faith effort to explore the issue in more detail and, without the benefit of such cooperation, its secondary analyses are reasonable and broadly consistent with the hypothesized pattern.

4.2 FAILURE TO DEMONSTRATE THAT SEALS AND MARICULTURE OVERLAP

The issue at the heart of this debate is whether and, if so, to what extent mariculture may have affected or may be affecting harbor seals' use of the estuary. Answering that question is difficult because the existing information is not sufficient to describe the baseline condition—that is, how the seals would use the estuary in the absence of mariculture.

Figure 1 in Becker et al. (2011, reproduced here as Figure 16) depicts the spatial relationship between mariculture and seal haulout areas. The areas of concern are UEN and OB, where the two may overlap, and UEF, where the two are in close proximity. At the Commission's February 2010 meeting, a Park Service scientist presented a photograph illustrating that on occasion seals can be found close to mariculture material (Figure 17). However, such instances appear to be rare and the seals and mariculture activities almost always are

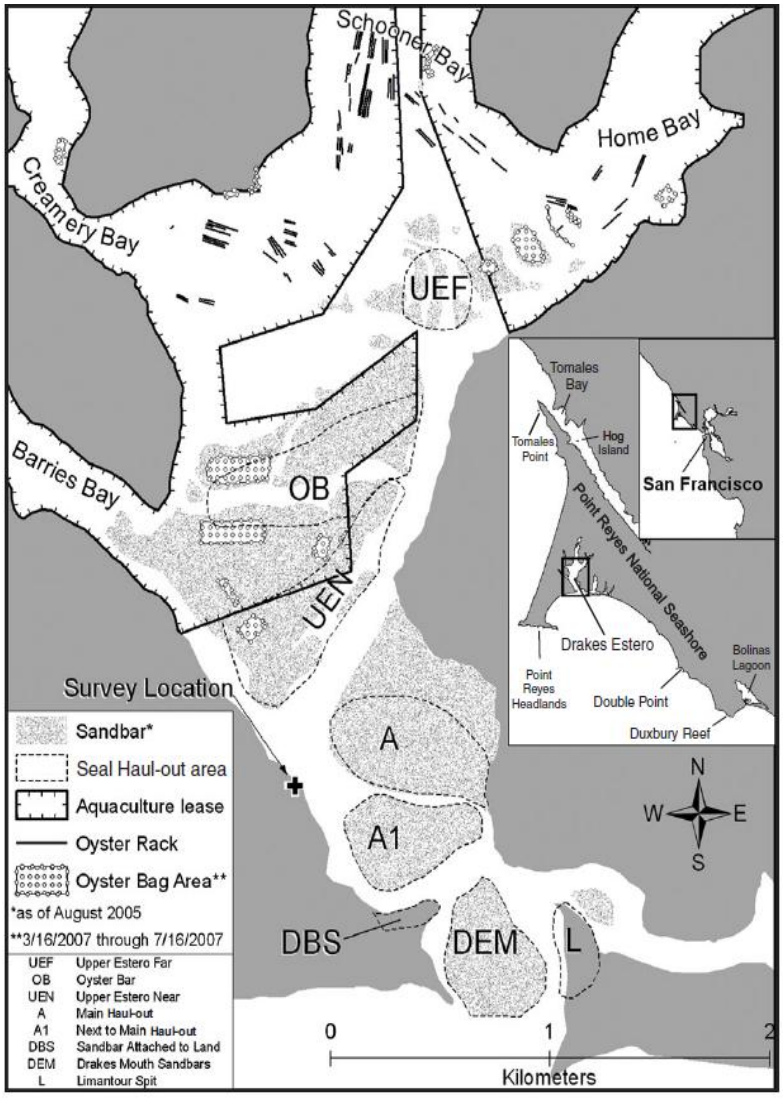


Figure 16. Figure 1 of Becker et al. (2011) depicting the relationship between mariculture activities and harbor seal haulout areas in Drakes Estero

separated by a considerable distance—hundreds of meters. Still, as noted earlier in this report, the observed separation does not provide a basis for distinguishing between two competing hypotheses, one being that the separation is sufficient to ensure that the seals are not disturbed or displaced and the other being that the seals are, in fact, disturbed by the activity and are avoiding the areas where mariculture occurs; that is, they have been displaced from parts of their habitat.

Figure 17. Figure from the National Park Service showing seals hauled out near mariculture material

A number of historical maps include markings intended to identify haulout areas that seals have used in the past (Figure 18). Those maps are not entirely consistent and, with one notable exception, it is difficult to determine their accuracy. The exception is a map showing markings made by Mr. Tom Moore (California Department of Fish and Game, retired) on May 20, 1991, to document his observations in the estuary (Figure 19). Specifically, Mr. Moore drew a circle on his map near bed #17 (Figure 19a) and recorded "1330 25." Because the map was used to record seal counts and included similar notations at other haulout sites, it is reasonable to interpret that note as indicating 25 seals counted at 1330. Mr. Moore's notes (Figure 19b) include the words: "1100 — ~ 1 2 doz mammals off point by [oyster bed] #17." Presumably this statement meant about 12 or a dozen seals, or it might have meant 1 to 2 dozen seals. In addition, in his notes, he wrote"#20 – good growth stake area – not a major haul-out," which suggests that seals hauled out around bed #20 at least periodically.

A number of arguments have been put forth that seals no longer use those areas because the lateral channel is too shallow or because it has filled in with eel grass. However, although such arguments may be reasonable hypotheses, they have not been confirmed scientifically. Again, the existing information is not sufficient to determine if the seals would use those areas in the absence of mariculture activities.

For the above reasons, the Marine Mammal Commission does not believe that the available information is sufficient to confirm or refute the possibility that the seals are using only a portion of their available habitat in the estuary.

4.3 SELECTIVE USE OF DATA

The authors of Becker et al. (2011) have been accused of selectively using only National Park Service data in their analyses, but that is not the case. Their use of annual oyster harvests clearly illustrates their use of data from outside the Service. They also used photographs from multiples sources (e.g., Google Earth) for their analysis of mariculture acreage.

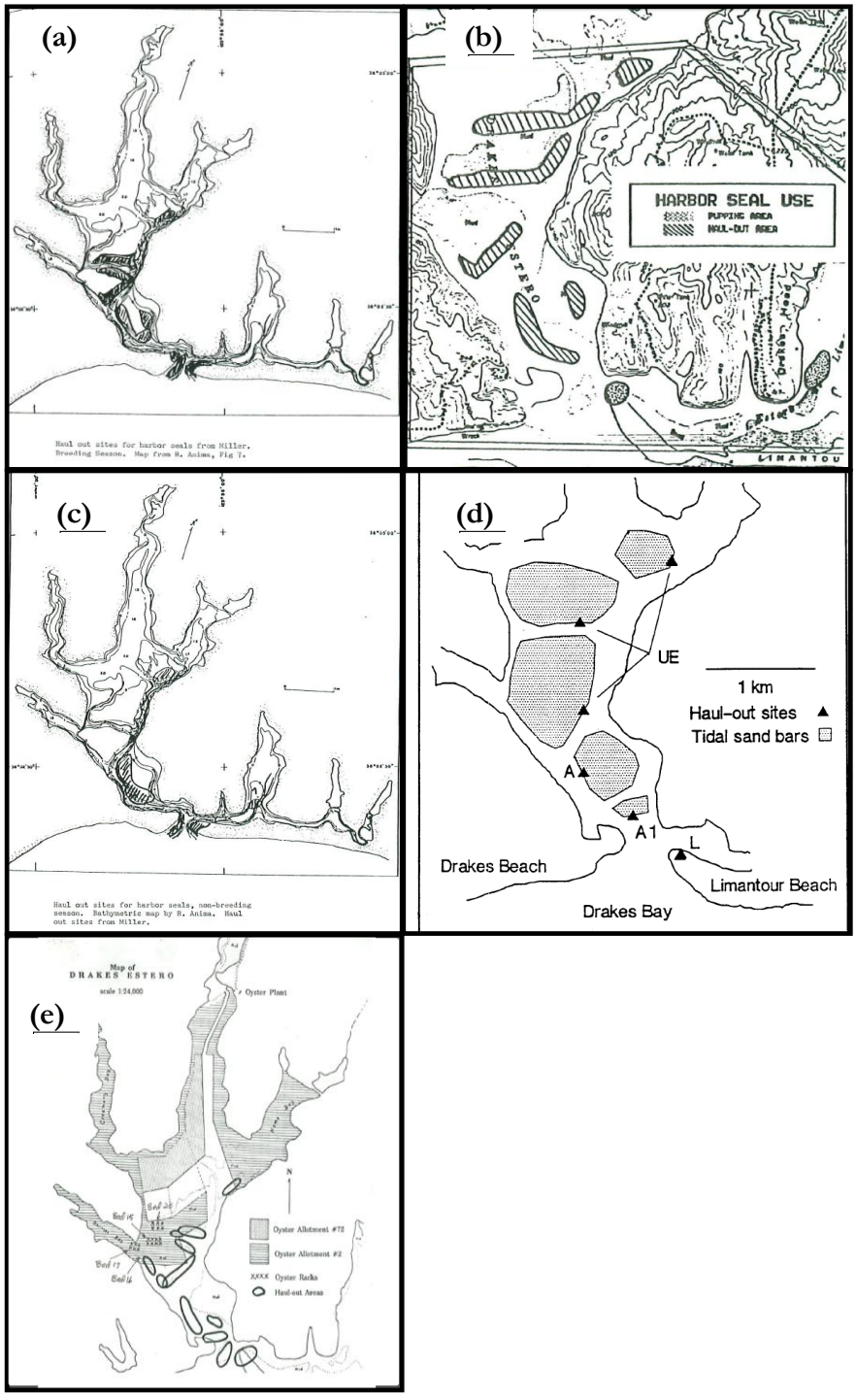


Figure 18. Various maps of harbor seal haulout sites in Drakes Estero. All maps are available on the Commission's website: (a) and (c) are attached to a 19 September 1991 letter from J. Sansing to B. Hunter, (b) is attached to a case incident report filed on 30 April 1989 (dated 9 December 1991 on Commission's website), (d) is from S. Allen's M.S. Thesis (dated 31 December 1988 on Commission's website), and (e) attached to a 15 May 1992 letter from B. Hulbrock to J. Sansing

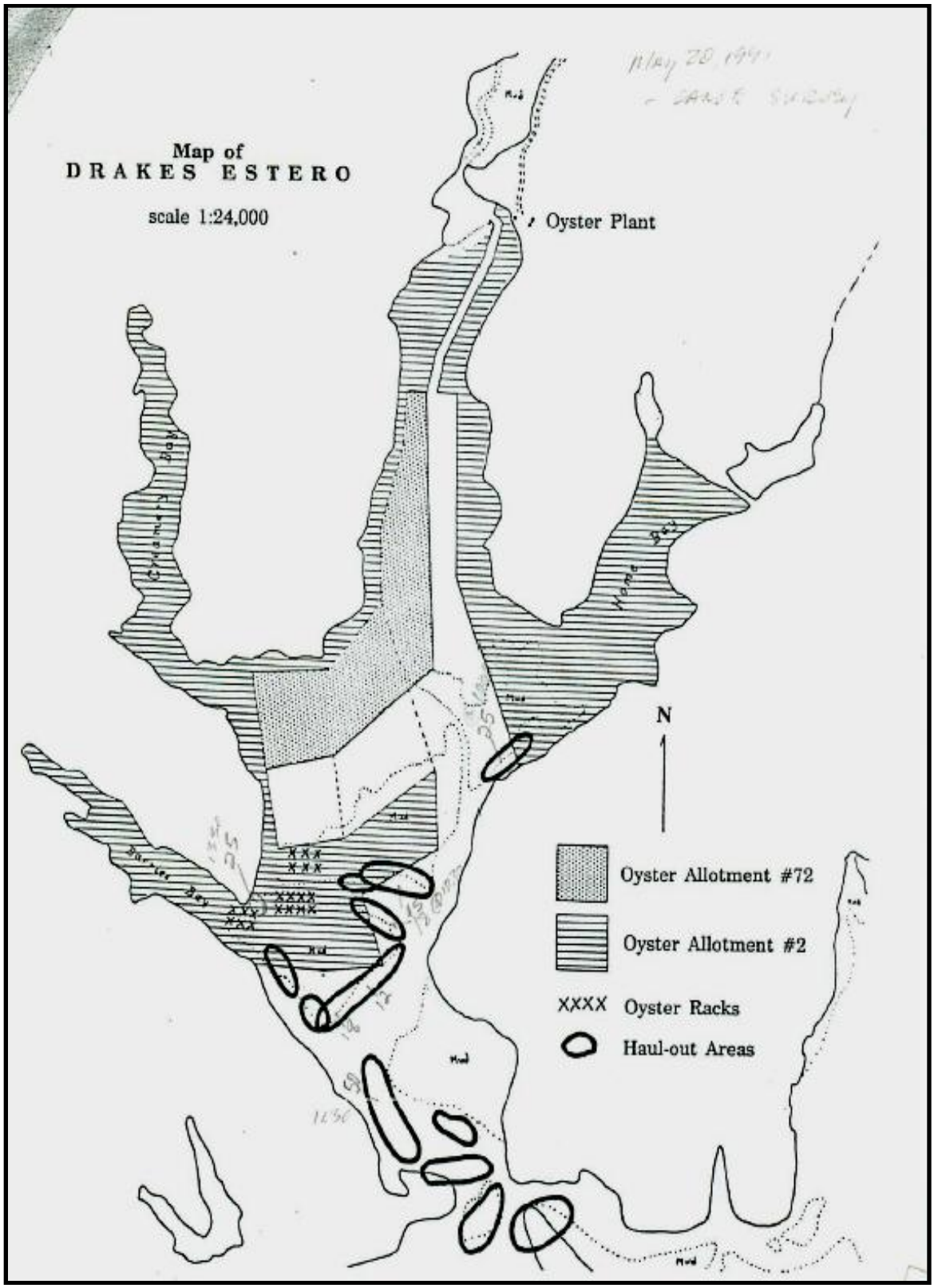
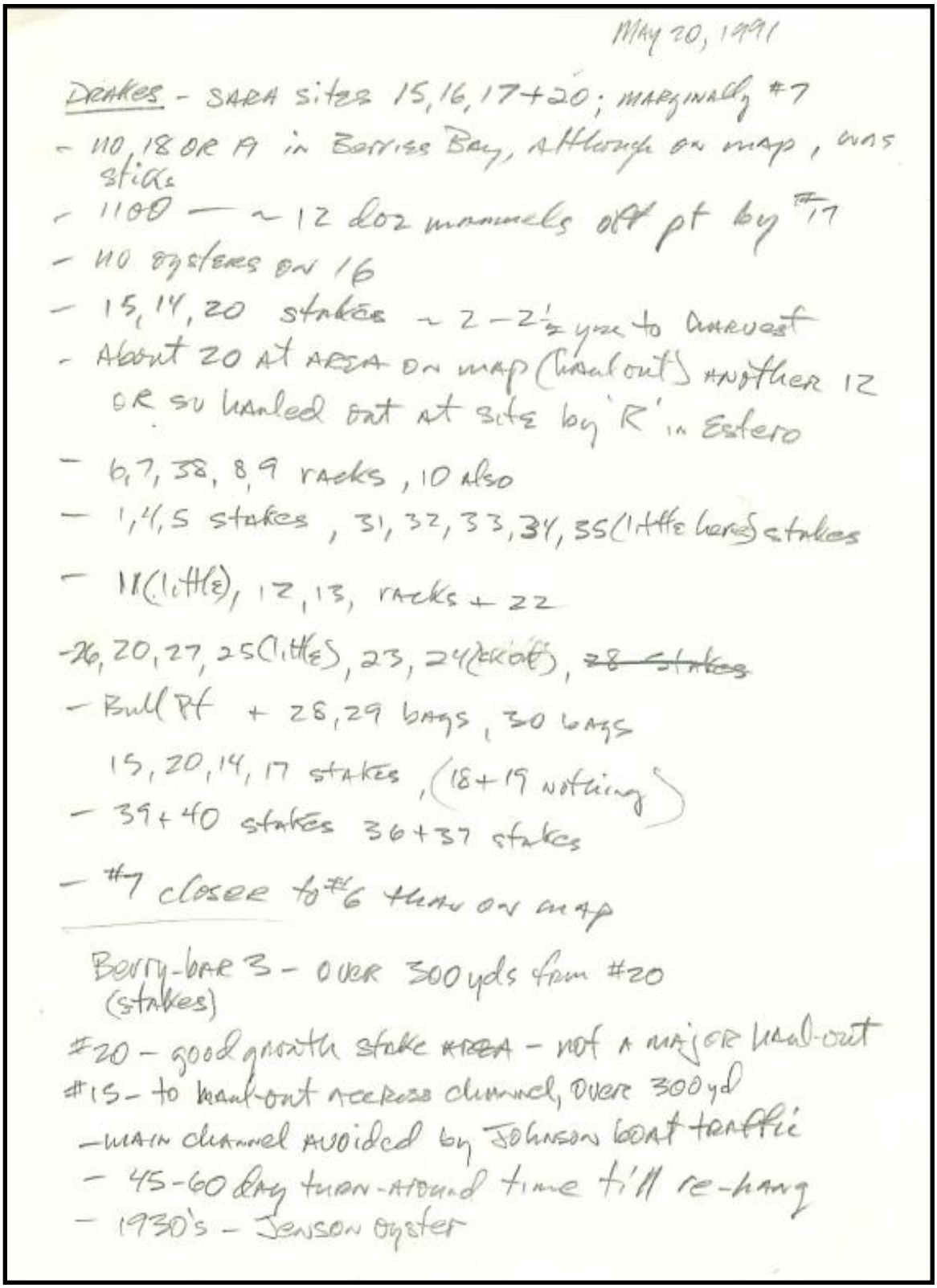


Figure 19a. Map used by Mr. Tom Moore of the California Department of Fish and Game on 20 May 1991 to document counts of harbor seals at various sites in Drakes Estero



May 20, 1991

Drakes - SARA sites 15, 16, 17+20; marginally #7
- 110, 18 OR 19 in Barries Bay, although on map, was sticks
- 1100 — ~ 12 doz mammels off pt by #17
- 110 oysters on 16
- 15, 14, 20 stakes ~ 2 – 2½ yrs to harvest
- About 20 at AREA on map (haul out) another 12 or so hauled out at site by 'R' in Estero
- 6, 7, 38, 8, 9 racks, 10 also
- 1, 4, 5 stakes, 31, 32, 33, 34, 55 (little bare) stakes
- 11 (little), 12, 13, racks + 22
- 26, 20, 27, 25 (little), 23, 24 (kelp), ~~28 stakes~~
- Bull Pt + 28, 29 bags, 30 bags
  15, 20, 14, 17 stakes, (18+19 nothing)
- 39+40 stakes 36+37 stakes
- #7 closer to #6 than on map

Berry-bare 3 – over 300 yds from #20 (stakes)

#20 – good growth stake AREA – not a major haul-out
#15 – to haul-out accross channel, over 300 yd
– main channel avoided by Johnson boat traffic
– 45-60 day turn-around time till re-hang
– 1930's – Jenson oyster

Figure 19b. Notes accompanying the map used by Mr. Moore

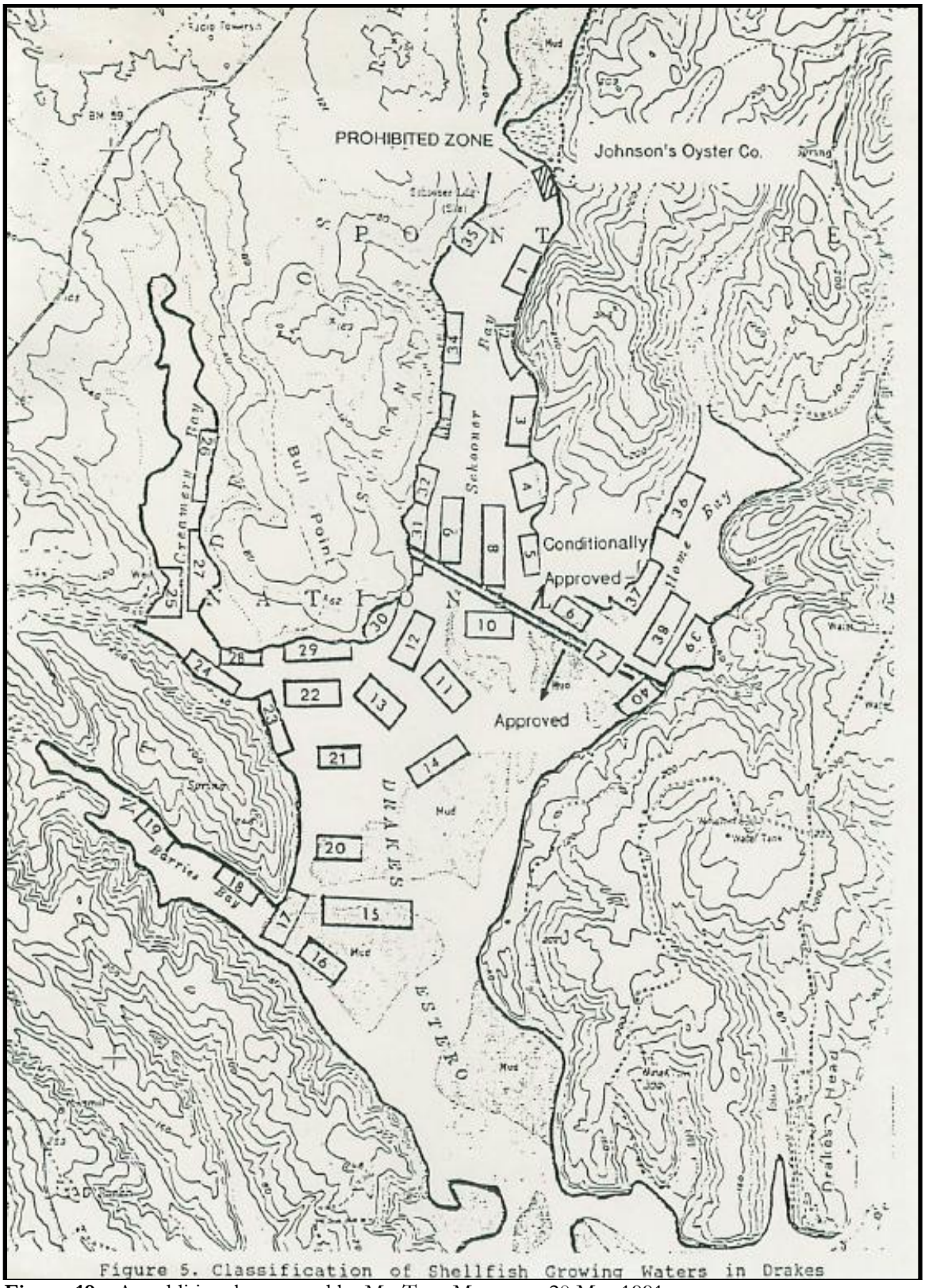


Figure 19c. An additional map used by Mr. Tom Moore on 20 May 1991

The authors also have been accused of "cherry picking" by including data from 1982 and 1983 in their analyses of factors influencing harbor seals' use of (1) Drakes Estero versus other Point Reyes haulout sites and (2) UEN, OB, and UEF within Drakes Estero. "Cherry picking" refers to the selective treatment of specific data, usually because of the influence of individual data points on the outcome of a particular analysis. The arguments for excluding 1982 and 1983 were put forth by Dr. Goodman (Appendix K) as follows:

(a) The Park Service did not use them in the Becker et al. (2009) paper and, when asked about additional data, were not aware that any other data existed;
(b) The data are separated by 13 years from the 1997-2009 data used in the report;
(c) The data from 1982 and 1983 are based on fewer counts; and
(d) The data occurred before the 1992 management agreement and 1996 change in management of kayaks.

The Park Service offered the following justification for using the 1982 and 1983 data points.

(a) There is no reason to believe that seals would behave differently in the 1980s versus 1997-2009.
(b) All regional colonies were being used at that time and mariculture harvest was similar to current levels.
(c) The regional and Drakes Estero populations were very near levels seen during the rest of the time series (see Becker et al. 2011, Fig. 2).
(d) The within-Drakes Estero analysis involved 21 years of data including multiple years both before and after the 1992 boating agreement on lateral channel closure of boats during the pupping season; the analysis of the effect of that 1992 agreement indicated a counterintuitive association of fewer pups in the upper estuary after the agreement (Becker et al. 2011, p. 9, paragraph 2). Thus, there is no evidence that the 1992 agreement improved conditions for mothers and pups in the upper estero.
(e) There is no reason to exclude these years due to a gap in the time series since the GLM analysis is not dependent on serial correlation and *year* was never an important covariate (Becker et al. 2011).
(f) Becker et al. (2011) included these years *a priori* in the first analysis.

Becker et al. (2011) included the 1982 and 1983 data in response to criticisms that the time period analyzed in Becker et al. (2009) was too short. In response to that criticism, the analysts incorporated data from outside the Service's database—that is, from records collected for the Point Reyes Bird Observatory. They added data not just from 1982 and 1983, but also from 1986, 1987, 1989, 1991, 1992, and 1993. They were not able to use all of these data in every analysis conducted in Becker et al. (2011) because they do not have data indicating regional seal numbers for the years from 1984 to 1996. However, they were able to use the intermittent data from 1986 to 1993 with a portion of the explanatory variables in the analysis of factors affecting within-colony dynamics.

Selective treatment can involve the addition or removal of data if the reason for either course is simply to influence the outcome of an analysis. Any data point used in an analysis should be determined in advance based on its inherent properties rather than its potential influence. A data point might be reasonably excluded if, for example, it was collected by a different process or under different conditions. When dealing with a temporal series of numbers such as is involved here, any arguments to exclude these data should be based on evidence that the data deviate in some fundamental way that is not addressed in the analysis.

The Commission does not agree that data from 1982 and 1983 necessarily should be excluded from the analyses based on the arguments put forward. Although it might have been best if the authors had included all these data points in the original analysis, none of the criticisms related to their use in the 2011 analysis justify their exclusion based on any inherent and demonstrable problems with the data. However, as described below, the Commission asked the Park Service to rerun certain analyses with and without those data for the purpose of exploring their relative influence on the results in Becker et al. (2011).

As a related matter, the authors also have been accused of falsely implying three decades of evidence for spatial displacement. The criticism has been based primarily on an apparent data gap of 14 years between 1983 and 1997. However, that criticism ignores the fact that in its second round of analysis of within-colony dynamics, Becker et al. (2011) also used data from 1986, 1987, 1989, 1991, 1992, and 1993. Thus, at least for one analysis within Becker et al. (2011) that 14-year data gap does not exist and the data series span a period from 1982 to 2009, inclusive, a total of 28 years.

Critics also have suggested that data from 2003 and 2004 should be excluded from the analysis because of the disruption of the Double Point colony in 2003. An alternative approach, which the Commission believes is more appropriate, is to retain those years in the analysis but model them to reflect a large-scale, disruptive event in 2003 with rapidly declining influence thereafter. The results of such an approach are provided in section 4.5 below.

4.4 FAILURE TO ACKNOWLEDGE ALTERNATIVE MODELS

At the urging of Drakes Bay Oyster Company and Dr. Corey Goodman, the Marine Mammal Commission coordinated a review of the statistical approaches used in Becker et al. (2011). The review was structured to allow the Company and Dr. Goodman to select a statistician, the National Parks Conservation Association and Save our Seashore to choose a second statistician, and the Marine Mammal Commission to select a third. The intent of the review was to allow the statisticians to judge the reasonableness of the statistics used by the Park Service in Becker et al. (2011). The three reviews are provided in Appendices J to L.

Dr. Goodman conducted the analyses on his behalf and that of Drakes Bay Oyster Company. He did so based, in part, on guidance from two additional statisticians. His approach was to use simple linear regression for testing a broad suite of explanatory variables, and then to rank those variables using their P values and r^2 values adjusted for the number of variables, or R_{adj}^2. He reported that he identified a number of models with far more explanatory power (i.e., much lower P values and much higher R_{adj}^2 values). The

Table 7. Top 12 models (i.e., combinations of explanatory variables) tested by Dr. Corey Goodman to explain the proportion of Point Reyes pups found in Drakes Estero. DP = Double Point

Rank[a]	In Becker et al. (2011)	Explanatory variables	*P* value	R_{adj}^2
1	No	DP pups + total regional seals + '92 protocols	0.00001	0.87357
2	No	DP pups + total regional seals	0.00003	0.79850
3	No	DP proportional pups	0.00002	0.74851
4	No	DP pups + total regional pups	0.00011	0.74453
5	No	DP seals + total regional seals	0.00023	0.71156
6	No	DP proportion seals	0.00033	0.61526
7	No	DP pups + OYST High/Low	0.00330	0.54992
8	No	DP pups + '92 protocols	0.00375	0.54016
9	No	Total regional seals	0.00428	0.43832
10	No	DP pups + OYST annual harvest	0.00854	0.47256
11	Yes	OYST High/Low + DP seals	0.01474	0.42230
12	Yes	OYST High/Low	0.04680	0.21456

[a] In the same sequence but renumbered here

explanatory variables for his top 10 models used to analyze regional haulout patterns and the top 2 models from Becker et al. (2011), their P values, and R_{adj}^2 values are as listed in Table 7.

However, it is difficult to compare Dr Goodman's results with those of the Park Service for two reasons. The purpose of this type of statistical analysis is to determine if a relationship exists between a dependent variable (in the above cases the proportion of Point Reyes pups found in Drakes Estero), and the various combinations of independent or explanatory variables listed above. First, the dependent and "independent" variables he used in numerous models, including his top models, have a built-in dependency—that is, the dependent variable also occurs as part of one of the explanatory variables. This means the regression results are artificially linked and inflated, and much more likely to appear "significant" using superficial statistical tests that do not account for this built-in dependency. The "adjusted R-squared" procedure used by Dr. Goodman does not account for this built-in dependency. Figure 20 illustrates that dependence by expanding the explanatory variables in Dr. Goodman's top six regression models. Second, he used explanatory variables that also are linked. For example, his top two models include the explanatory variables Double Point (i.e., DP) pups and total regional seals. However, the number of Double Point pups also is used in calculating the total regional seals.

Dr. Dominique Richard's review (Appendix L, conducted on behalf of the National Parks Conservation Association and the Save Our Seashore) supported the analyses and results of Becker et al. (2011). He found that (1) the overall approach taken was reasonable and consistent with established and appropriate statistical methods, (2) the results support the hypothesis of an inverse correlation between annual oyster harvest and seal haulout patterns within Drakes Estero, and (3) that the results in Becker et al. (2011) supersede those of Becker et al. (2009).

Models to explain the proportion of pups in DE

1) Explanatory variables: DP pups plus total regional seals plus '92 protocols

$Pups_{DE}/Pups_{Reg} = Pups_{DP} + Seals_{Reg} + 92$

$Pups_{DE}/Pups_{Reg} = Pups_{DP} + (Adults_{Reg} + Pups_{notDE} + Pups_{DE}) + 92$ (expand $Seals_{Reg}$)

2) Explanatory variables: DP pups plus total regional seals

$Pups_{DE}/Pups_{Reg} = Pups_{DP} + Seals_{Reg}$

$Pups_{DE}/Pups_{Reg} = Pups_{DP} + (Adults_{Reg} + Pups_{notDE} + Pups_{DE})$ (expand $Seals_{Reg}$)

3) Explanatory variables: DP proportional pups

$Pups_{DEprop} = Pups_{DPprop}$

$Pups_{DEprop} = Pups_{DE}/Pups_{Reg}$ and $Pups_{DPprop} = Pups_{DP}/Pups_{Reg}$ (note)

$Pups_{DP} = Pups_{Reg} - Pups_{notDP,\ notDE} - Pups_{DE}$ (note)

$Pups_{DE}/Pups_{Reg} = (Pups_{Reg} - Pups_{notDP,\ notDE} - Pups_{DE})/Pups_{Reg}$ (substitute)

$Pups_{DE}/Pups_{Reg} = 1 - (Pups_{notDP,\ notDE}/Pups_{Reg}) - (Pups_{DE}/Pups_{Reg})$ (simplify)

4) Explanatory variables: DP pups plus total regional pups

$Pups_{DE}/Pups_{Reg} = Pups_{DP} + Pups_{Reg}$

$Pups_{DE}/Pups_{Reg} = Pups_{DP} + (Pups_{notDE} + Pups_{DE})$

5) Explanatory variables: DP seals plus total regional seals

$Pups_{DE}/Pups_{Reg} = Seals_{DP} + Seals_{Reg}$

$Pups_{DE}/Pups_{Reg} = (Adults_{DP} + Pups_{DP}) + (Adults_{Reg} + Pups_{Reg})$

$Pups_{DE}/Pups_{Reg} = (Adults_{DP} + Pups_{DP}) + (Adults_{Reg} + (Pups_{notDE} + Pups_{DE}))$

6) Explanatory variables: DP proportional seals

$Pups_{DE}/Pups_{Reg} = Seals_{DP}/Seals_{Reg}$

$Pups_{DE}/Pups_{Reg} = Seals_{DP}/(Adults_{Reg} + Pups_{notDE} + Pups_{DE})$

Figure 20. Statistical models (single or combined explanatory variables used by Dr. Corey Goodman to explain the proportion of regional pups in Drakes Estero. The models are confounded because terms in the dependent variable are also part of the independent variable; thus, the models have a built-in dependency. (DE = Drakes Estero; DP = Double Point; Reg = Regional; notDE = not at DE; notDP = not at DP; notDP,notDP = not at DP or DE)

The Commission selected Dr. John Harwood to review the statistics underlying Becker et al. (2011). The major points of Dr. Harwood's review (Appendix M) are as follows.

- Becker et al. (2011) provides "convincing evidence that the proportion of harbour seals and pups counted at the three haul-out sites closest to oyster cultivation in Drakes Estero was lower in years of high oyster production."

- There is some evidence that the proportion of the Point Reyes harbor seal population using Drakes Estero was also lower in years when oyster production was high.
- However, "…the effect of natural disturbance caused by the presence of an aggressive elephant seal at a neighboring colony (Double Point) on the proportion may have been underestimated." He recommended modeling the disturbance at Double Point "in exactly the same way as the 1998 ENSO event: a fixed effect (whose size is estimated by the appropriate coefficient in the GLM) in 2003, whose influence declines exponentially over time."
- "The result may also be sensitive to the exclusion of two data points from the early 1980s that are separated from the rest of the time series by an interval of 13 years." He believes that the use of these two data points needs to be justified. The robustness of the regional results to the 1982 and 1983 data points and the way in which natural disturbance at Double Point is modeled should be investigated.
- The proportion of pups counted in Drakes Estero and the proportion of seals should not be considered as separate time series because the number of pups and their mothers are included in the number of total seals.
- The proportion of all other seals (immature animals, adult males, non-breeding adult females) counted in Drakes Estero does not appear to be related to the level of the oyster harvest.
- The method of estimating the proportion of seals that may have been affected by mariculture is reasonable but the multiplier used to convert that proportion to an estimate of total seals affected is questionable.
- The use of maximum counts for the regional analysis may not be appropriate because more counts were conducted in Drakes Estero and the maximum count is likely to increase with an increasing number of counts.
- With the above exceptions, the statistical approaches generally appear to be appropriate (he did not attempt to reproduce them).
- "[T]hese changes [a doubling in the number of immature, adult male and non-breeding adult females counted in all the Point Reyes colonies between 1999 and 2004, followed by a sharp fall] in the structure and distribution of the Point Reyes population occurred at exactly the same time as the sharp decline in the size of the oyster harvest. It is very difficult to disentangle the effect of these different factors using simple covariates (such as the number of seals counted at Double Point, or the total number of seals at other colonies) in a linear model."
- Finally, based on the preceding concern, an alternative state-space model approach may be more effective at incorporating the biology underlying this issue.

4.5 ADDITIONAL ANALYSES REQUESTED BY THE COMMISSION

During the course of this review, a number of questions were raised that warrant closer investigation. To address those questions, the Commission requested that the Park Service conduct a number of additional analyses. The following results are from additional exploratory analyses and should not be considered final. However, they may provide insights useful for guiding future studies.

Modeling the loss of haulout site A on within-colony dynamics:

The loss of haulout site A meant that a number of seals that previously used that site had to move either to other sites within the estuary or to other colonies outside the estuary (or possibly farther). Within the estuary, the movement of those seals may have altered significantly the distribution of seals between the upper (UEN, OB, and UEF) and lower haulout sites. The Commission requested this analysis to provide a basis for judging that possible effect.

The Park Service ran the analysis using 21 years of data and the generalized estimating equations statistical model. The analysis included ENSO and Oyster (high/low) effects, which were identified in Becker et al. (2011) to constitute the best model. The results were as follows:

Table 8. Results from an analysis of the effects of losing haulout site A on the distribution of seals at other sites within Drakes Estero

Coefficients	Estimate	Standard error	P value
Intercept	0.923	0.411	0.025
ENSO	0.494	0.196	0.012
Oyster High/Low	-0.453	0.207	0.028
Subsite A	1.374	0.535	0.010

These results indicate that all three factors may have contributed to seal haulout patterns within the estuary (i.e., all P values < 0.05) This outcome can be interpreted several ways. First, they could be used to infer that the movement of seals from haulout site A caused only an apparent reduction in the proportion of seals using the upper haulout sites. If many of the seals from haulout site A moved to other sites in the lower part of the estuary, an analysis of proportions might falsely indicate a reduction in the use of the upper estuary when, in fact, it might have been an increase in the use of the lower estuary. An alternative analysis would be that the loss of haulout site A did have a significant impact on the relative distribution of seals between the upper and lower estuary sites, but oyster high/low also may have had an important influence. The results do not provide a basis for distinguishing between these two hypotheses.

Modeling of Double Point as an abrupt event with rapidly diminishing effects:

Dr. Harwood's review (Appendix M) suggested that the Park Service might better model the effects of the Double Point elephant seal as either an exponentially and logarithmically diminishing effect from 2003. The Park Service conducted this analysis using a simple quasi-binomial generalized linear model to assess overdispersion, which it found to be greater for the exponential (3.2) than the logarithmic (1.9) fit. The Service also suggested that on biological grounds (i.e., harbor seals age of first breeding is 3-5 years) the more dampened logarithmic change seemed a more appropriate approach than the rapid decline of an exponential model.

The Service then compared models using years since the Double Point disturbance (log and exp models) with models using years since the Double Point disturbance (log model) and oyster (either oyster high/low or continuous).

The results indicate that a combination of oyster (high/low) and an abrupt and logarithmically decaying influence of the Double Point elephant seal best explain (lowest QAICc and highest r^2) the regional distribution of seals. The Park Service concluded that the approach suggested by Dr. Harwood gave better results, but that measures of oyster harvest also improved the model, whether in the binary high/low or continuous form.

Table 9. QAICc ranking of models with exponentially decaying function for Double Point

Model	QAICc	ΔQAICc	r^2
Oyster (High/Low) + log(Double Point.yrs)	81.3	0.0	0.83
Oyster (continuous)+ log(Double Point.yrs)	84.1	2.8	0.78
Log(Double Point.yrs)	84.7	3.4	0.72
Exp(Double Point.yrs)	88.2	6.9	0.67

Using a rapidly decaying effect for Double Point and mean counts to assess the effects of removing 1982 and 1983 data:

To explore the influence of count data from 1982 and 1983 the Commission asked the Park Service to conduct two analyses similar in all regards except the inclusion of those data. The Commission requested that the Park Service use a rapidly decaying effect for the 2003 event at Double Point and run the analyses using the mean values of daily maximum counts, rather than the maximum counts as were used in Becker et al. (2011). The Commission made this request because it considers the mean counts to be a better, more stable indicator of haulout patterns. The results are listed in Table 10.

The best models as indicated by these exploratory analyses (lowest AICc and highest r^2 values) continue to support the hypothesis that oyster harvest (particularly oyster high/low) is at least correlated with seal use of the different haulout sites within Drakes Estero. The results also suggest that the 1982 and 1983 data do not have an overriding effect on this apparent relationship.

5.0 DISCUSSION AND SUMMARY

The terms of reference for this review indicated that the Commission would (1) use the best available scientific information regarding human impacts on harbor seals in the estuary; (2) evaluate the strengths and weaknesses of those data, including information gaps, and (3) recommend research and management activities to reduce scientific uncertainty and ensure the protection of harbor seals and their habitat.

To the Commission's knowledge, it has reviewed and used the best available scientific information regarding human impacts on harbor seals in the estuary. That does not mean that the data are fully adequate—both the Park Service and the Drakes Bay Oyster Company

Table 10. Comparison of results with and without 1982 and 1983 data based on a model including a rapidly decaying event at Double Point in 2003 and mean peak reproductive season counts. The Service conducted the analysis using simple linear regression ranked by Akaike Information Criterion adjusted for small sample sizes. (H/L = high/low)

With 1982, 1983				Without 1982, 1983			
Model	**AICc**	**ΔAICc**	**r^2**	**Model**	**AICc**	**ΔAICc**	**r^2**
Regional population + oyster (H/L)	211	0	0.57	Oyster (H/L)	182	0	0.42
Oyster (H/L)	212	1	0.42	Exp(Double Point event) + oyster (H/L)	184	2	0.48
Exp (Double Point event) + oyster (H/L)	214	3	0.47	Regional population + oyster (H/L)	185	3	0.44
Year	214	3		Oyster continuous	187	5	
Regional population	215	4		Exp(Double Point event)	187	5	
Oyster continuous	217	6		Double Point counts + oyster continuous	187	5	
Regional population + oyster continuous	217	6		Regional population	188	6	
Log (ENSO)	217	6		Log(ENSO)	188	6	
Log (Double Point event)	218	7		Log(Double Point event)	188	6	
Exp (Double Point event)	218	7		Double Point counts	188	6	
Log (Double Point event) + oyster continuous	218	7		Year	189	7	
Double Point counts + oyster continuous	219	8		Log(Double Point event) + oyster continuous	190	8	
Double Point counts	220	9		Regional population + oyster continuous	191	9	

are aware of data gaps and uncertainties that confound both the study and management of the estuary. Unfortunately such problems are common in most, if not all, U.S. coastal waters. In such cases, analysts must use the best available data and managers must incorporate the uncertainties into their decision-making processes.

In the Commission's view, the information examined during the course of this review is sufficient to conclude that, from time to time, mariculture activities in the estuary do disturb harbor seals. The Commission also believes that the data provide reasonable evidence[9] of a correlation between mariculture activity and seal haulout use, but that evidence is not sufficient to conclude causation.

[9] The term "evidence" has added to the controversy surrounding this issue. The Commission does not believe that the Service used this term in the title of the Becker et al. (2011) paper to mean "proof" of displacement, but rather to mean "information that supports the hypothesis of displacement." Such use would be entirely consistent with scientific custom. For example, the term "weight of evidence" is often used to mean consideration of the relative strengths of information supporting opposing hypotheses.

5.1 DATA STRENGTHS AND WEAKNESSES

The Commission views the strengths and weaknesses of the existing data to be as follows.

- The seal counts provide a good indication of (1) the number of seals using estuary haulout sites, the estuary in general, and neighboring sites. These counts should be continued, as they are central to monitoring the status of the population and changes that may occur as a result of both natural and human-related factors. The Park Service and volunteers should be commended for compiling these count data.
- The disturbance records indicate that disturbance occurs, but the records are not an adequate basis for determining the frequency and nature of such incidents or their significance to the Drakes Estero population of harbor seals. The information collected about disturbances sources is often based on the assumption that all boats seen in the estuary are engaged in mariculture activities. That may not always be the case. At least this source of uncertainty could be resolved by marking all mariculture boats and workers so that other visitors cannot be mistakenly assumed to be engaged in mariculture activities. This is a simple solution that could be implemented easily through cooperation between the Park Service and Drakes Bay Oyster Company.
- Observer notes often were incomplete and should be expanded to include a basis for statements about sources and activities thought to have caused disturbances. Such descriptors provide helpful information for analysts who need to use the disturbance dataset but must understand its reliability before doing so.
- The photographs of the estuary taken by automated cameras should be reviewed to assess their value based on (1) whether they indicate disturbance and (2) whether they are sufficient to detect disturbances if and when they occur. As indicated above regarding the reported disturbances on 8 May 2007 and 14 March 2008, the photographs should be assessed for such things as range of view, sufficient clarity to identify persons or objects within the photographs, and the need to interpret activity between photographs. The photographs documented boats in the estuary, but the presence of boats has not been in question. Handheld photographs and videos taken by monitors might be more useful for documenting disturbance. However, such photographs would still have to be of good quality to be useful. Marking boats and field workers should improve the utility of such photographs.
- If, with regard to harbor seals, the overriding intent is to reduce disturbances and displacement, then observers should immediately bring disturbances to the attention of the Park Service, which then should bring them to the attention of the Drakes Bay Oyster Company. If so informed, the Park Service and the company have the opportunity to evaluate and adjust activities as appropriate.
- Observations of seal mortality in the estuary are important for a variety of management-related reasons, and mortality events should be characterized and evaluated as they occur.
- Intermittent aerial photographs or images of the estuary are helpful for identifying mariculture effort on certain tidal flats, but the amount of information gained will generally be limited to identification of the areas involved and estimation of their approximate extent. If aerial images could be obtained with greater resolution, they could be useful in characterizing seal habitat use patterns.

5.2 MAJOR DATA GAPS

The issue of potential mariculture effects on harbor seals has been confounded not only by problems with existing data, but also by the lack of certain key data types. The Commission considers the four major information gaps to be as follows.

(1) If this matter is to be resolved constructively, then the Park Service and the Drakes Bay Oyster Company must work together to develop an accurate quantification of mariculture activities that are plausibly related to disturbance. Such an assessment is essential to (a) determine if, and if so, the extent to which mariculture activities are causing disturbance and displacement and (b) identify means to avoid such effects. The assessment must account for boat activities, human activities, and the presence of equipment. It must be based on the various growing methods used and their differences with regard to tending, location, and season.

(2) The haulout patterns and habitat uses and needs of harbor seals within the estuary also must be evaluated. This would require an adaptive management approach that adjusts mariculture effort in different parts of the estuary to allow seals to select their habitat in the absence of disturbance. These data are needed to determine whether the measures in the 1992 agreement are or are not effective and sufficient and whether the protection zone established by the California Coastal Commission is or is not needed.

(3) The tolerance of seals for disturbance and the biological significance of such disturbance should be evaluated. At present, indicators of disturbance are defined as ranging from head alerts to flushing into the water. The existing information is not sufficient to describe the biological consequences or reactions at either end of this continuum. For example, head lifts may well be of little meaning in this case. If a seal raises its head to assess a potential threat, whether detected by sight or hearing, and then simply returns to resting, it is not clear that such an act has biological significance. Alternatively, if a seal flushes into the water but is not or cannot be tracked after that, it may return to its resting area in a matter of minutes, or it may leave the haulout site altogether. It would be helpful to have better information about how disturbance affects the behavior of seals subsequent to the disturbance itself. In conducting such assessments, it will be necessary to take into account the fact that all seals will not react in the same manner; that is, some seals may tolerate certain levels of human activity in the estuary while other seals may have less tolerance for such activity and will abandon the area.

(4) Other sources of disturbance and displacement also should be investigated to assess their impact on harbor seals in the estuary. As indicated in Figure 9, reported disturbance attributed to mariculture comprises only a small fraction of the total disturbance of seals occurring in the estuary. Hikers, kayakers, horseback riders, aircraft, and other sources also may be affecting the seals and those effects may increase as human populations grow and use of the Point Reyes National Seashore increases. Understanding the effects of these other activities is required to assess the combined impacts of human activities on harbor seals and their use of the estuary.

5.3 RECOMMENDED RESEARCH AND MANAGEMENT ACTIVITIES

The Park Service is responsible for informing the Secretary of the Interior about management alternatives for the estuary and, specifically, whether it should extend the current Reservation of Use and Occupancy and a Special Use Permit to Drakes Bay Oyster Company or convert the area to wilderness. In the Commission's view, either choice should be followed by careful monitoring. If the Secretary decides to complete the conversion to wilderness, then the harbor seal population should be monitored carefully to determine if and how it adjusts to the absence of mariculture. On the other hand, if the Secretary decides to renew the Reservation of Use and Occupancy and Special Use Permit issued to the Drakes Bay Oyster Company, then a cooperative adaptive management approach should be implemented to provide useful information about potential mariculture effects and means for addressing them.

The National Park Conservation Association and the Sierra Club asked the Marine Mammal Commission to comment on the application of the precautionary principle in this matter. The precautionary principle gives extra weight in favor of resource protection when the resource is subject to a threat of uncertain magnitude. This puts the burden of proof on decision-makers who might not be inclined to take protective action to demonstrate that the threat will not cause undue harm. The Commission is committed to a precautionary approach in its own decision-making, consistent with the statutory and regulatory standards of the Endangered Species Act and the Marine Mammal Protection Act. But in the present case, the population in question is not listed as threatened or endangered under the former or designated as depleted under the latter, and the Secretary of the Interior will make his decision on other grounds. Therefore, in this report the Commission's comments are confined to the science of evaluating the uncertainties, without recommending a corresponding standard of certainty that the Secretary should apply when weighing the risks and the costs of his decision.

Implementing an adaptive management approach is not a simple or trivial matter. To be successful, an adaptive management approach would have to be well conceived, adequately supported, and responsibly implemented by all parties involved. Most importantly, it would have to be based on getting at the truth, rather than having those with conflicting viewpoints seeking simply to win the debate. In this case, which has been so hotly contested, the Commission believes that such an approach must—

- Be guided by an independent steering committee consisting of scientists with relevant training and experience in mariculture, marine mammal ecology, experimental design, statistical analysis, and demographic modeling;
- Have an executive authority chartered to answer specific management-relevant questions and to report progress on resolving those questions at regular intervals;
- Be informed by representatives from the relevant government agencies, mariculture industry, conservation community, and the public at large;
- Develop and implement methods for mapping and characterizing the estuary habitat and the seals' use of that habitat with and without mariculture;

- Develop and implement methods for characterizing mariculture activity level in the estuary as a function of oyster growing method, location, and season;
- Devise and implement methods for marking or flagging all mariculture activity in the estuary so that it can be distinguished from other types of activity;
- Devise and implement methods for tracking all oyster-related watercraft in the estuary using global positioning system (GPS) technology;
- Evaluate the potential utility of an observer program for all mariculture activities;
- Develop and implement a means for assessing the sensitivity of harbor seals to various types of disturbance (e.g., boat activities, human activities on the tidal flats, the presence of bags, stakes, and lines) at various distances and locations, and during different seasons;
- Conduct periodic reviews of and revise accordingly the existing system for collecting data on harbor seal disturbance;
- Evaluate the efficacy of the measures included in the 1992 agreement and determine if any changes to the agreement are needed;
- Evaluate the utility and efficacy of the seal protection zone imposed by the California Coastal Commission;
- Evaluate whether disturbance can lead to long-lasting or permanent changes in haulout patterns;
- Evaluate the relative frequency and significance of other types of disturbance (e.g., kayakers, hikers, aircraft, researchers);
- Evaluate the occurrence and frequency of motorboats not related to mariculture in the estuary;
- Evaluate the potential for disturbance of harbor seals in the water;
- Evaluate the movements of harbor seals among the Point Reyes colonies;
- Evaluate baseline rates of survival and reproduction for seals that use Drakes Estero and the other Point Reyes colonies;
- Develop and implement measures to reduce the probability of disturbance and displacement, and evaluate their efficacy;
- Be guided by the development of a Bayesian, state-space model to incorporate all the above information into a single conceptual framework that can be used to guide management of the estuary.

The Marine Mammal Commission would be pleased to advise the Secretary of the Interior regarding the science needed to understand harbor seal use of the estuary following his decision.

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