# AT-SEA THREATS TO XANTUS' MURRELETS (*SYNTHLIBORAMPHUS HYPOLEUCUS)* IN THE SOUTHERN CALIFORNIA BIGHT

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## ABSTRACT

A large proportion of the small global population (<10,000-20,000 breeding individuals) of the Xantus' murrelet (*Synthliboramphus hypoleucus*) breeds and forages in the Southern California Bight (SCB) where murrelets face several potential at-sea threats, in addition to impacts at breeding colonies from predators. Using at-sea distribution from recent radio telemetry studies and other available information, we provide an overview of at-sea threats and their impacts in the SCB. From April to June in 1995 to 1997, radio-marked murrelets from Santa Barbara Island were distributed widely in the northwestern SCB, rarely using other regions. In June, these murrelets dispersed northward off the coast of central California. The main at-sea threat to murrelets in the SCB is oil pollution, especially: spills from tankers, oil platforms and pipelines in Santa Barbara Channel and off Point Conception; spills from tankers in marine traffic lanes near Santa Barbara Island and the Los Coronados Islands; and chronic oiling. The 1969 Santa Barbara *Platform A* oil spill probably had serious impacts on small murrelet colonies in the northern Channel Islands. Mortality from oil pollution has not been well established because of low potential for recovery of dead oiled murrelets.

**Keywords:** Xantus' murrelet, *Synthliboramphus hypoleucus*, at-sea distribution, seabird conservation, oil pollution, Southern California Bight, Channel Islands.

## INTRODUCTION

Within the Southern California Bight (SCB), the Channel Islands form the northern limit of the breeding range for Xantus' murrelets (*Synthliboramphus hypoleucus*) which also extends south to the San Benito Islands and Guadalupe Island off central Baja California, Mexico (Jehl and Bond 1975; Drost and Lewis 1995). Less than 10,000-20,000 breeding individuals may exist in the world (Drost and Lewis 1995; H.R. Carter, unpublished data). Small colonies are known on six of the eight California Channel Islands (excluding San Nicolas and Santa Rosa islands), as well as at the nearby Los Coronados Islands in Baja California (Figure 1). Santa Barbara Island (SBI) supports the largest known U.S. colony (750-1,500 pairs) but the colony at the Los Coronados Islands also supports significant numbers (325-1,125 pairs). In total, only 1,500-3,500 pairs nest in the SCB (Carter et al. 1992, 1996, 1997, unpublished data; Drost and Lewis 1995).

Xantus' murrelets are impacted at breeding colonies in California and Baja California by high levels of depredation of murrelet adults and eggs by introduced predators (e.g., black rats *Rattus rattus* and feral cats *Felis catus*) or native predators (e.g., deer mice *Peromyscus maniculatus* and barn owls *Tyto alba*) which has led to colony extirpations, reduction in colony size, or reduced breeding success (Murray et al. 1983; Drost and Lewis 1995; McChesney and Tershy 1998). Xantus' murrelet was earlier considered a candidate species for possible listing under the U.S. Endangered Species Act because of the small world population size, restricted breeding range, and known threats at colonies. It was recently designated as a Highest Priority Species at Risk by the Waterbird Society (Nettleship 1998). The Pacific Seabird Group formed the Xantus' Murrelet Technical Committee in 1994 to summarize available information on the species, assess threats to survival, and consider potential for listing. Most attention has focused on known colony threats

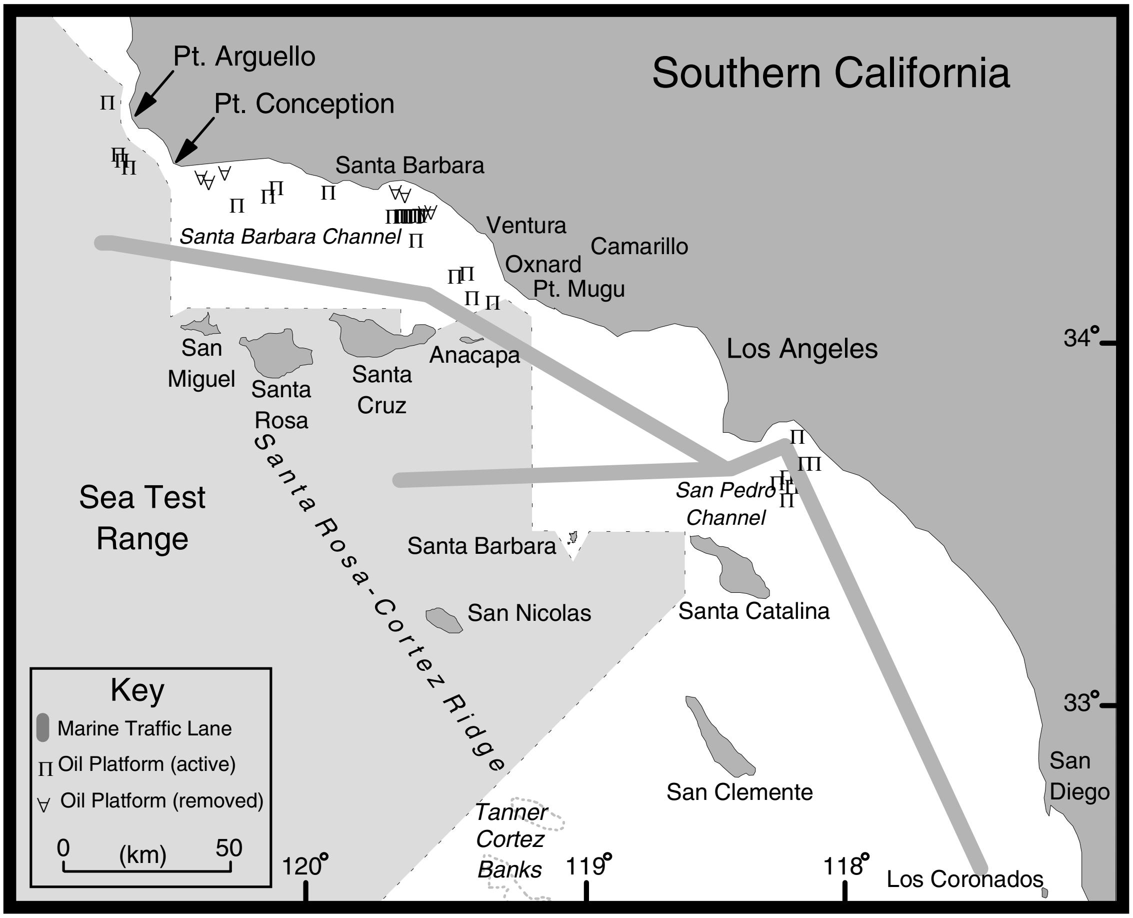


**Figure 1. Southern California Bight showing California Channel Islands, offshore oil platforms, sea test range, and marine shipping traffic lanes.**

but several potential at-sea threats exist in the SCB that have not been well evaluated.

The status of SCB murrelet populations is poorly known. Numbers at SBI in the 1970s may have increased since the turn of the century because of removal of introduced cats (Hunt et al. 1980; Drost and Lewis 1995). However, they may have declined more recently as a result of high levels of depredation and possibly other factors; a 1991 survey found lower numbers of murrelets than in the 1970s (Carter et al. 1992). Numbers at Anacapa Island appear to have been drastically reduced from rat predation and possibly oil and organochlorine pollution but some birds continue to nest in sea caves (Carter et al. 1997; H.R. Carter and G.J. McChesney, unpublished data).

In this paper, we provide an overview of recent research efforts by the U.S. Geological Survey (Biological Resources Division) and Humboldt State University, with cooperation by the U.S. Navy (Naval Air Warfare Center, Weapons Division) and the California Department of Fish and Game (Office of Spill Prevention and Response), to better assess potential at-sea threats to this species in the SCB. To integrate this overview with the limited previous research, we first provide a brief summary of known murrelet biology.

## MURRELET BIOLOGY

Breeding biology studies between 1975 and 1978 at SBI (Hunt et al. 1979, 1980; Murray et al. 1979, 1983) found that murrelets nest mainly in rock crevices, lay clutches of one to two eggs, visit nests nocturnally, exhibit long (48 to 72 hr) incubation shifts, have long incubation periods (27 to 44 d), exhibit egg neglect, hatch precocial chicks, and raise chicks at sea (after 2 d of brooding in the nest site). Murrelets exhibit several adaptations that reduce the period of time they must attend nests and permit long-distance foraging from colonies. Like other alcids, murrelets probably are relatively long-lived birds with high annual survival rates and low annual reproductive output and recruitment. This alcid life history pattern often contributes to limited population recovery following large-scale mortality events, especially if breeding success is reduced. Several sources summarize various other aspects of their life history, including taxonomy, morphology and plumages, vocalizations, and at-sea range (Jehl and Bond 1975; Johnsgard 1987; Springer et al. 1993; Drost and Lewis 1995; Gaston and Jones 1998).

SBI studies in 1975 to 1978 and annual monitoring from 1985 to 1998 have shown that the timing of colony attendance and breeding at SBI varies between years (February to June) with post-colony dispersal occurring between

May and July (Hunt and Butler 1980; Drost and Lewis 1995; Ingram and Carter 1997; Martin and Sydeman 1998). Colony surveys in the Channel Islands in 1991-1996 found at-sea congregations of murrelets beside colonies at night during the pre-breeding and breeding periods (Carter et al. 1992, 1997), as reported earlier at Baja California colonies (Jehl and Bond 1975). On the basis of birds captured at sea, congregations include breeding and non-breeding birds which either congregate before visiting nest sites or for other breeding-related purposes (Whitworth et al. 1997a,b, in press). After breeding, murrelets quickly move away from colonies and range well offshore from southern Baja California to British Columbia, Canada, from late summer through fall (Karnovsky et al. 1996; Gaston and Jones 1998).

Murrelet diet and at-sea biology during the breeding season in the SCB are not well known (Hunt et al. 1979; Briggs et al. 1987). The main prey identified in one small sample (n = 22) of birds collected near SBI in 1976 were larval northern anchovies (*Engraulis mordax*), although larval sauries and rockfish also were recorded. However, this sample may have reflected unusually abundant anchovy at that time (Whitworth et al., in press). We suspect that murrelets forage opportunistically, as do many alcids, on abundant or available small fish and zooplankton in offshore waters, often at oceanographic fronts, where prey can be found near the surface or reached at some depth (perhaps up to 20-40 m as found in other small alcids) through wing-propelled pursuit diving (Bradstreet and Brown 1985; Vermeer et al. 1987; Gaston and Jones 1998; Whitworth et al., in press).

## AT-SEA DISTRIBUTION OF MURRELETS IN THE SCB

In 1975 to 1978, at-sea distribution and abundance of seabirds in the SCB were determined using shipboard and aerial surveys (Hunt et al. 1979; Briggs et al. 1987; Baird 1993). These studies concluded that murrelets concentrated within 20 km of the largest known colony at SBI during the breeding season. However, long-term cyclic changes in oceanographic conditions and potential murrelet prey resources (MacCall 1996; McGowan et al. 1996) apparently have affected the at-sea distribution of Xantus' murrelets in the SCB (Whitworth et al., in press). In 1995-1997, we used radio telemetry techniques to study the at-sea distribution of SBI murrelets in the SCB during the breeding period and post-breeding dispersal period (Whitworth et al. 1997a,b, in press). In addition, blood samples have been taken from murrelets with and without radios to examine baseline health parameters and stress response (S.H. Newman, unpublished data). Radios were attached to murrelets at SBI in April and May and then radio-marked murrelets were tracked at sea from aircraft during surveys which covered most SCB waters from April to June. These studies indicated variation in overall murrelet at-sea distribution between months and years, extensive foraging ranges from SBI, use of many areas of the SCB far from SBI, and much variation in individual murrelet movements. We concluded that capture and radio marking had little or no long-term effects on murrelet behavior and subsequent at-sea distribution (Whitworth et al., in press). While the radio-marked sample apparently included incubating and non-incubating murrelets, their at-sea distributions were not found to differ and telemetry locations were used to describe the current at-sea distribution of SBI murrelets. However, we also now know that murrelets breed widely in the Channel Islands from colony surveys. Thus, overall murrelet at-sea distribution is wider than shown with SBI radio-marked birds alone. For example, Unitt (1984) reported murrelets as "fairly common" between March and July off southern San Diego County, presumably reflecting foraging by murrelets from the Los Coronados Islands and Santa Catalina Island.

During the 1996 and 1997 breeding seasons, radio-marked SBI murrelets were patchily distributed, relatively far from SBI (63 ± 27 [SD] km), in the northwestern SCB (Figure 2). In April 1996, SBI murrelets were found in a broad east-west band between SBI and the northern Channel Islands. In May 1996, SBI murrelets were densely concentrated just south of San Nicolas Island with some as far south as the Tanner-Cortez Banks. In April and May 1997, SBI murrelets were found even farther away (113 ± 45 km), mainly south of San Miguel and Santa Rosa islands but extending around all the northern Channel Islands and south to the Tanner-Cortez Banks.

While absolute murrelet densities at sea were not measured, SBI radio-marked murrelets were found in distinct aggregations in 1996-1997 during individual aerial surveys which covered between 18,000-28,000 km$^2$. In contrast, murrelets did not aggregate in specific regions of the SCB in 1995 (Figure 2) although fewer locations were obtained. Nesting was late and breeding effort much reduced at SBI in 1995 (Martin and Sydeman 1998) and oceanographic and prey conditions may have precipitated early dispersal from the SCB. In all three years, few SBI murrelets were found foraging near SBI, unlike previous studies. SBI murrelets avoided areas east of San Clemente and Santa Catalina islands in the eastern SCB, as well as the far southwestern corner of the SCB (Figure 2). In 1997, post-breeding dispersal occurred northward from the SCB, past Point Conception and the Santa Maria Basin and along the central California coast (Figure 2). SBI murrelets generally remained within 40 km of the central California coast through May but individuals were found as far as 100 km offshore in early June.

## AT-SEA THREATS

The SCB (Figure 1) is rimmed by one of the most densely populated coastal regions in the world and is used for a variety of commercial, military, industrial, and recreational purposes that may have direct and indirect population-level effects on murrelets (Anderson et al. 1993; Baird 1993; Drost and Lewis 1995). We considered that five at-sea threats had serious potential to impact murrelets in the

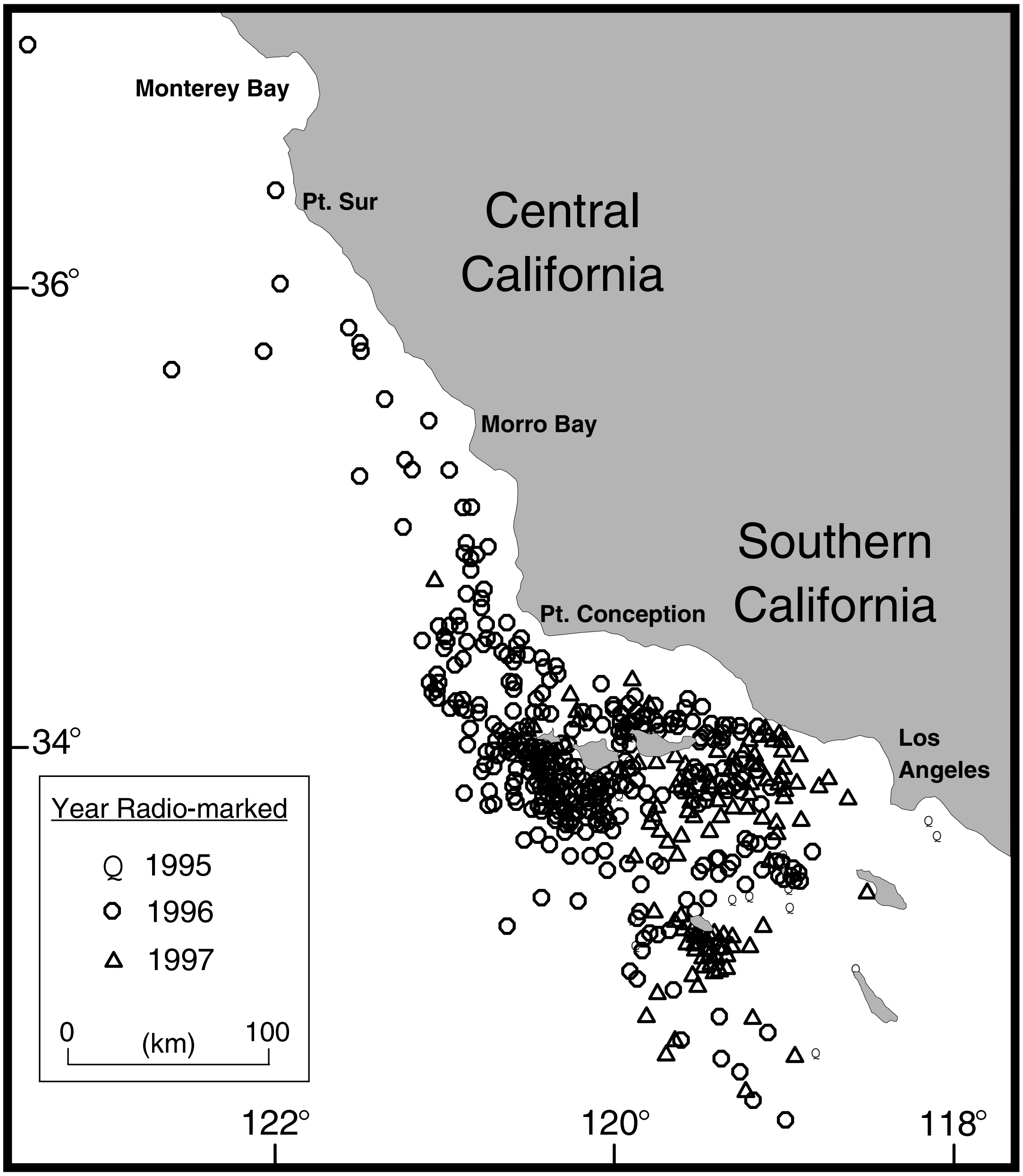


**Figure 2. At-sea locations of radio-marked Xantus' murrelets from Santa Barbara Island, 1995 to 1997 (Whitworth et al. 1997b; in press). Locations are coded by year when murrelets were radio marked.**

SCB: 1) oil spills from tankers and platforms, and chronic oiling; 2) military operations in the sea test range; 3) organochlorine pollution; 4) incidental by-catch from commercial gill-net fisheries; and 5) attraction to bright lights from vessels and platforms at sea. Other possible at-sea threats also exist, including: disturbance of murrelets at night adjacent to colonies and during the day at preferred foraging areas by boats or aircraft; reduced availability of prey due to competition from fisheries or climate change; plastic pollution; and die offs related to biotoxins. In this paper, we do not discuss the latter threats because of their lower potential to seriously impact murrelets at this time.

## OIL POLLUTION

### Increased Threat of Oil Pollution

In western North America, large marine oil spills (e.g., 1989 *Exxon Valdez*) that occur in areas with large populations of seabirds typically have resulted in large-scale seabird mortality (Page et al. 1990; Piatt et al. 1990; Burger and Fry 1993). In California and Washington, even smaller coastal spills (e.g., 1986 *Apex Houston*, 1991 *Tenyo Maru*) have resulted in significant impacts on local populations or rare species (Page et al. 1990; Piatt et al. 1991; Carter and Kuletz 1995). Alcids appear to be extremely susceptible to oiling and often comprise the bulk of seabird mortality from many oil spills in western North America. Thus, although no oiled Xantus' murrelets have been recovered from documented spills, we consider oiling as a serious threat in parts of the SCB where murrelets aggregrate for foraging or congregate near colonies.

The threat of oil pollution to Xantus' murrelets in the SCB has risen substantially since the early 1960s because of increased oil tanker traffic into Los Angeles Harbor and other ports, plus installation of many offshore oil platforms. Three major oil tanker and commercial ship transport lanes enter Los Angeles Harbor-Long Beach (Figure 1), which supports the highest volume of oil transport of any harbor in California, Oregon and Washington (i.e., in 1992, 1,521 oil tanker trips contained 391.8 x $10^6$ barrels [bbl; DAL 1990; DNA Associates 1993]). However, significant tanker traffic and oil volume also passed through other ports in Southern California in 1992: Estero Bay-Avila Beach area (128 trips; 21.9 x $10^6$1 bbl); Santa Barbara Channel (103 trips; 10.1 x $10^6$ bbl); and San Diego (8 trips; 0.4 x $10^6$ bbl). From 1963 to 1989, 35 offshore oil platforms were built in federal and state waters (M. McCrary, unpublished data), including 4 platforms off Point Conception and Point Arguello, 23 platforms in Santa Barbara Channel, and 8 platforms in San Pedro Channel (Figures 1 and 3; see Anderson et al. 1993). However, 8 platforms in state waters (7 in Santa Barbara Channel and one in San Pedro Channel) were removed between 1974 and 1996. Recent oil production from

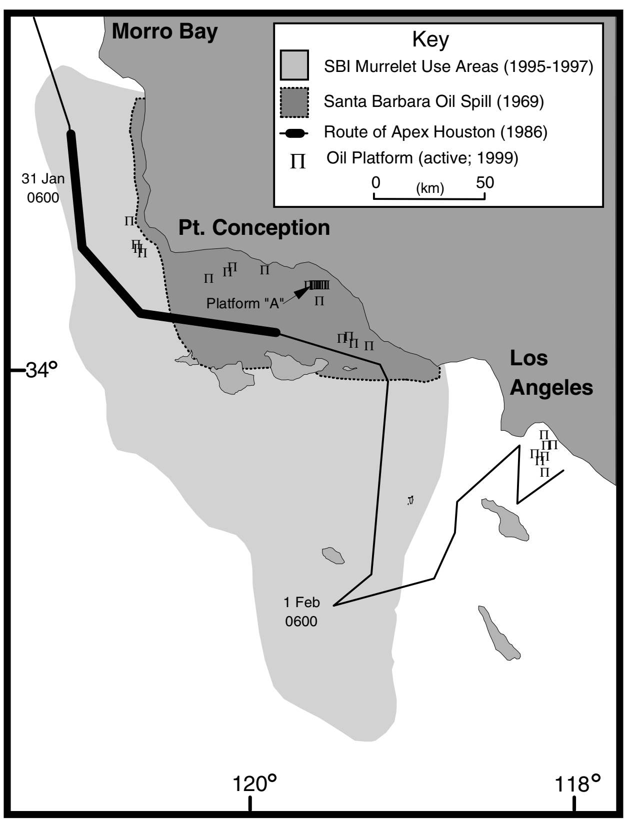


**Figure 3. At-sea distributions of radio-marked Xantus' murrelets (1995 to 1997) in relation to active offshore oil platforms, extent of the 1969 Santa Barbara *Platform A* oil spill in February-March 1969 (Nash et al. 1972), and the route of the oil barge *Apex Houston* in January-February 1986 (Page and Carter 1986).**

California offshore oil platforms was 6.4 x $10^6$ bbl in 1996 and 4.5 x $10^6$ bbl in 1998 (Sorensen et al. 1997; Parker et al. 1999).

In the SCB, seabird mortality has been documented for spills from offshore platforms, pipelines, on-shore oil facilities, tankers, and other military and commercial shipping (Anderson et al. 1993; Carter and Kuletz 1995; H.R. Carter and P.R. Kelly, unpublished data). Prior to 1988, seabird impacts were not documented for most oil spills (including the large 1976 *Sansinema* tanker spill in Los Angeles Harbor)(Anderson et al. 1993). From 1988 to 1998, many spills with recovery of more than 50 oiled birds have occurred from on-shore facilities, docks, tankers, or ships at anchor at Los Angeles Harbor, Ventura-Port Hueneme area, and Avila Beach area, including: 1988 Mobil/Los Angeles River; 1990 *American Trader*; 1991 *Sammy Superstar*; 1991 Mobil/Santa Clara River; 1992 Unocal/Avila Beach; and 1997 Bollona Creek (Oceanor 1990; Anderson et al. 1993, 1996; H.R. Carter and P.R. Kelly, unpublished data; J. Holcomb, unpublished data). These spills remained near shore and no murrelets were recovered.

In the 1970s, the vast majority of murrelets in the SCB were thought to be densely concentrated in a restricted area within 20 km of SBI (Hunt et al. 1979; Briggs et al. 1987). This area was far from potential sources of oil spills at that time such that only the largest spills might affect this area (although such effects might be great). Ford (1984) concluded that, during the breeding season, murrelets in the SCB were not seriously threatened by oil spills from offshore platforms or tankers. Similarly, King and Sanger (1979) assigned a very low Bird Oil Index value for Xantus' murrelets, based on the little information available in the early 1970s. At-sea distribution of SBI murrelets in 1995 through 1997 has demonstrated a much greater occurrence of foraging murrelets in areas of higher oil spill potential, especially Santa Barbara Channel, off Point Conception, and along the northern Santa Rosa-Cortez Ridge. In addition, murrelets from other colonies in the northern Channel Islands probably forage to a greater extent in these areas than SBI murrelets. While recent distribution might result in greater mortality, their wider foraging ranges also might lead to lower mortality near SBI. However, at-sea congregations around colonies at night likely lead to very high risks to murrelets from oil spills that occur near SBI and other colonies during the period of colony attendance. SBI murrelets rarely were found close to the mainland shore or in the eastern portion of the SCB in the 1970s or 1990s, which reduced their exposure to frequent, small oil spills from on-shore oil facilities near the Ventura-Oxnard area and within Los Angeles Harbor.

### Low Carcass Recovery

Recovery of oiled carcasses of seabirds and estimates of non-recovered carcasses have become common evidence of mortality from oil pollution events (Page et al. 1990; Ford et al. 1996). However, deposition of murrelet carcasses on SCB beaches is unlikely because of low on-shore transport, prevailing winds and currents, and at-sea carcass sinkage and scavenging; beached carcasses are often removed by avian or mammalian scavengers and people (see Hickey 1993; Browne 1994; Ford et al. 1996). Few murrelets are ever recovered on beaches in the SCB, even during periods of specific search effort. On beached bird surveys conducted in the SCB between 1974 and 1983, only 14 dead murrelets were recovered and only one murrelet was oiled (recovered 19 May 1977 at Leucadia Beach, San Diego County). Four murrelets were recovered on San Nicolas Island and ten were recovered on the mainland coast between Los Angeles and the Mexican border (Lewis and Hunt 1978; Stenzel et al. 1988, unpublished data; Santa Barbara Museum of Natural History [SBNHM] #1192).

**Northwestern SCB spills**

Several possible oil-spill scenarios could affect substantial numbers of murrelets in the SCB. In general, the scenario that would most likely impact large numbers of murrelets involves spills in the northwestern SCB area during the colony attendance period. Oil likely would be driven by strong prevailing spring currents and northwest winds into areas with concentrations of foraging murrelets (Figure 2), particularly in western Santa Barbara Channel, around the northern Channel Islands, and along the northern Santa Rosa-Cortez Ridge. A significant proportion of SBI murrelets foraging at sea could be killed, as well as murrelets from smaller colonies (i.e., foraging and congregating) at San Miguel, Santa Cruz, and Anacapa islands. Mortality could involve hundreds to thousands of murrelets (including adults, subadults, and chicks) and cause colony extirpations, depending on: the size, timing and trajectories of the oil spill; attendance of congregations; and at-sea distribution. Thus, a single catastrophic event in the northwestern SCB at this time could decimate the entire SCB murrelet population.

The likelihood of a large spill in the northwestern SCB is relatively high for tankers (because of substantial traffic, rough weather off Point Conception, possibility of grounding on the northern Channel Islands, or collisions in Santa Barbara Channel) and for offshore oil platforms (which are concentrated off Point Conception and in Santa Barbara Channel). However, the frequency of such large spills has been very low in the past few decades. For oil tankers, international rates of “large” spills (>1.0 x $10^3$ bbl) per bbl transported are higher: 0.47 spills/1.0 x $10^9$ bbl in port, 0.83 spills/ 1.0 x $10^9$ bbl at sea, and 1.3 spills/1.0 x $10^9$ bbl total (Anderson and LaBelle 1994). Based on 1992 levels of oil entering or departing from Los Angeles Harbor, these figures correspond to 1.8, 3.3, and 5.1 spills per decade, respectively. National rates for large spills from offshore platforms and pipelines from 1964-1992 were 0.45 and 1.32 spills per 10,000 x $10^6$ bbl of production, respectively (Anderson and LaBelle 1994). For the SCB, these rates would roughly correspond to 0.025 large spills per decade from platforms and 0.073 spills per decade from pipelines, respectively, using current production of roughly 5.5 million bbl/yr in California. Thus, the likelihood of a large spill in the northwestern SCB from an oil tanker is greater than from an offshore platform. However, such spill rates may differ in the SCB where several platform spills have occurred since the early 1960s and tanker oil spills with recorded seabird mortality have occurred mainly in Los Angeles Harbor. In fact, during the 1995 to 1997 period, two significant platform/pipeline spills occurred (i.e., 1996 Platform Heritage, 1997 Platform Irene) but without recovery of dead oiled murrelets while no significant tanker spills occurred away from shore facilities.

**1986 *Apex Houston* barge oil spill** - No large tanker spills away from shore have been closely investigated for seabird mortality in the SCB. To illustrate how past or future tanker spills might impact murrelets, we mention the case of the oil barge *Apex Houston* which traveled through the SCB on 31 January 1986 and may have leaked oil enroute (Page and Carter 1986; Page et al. 1990). Off Point Conception and in Santa Barbara Channel, the barge experienced heavy weather (i.e., thick portion of route in Figure 3) which may have caused oil leakage through a missing hatch cover, as found beforehand in central California. If such a spill occurred later in the colony attendance period, hundreds to thousands of murrelets would be at risk because oiling would occur widely along the route of the barge while it traveled throughout much of the SCB, including the vicinities of SBI and other colonies.

**1969 Santa Barbara oil spill** - The 1969 Santa Barbara *Platform A* blowout resulted in a massive spill (over 7.1 x $10^4$ bbl) that began on 28 January 1969, slowed by 8 February and further in April, but continued until December 1969 (Nash et al. 1972; Steinhart and Steinhart 1972; Anderson et al. 1993). During February to April (i.e., during the early part of the murrelet colony attendance period), oil spread throughout Santa Barbara Channel, north to Pismo Beach and south to Los Angeles (Figure 3). About 3,600 seabirds were estimated to have been killed in February and March (CDFG 1969a,b; Drinkwater et al. 1971; Straughan 1971). Actual seabird mortality undoubtedly was several times higher but the injury assessment was limited and inadequate. A late oil discharge in December 1969 from *Platform A* alone was thought to kill an additional 600 birds, although only 60 live oiled birds were recovered (Sanders 1970). While no dead murrelets were recovered, it was not likely that carcasses of murrelets oiled far from shore would drift to the partly-surveyed mainland shore (Hickey 1993). Most carcasses probably sank or were scavenged, preventing their recovery. Substantial numbers of murrelets probably were killed, although SBI murrelets may have been less affected than colonies in the northern Channel Islands which may have been greatly reduced or extirpated, especially at Santa Cruz and Anacapa islands. Previously, no effects to murrelets were attributed to the spill.

### Spills near Santa Barbara Island and Los Coronados Islands

If spilled oil was driven by prevailing spring currents and winds into nearshore waters around these large colonies, a large proportion of congregating murrelets could be killed. Mortality could involve hundreds to thousands of murrelets (including adults, subadults, and chicks) from the largest SCB colonies, depending on: the size, timing and trajectories of the oil spill; and attendance of congregations. Thus, a single catastrophic event near SBI or Los Coronados Islands could severely reduce the size of the entire SCB murrelet population. However, the chance of a large spill is lower than in the northwestern SCB (because of distance from oil platforms and the marine traffic lane off Point Conception and in Santa Barbara Channel) such that population decimation is less likely from a single spill event. In the past, spills were more likely near the Los Coronados Islands colony because of close proximity to San Diego Harbor and spills were less likely near SBI because of distance from offshore oil platforms, high tanker traffic in Santa Barbara Channel, Los Angeles Harbor, and other ports. However, oil tankers have recently increased use of the marine traffic lane near SBI (and decreased use of Santa Barbara Channel where the chance of an oil spill was greater) which has increased the chance of spills near SBI. If a large spill occurs, low carcass recovery would be expected because of few beaches on the southern Channel Islands (except San Nicolas Island), low on-shore transport of carcasses, and high rates of at-sea and beach carcass loss.

### Chronic Oiling

High chronic oiling of seabirds occurs in Santa Barbara Channel and in offshore waters off central and southern California (Munro 1957; Lewis and Hunt 1978; Stenzel et al. 1988; Anderson et al. 1993). In the Channel, such oiling results largely from frequent small spills from tankers and offshore oil platforms/pipelines, as well as natural seeps. Further offshore, such oiling results largely from bilge dumping by commercial ships (and dumping of tank-cleaning residues by some oil tankers) prior to entering Los Angeles and San Francisco harbors. Small numbers of murrelets probably are oiled and killed regularly but carcasses are not recovered. Natural seeps may not contribute significantly to such mortalities due to their close inshore distribution where few murrelets forage and possibly avoid seep areas (Figure 2; Anderson et al. 1993). As in southern California (see above), few murrelets have been recovered on beaches in central California. However, one dead oiled murrelet was reported on a beach in Santa Cruz County (Streator 1947). On beached bird surveys between 1971 and 1985 in south-central California (i.e., Monterey Bay-Point Conception), only eight non-oiled dead murrelets were recovered: five in Monterey Bay and three near Cambria-Morro Bay (Stenzel et al. 1988, unpublished data). High levels of beach scavenging of murrelets undoubtedly contribute to low carcass recovery. In a recent pilot study, four out of five small-bodied birds (i.e., the size of murrelets) were removed within a few hours by common ravens *Corvus corax* (P.R. Kelly, unpublished data). Nocturnal mammals undoubtedly also remove many carcasses from beaches in central California.

## MILITARY OPERATIONS

Few data are available concerning effects on seabirds from military operations in offshore waters along western North America, although human disturbance of certain colonies has occurred from frequent overflights (Speich et al. 1987; McChesney 1997). In the SCB, an extensive sea test range (STR) is operated by the U.S. Navy (Naval Air Warfare Center, Weapons Division; Figures 1 and 4) for military weapons testing and various training exercises (i.e., live-fire-missile and target-drone testing, low-level aircraft flights, and naval fleet maneuvers). Weapons testing involves a variety of air-to-air, surface-to-air, sea-to-air and air-to-sea detonations of varying magnitudes over the ocean surface. Some detonations occur at great heights (i.e., 1.0-30.0 x $10^3$ m) and most explosions do not occur on the surface of the ocean. Full fleet exercises occur within specific areas of the STR and are associated with rotorcraft and fixed-wing aircraft (primarily jet) overflights. In the past, there was little concern about effects of STR operations on Xantus' murrelets, since they were thought to forage close to the SBI colony on the eastern edge of the STR where less military activity occurred (Figures 1 and 4). Over the last two decades, there has been an increase of weapons testing and fleet exercises, and our telemetry studies have shown extensive overlap of murrelet at-sea distribution and areas of extensive STR operations. In the SCB, such military operations may cause murrelet movements at sea but it is not known if STR operations cause mortality and no carcasses have been recovered after specific detonations.

The frequency and geographic locations of military operations and exercises leads us to suspect that small numbers of murrelets may be killed and larger numbers disturbed. Areas of overlap between high frequencies of military activities and large numbers of locations of radio-marked SBI murrelets were south of San Miguel and Santa Rosa islands and west of San Nicolas Island (STR areas 4A, 4B, and 5B) (Figures 2 and 4). Overlap between medium frequencies of military activities and radio-marked murrelets also occurred west of San Miguel Island and north of San Nicolas Island (STR areas 3A, 3D, W-537). In fact, 81% of SBI murrelet locations in 1995-1997 were found within STR boundaries. Aerial telemetry flights could not be conducted during active military operations, since aircraft were excluded for safety reasons. SBI murrelets present in these areas before operations, however, appeared to have moved to other areas when surveys were next conducted (1 to 2 d later). Disturbance to murrelets during operations may have precipitated movements, although other factors also might have been responsible (i.e., change in prey availability due to weather or oceanographic conditions). Mortality of murrelets from

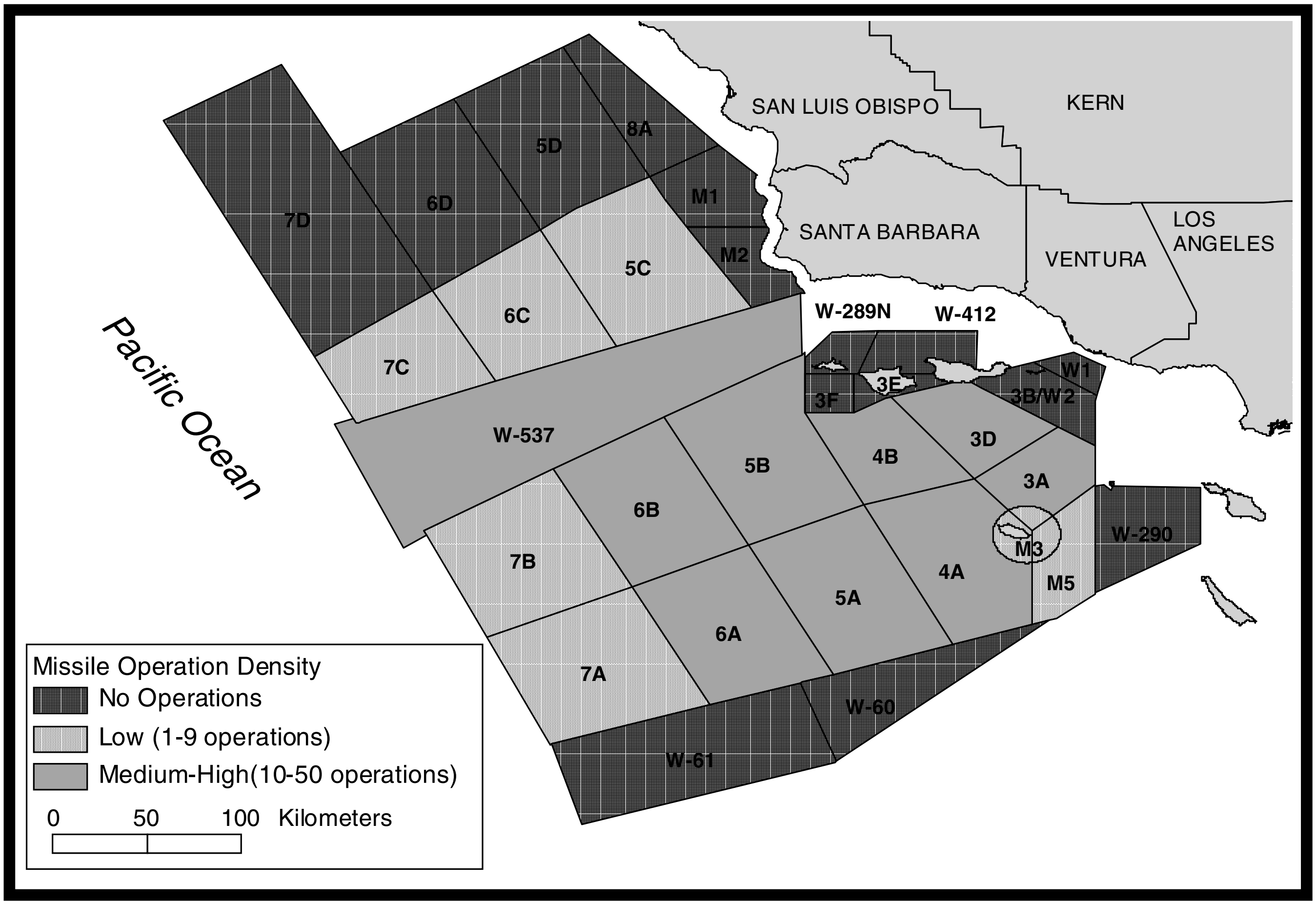


**Figure 4. Sea test range missile operation density from October 1994 to September 1995 (U.S. Navy 1998).**

military operations does not appear to be extensive since many radio-marked murrelets foraged in the STR and survived several operations. While non-oiled murrelets recovered on San Nicolas Island (see above) could reflect some mortality from military operations near San Nicolas Island, it is likely that onshore carcass deposition rates from natural mortality are high there due to the abundance of accessible sandy beaches and closer proximity to offshore foraging areas. Some concern remains about possible frequent disturbance of foraging murrelets during periods of heavy STR use in the breeding season. Disturbances may be reduced if the final Sea Range Environmental Impact Statement (see U.S. Navy 1998) recommends moving some operations and exercises farther away from areas used by murrelets during the breeding season.

## ORGANOCHLORINE POLLUTION

In the 1960s and 1970s, extensive organochlorine pollution of the SCB resulted in poor reproductive success of brown pelicans (*Pelecanus occidentalis*) and double-crested cormorants (*Phalacrocorax auritus*) (Gress et al. 1973; Anderson et al. 1975). It is possible that murrelets also were affected by this pollution, but low egg hatching success at SBI in 1975 through 1978 was attributed mainly to high levels of egg predation by deer mice (Murray et al. 1983) and the small colony at Anacapa Island was attributed mainly to rat predation (Drost and Lewis 1995). While a reduction in environmental levels of pollutants has occurred since the early 1970s, heavily contaminated sediments remain and continue to affect raptors and seabirds (D. Welsh, pers. comm.). Compared to pre-1947 conditions, recent studies of murrelet eggs collected in 1992 have shown low levels of egg-shell thinning (i.e., 1.5%) and pollutants (i.e., 0.86 ppm total DDT; 0.35 ppm total PCB), compared to other seabird species (Fry 1994; Kiff 1994). Current effects from organochlorine pollution appear to be low.

## GILL-NET FISHING

Gill-net fisheries are well known for incidental bycatch of seabirds, particularly alcids (Nettleship et al. 1984; DeGange et al. 1993). From 1983 to 1994, gill-net fisheries in the SCB were found to kill small numbers of seabirds in the SCB, especially cormorants (Julian and Beeson 1998). Alcids were reported killed only once in observer programs (i.e., three pigeon guillemots [*Cepphus columba*] in 1985) but a few "unidentified" birds may have been murrelets. Despite no recovery of murrelets in gill nets in the SCB, ten Xantus' murrelets were recovered by the Canadian

Department of Fisheries and Oceans from drift nets set by the fishing vessel *Tomi Maru* off the coast of British Columbia on 7 days between 5 July and 20 August 1987 (now specimens in the Royal British Columbia Museum [RBCM], Victoria, British Columbia). These little-known specimens are the only recorded mortalities of Xantus' murrelets in fishing nets, but six of the ten birds also were heavily oiled (RBCM specimen tag information) and seven of the ten birds were undergoing flightless pre-basic molt when killed (H.R. Carter, pers. obs.). Gill-net mortality may kill small numbers of murrelets in the SCB, but it is unlikely that large numbers are killed.

## LIGHT ATTRACTION

Murrelet attraction to bright light sources at sea and on land is well known (e.g., Howell 1910, 1917; McClellan 1926; Whitworth et al. 1997a). Jehl and Bond (1975) specifically reported many Xantus' murrelets captured aboard ships in Baja California at: Cedros Island (February 1941); Cabo Colnett (March 1949); San Martin Island (April 1951); Guadalupe Island (April 1968); and the San Benitos Islands (April 1968 and May 1971). Such captures probably resulted from light attraction. Xantus' murrelets were strongly attracted to bright lights on our research vessels, primarily on dark, foggy nights. Murrelets were captured on board the F/V *Instinct* at SBI (May 1994) and Santa Cruz Island (August 1994); some birds struck lights and were stunned (H.R. Carter and D.L. Whitworth, personal observations). At SBI, our bright boat lights also attracted potential murrelet predators, especially western gulls, but no mortality was noted. Sanger (1973) described one Xantus' murrelet that died from collision with a ship off the northern British Columbia coast on 25 October 1971, probably as a result of light attraction. Extremely bright sources of light, especially on offshore oil platforms and squid fishing boats, undoubtedly attract murrelets and may result in mortality. Brightly-lit offshore oil platforms occur mainly in Santa Barbara Channel and off Point Conception (Figure 1). Ashy storm-petrels (*Oceanodroma homochroa*) have been recovered dead on Platform Honda (SBNHM #5784, September 1991; SBNHM #5785, October 1991) and from mainland locations in Southern California with bright lights in Goleta, Santa Barbara, Montecito, Ventura, Oxnard, and Point Mugu (SBNHM #4275, #4356, #4544, #5469, #5782, #5847). Similar attraction to mainland lights by murrelets has not been reported in the SCB. However, Roberson (1985) reported a "confused" murrelet attracted to lights at a football game in Monterey on 20 September 1952. Squid fishing boats used extremely bright lights along the coasts of Santa Cruz and Santa Catalina islands in 1995 to 1997 (H.R. Carter and D.L. Whitworth, personal observations), but largely in late summer and fall after most murrelets have dispersed northward. If this fishery occurred during the murrelet breeding season, significant adverse effects would be expected, including mortality, depredation, and great disruption of at-sea congregations. At present, light attraction may result in mortality of at least small numbers of murrelets, but further effort is needed to evaluate the extent of these effects. In 1999, bright lights from squid-fishing boats may have led to increased murrelet depredation by barn owls at SBI (P. Martin, personal communication).

## SUMMARY

Only one major at-sea threat (i.e., oil pollution) has the potential to kill significant numbers of Xantus' murrelets in the SCB. Large-scale mortality probably has occurred only once in the 1969 Santa Barbara *Platform A* oil spill but small numbers of murrelets probably are killed regularly in smaller spills and through chronic oiling. Impacts of oil pollution have not been well documented because of low specific effort and the difficulty of recovering carcasses. Our telemetry data have provided a better understanding of how foraging behavior exposes murrelets to risk of mortality from several threats over a wide area of the SCB. We suggest that mortality from oil pollution should be considered as the most serious at-sea threat in the SCB and might have significant effects on Xantus' murrelet populations over time. However, much additional work is needed to further examine the magnitude of population effects.

### On-going Research

Efforts are underway to improve our knowledge of the at-sea distribution of murrelets and other seabirds in the SCB. From 1999 to 2001, we will conduct further research, including: 1) extensive aerial surveys to examine seabird (including Xantus' murrelet) and marine mammal distribution at sea in Southern California, using directly comparable techniques to those used in the 1970s; and 2) additional radio telemetry and blood studies on Cassin's auklets (*Ptychoramphus aleuticus*). In future injury assessments, the California Department of Fish and Game (Office of Spill Prevention and Response) will focus special attention on assessing effects on Xantus' murrelets. The U.S. Navy initiated efforts to conduct radio telemetry studies of murrelets to provide preliminary information on whether murrelets might be impacted on the STR. Population models for Xantus' murrelets (Sydeman et al. 1998) could be used to assess effects from oiling mortality, in addition to depredation and low breeding success at colonies.

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