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Title: **AERIAL SURVEYS OF WEDDELL SEALS DURING 2007-08, WITH NOTES ON THE HISTORY OF AERIAL CENSUSES IN THE ROSS SEA AND RECOMMENDATIONS FOR CONTINUED COUNT EFFORT**

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ABSTRACT

Weddell seals (*Leptonychotes weddellii*) have proved to be an important predator of Antarctic toothfish (*Dissostichus mawsoni*), and currently there is no ecosystem monitoring program (CEMP) in place under CCAMLR with respect to the Ross Sea toothfish fishery. In a previous paper submitted to EMM in 2007 (WG-EMM 07/13), we described procedures whereby aerial photography could be used to monitor Weddell seals along the Victoria Land coast. That area would be important to monitor changes in distribution and abundance, as seals from all the colonies along that coast likely forage in CCAMLR SSRUs 88.1H and 88.1J (WG-EMM 06/29). Herein, we compare air with ground counts made in Erebus Bay, McMurdo Sound, in November 2007, and summarize historical results of aerial surveys made along the coast of Victoria Land. The high correspondence between air and ground counts shows that aerial photography can successfully be used to document changes in distribution and abundance of Weddell seals. Ground counts of Erebus Bay colonies made annually, 1974-2007, demonstrate the sensitivity of count data to environmental variability and the variance that could be expected over a time when the Ross Sea system was without influence from industrial fishing. On the basis of this and the previous paper, a Weddell seals monitoring program can now be put into effect under CEMP, begun with a one-time survey to identify all important haul out locations and the ones that best lend themselves to aerial surveillance.

SUMMARY OF FINDINGS AS RELATED TO NOMINATED AGENDA ITEMS

Agenda Item	*Findings*
7	The findings presented in this report apply to the establishment under CEMP of monitoring of finfish fisheries in the high latitude Southern Ocean and specifically the Ross Sea.

AERIAL SURVEYS OF WEDDELL SEALS DURING 2007-08, WITH NOTES ON THE HISTORY OF AERIAL CENSUSES IN THE ROSS SEA AND RECOMMENDATIONS FOR CONTINUED COUNT EFFORT

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ABSTRACT. Weddell seals (*Leptonychotes weddellii*) have proved to be an important predator of Antarctic toothfish (*Dissostichus mawsoni*), and currently there is no ecosystem monitoring program (CEMP) in place under CCAMLR with respect to the Ross Sea toothfish fishery. In a previous paper submitted to EMM in 2007 (WG-EMM 07/13), we described procedures whereby aerial photography could be used to monitor Weddell seals along the Victoria Land coast. That area would be important to monitor changes in distribution and abundance, as seals from all the colonies along that coast likely forage in CCAMLR SSRUs 88.1H and 88.1J (WG-EMM 06/29). Herein, we compare air with ground counts made in Erebus Bay, McMurdo Sound, in November 2007, and summarize historical results of aerial surveys made along the coast of Victoria Land. The high correspondence between air and ground counts shows that aerial photography can successfully be used to document changes in distribution and abundance of Weddell seals. Ground counts of Erebus Bay colonies made annually, 1974-2007, demonstrate the sensitivity of count data to environmental variability and the variance that could be expected over a time when the Ross Sea system was without influence from industrial fishing. On the basis of this and the previous paper, a Weddell seals monitoring program can now be put into effect under CEMP, begun with a one-time survey to identify all important haul out locations and the ones that best lend themselves to aerial surveillance.

1 INTRODUCTION

Weddell seals (*Leptonychotes weddellii*) have proved to be an important predator of Antarctic toothfish (*Dissostichus mawsoni*) and are distributed along the Victoria Land coast where they no doubt forage in the areas now being fished commercially for this species (see Ainley et al. 2006, Ainley & Siniff 2008). A monitoring program to evaluate the potential impact of this fishery on this important top level predator and its foodweb would seem to be required under CCAMLR's precautionary and ecosystem management principles.

The use of aircraft and aerial photography has long been used to monitor the trends in the population of pinnipeds in the Arctic (e.g., McLaren 1966, Burns & Harbo 1972, Lavigne et al. 1982, Gilbert 1989, Johnston et al. 2000, NMML

2007). Because Weddell seals haul out on the sea ice surface to give birth, suckle young, rest and moult, it would be easy to use photographic techniques to obtain population trends along the Victoria Land coast, similar to Arctic ice seals (see references above; also Ainley et al. 2007). In fact, historically, aerial census has been used successfully to assess population trends of Weddell seals in the Antarctic. Smith (1965) conducted repeated aerial counts of seals in southeastern McMurdo Sound in order to quantify the seasonal dynamics of the population as well as to derive a total count. This was the period in which the New Zealand Antarctic Programme (NZAP) was killing seals to use as food for sled dogs. Thus, it was important to derive baseline information on the population and accordingly NZAP assumed responsibility for the assessment. Stirling (1969), also under the auspices of NZAP, tallied numbers of Weddell seals at sites along the coast of Victoria Land, also by helicopter reconnaissance.

In 2007, we reviewed aspects of the Weddell seal's population dynamics that lend themselves to aerial monitoring (Ainley et al. 2007: WG-EMM 07/13). Upon considering that document, the CCAMLR working group on Ecosystem Monitoring and Management (EMM) "agreed that establishing time-series monitoring of important species in different areas will help document the variability in the [Ross Sea] system as baseline data and, in particular, will help identify when the system is changing [with respect to fishing for toothfish]". Herein, we present additional validation of the recommendations made in WG-EMM 07/`3, as well as report tends in the Erebus Bay population 1974-2007.

2 METHODS

To further evaluate the use of aerial counts for monitoring Weddell seal population trends, we initiated trial counts for comparisons to past aerial counts and current ground counts for the Erebus Bay (McMurdo Sound) Weddell population. Counts of seals were made by taking photographs from an altitude of 1000 ft (ca 305 m) using an A-Star helicopter, and a Nikon D70s camera with 70-300 zoom lens. The flight began at 15:00 on 28 November 2007, and lasted about 20 min. Weather was clear and sunny. Seals were then counted in the digital images, with all age classes (sizes) combined.

A ground count was made of seals in Erebus Bay on 26 November 2007. The effort required about 8 hrs, and travel between seal colonies was by skidoo. This was just one of several such counts that are made each spring season as part of the ongoing research program that has been assessing demographic variability in the McMurdo Weddell population since 1963. The data base associated with this long term effort is unique and has provided valuable insights into the ecology of this major Antarctic species, as well, we shall show, for the proper design of any monitoring program for Weddell colonies along the Victoria Land coast (see also EMM 06/29, 07/13).

Counts were also made by helicopter, not using photos, at various sites along Victoria Land on 14 and 27 November 2007. These were made as part of an effort to locate seals tagged in Erebus Bay. Direct counts were estimated by 5's for large groups. For very large groups, the helicopter landed and ground counts were made (and each seal inspected for a tag).

3 RESULTS

Six colonies were common to both the aerial effort on 28 November and the ground effort on 26 November 2007 in Erebus Bay (Table 1). Counts for those sites were highly correlated (r = 0.995). Counts at two sites were higher on the basis of aerial photos, while counts at four were higher based on the ground survey. Nevertheless the total count for the six sites common to both census efforts were within 5%. No doubt counts would have been closer if they had been made on the same day and at the same time of the day (see Discussion).

Table 1. Counts in Erebus Bay vicinity made from the air on 28 November 2007, compared with those made on the ground two days earlier (26 November 2007).

	28-Nov Flight 15:00	26-Nov Ground All Day	Percent Difference
Barne Glacier	30		
Ice crack, Barne - Inaccessible Island	6		
Inaccessible Island	24	76	-69
Big Razorback Island	185	208	-11
Little Razorback Island	8	13	-39
Erebus Ice Tongue (outer)	61		
Turtle Rock, and crack either side	169	146	14
Hutton Cliffs	201	151	25
South Base, Erebus Ice Tongue	34		
North Glacier (Erebus Ice Tongue)	24		
North Base, Erebus Ice Tongue	60		
Turks Head	209	244	-15
TOTALS, sites common to both efforts	**796**	**838**	**-5**
TOTALS, all sites	1,011	838	

On the basis of aerial surveys, three by Stirling (1969) in the 1960s and two by Garrott et al. in 2007, Weddell seals have been detected at 22 localities along the southern four-fifths of the Victoria Land coast, including other sites along the coasts of Beaufort, Franklin and Ross Islands (Table 2). The sites surveyed in the 1960s were not exactly the same in scope as those surveyed again in 2007. In considering the latitude-longitude coordinates it is apparent that the sites tallied in the 1960's encompassed much larger areas, so the counts are

not exactly comparable. What is clear, however, is that Weddell seals are distributed in many locations along Victoria Land.

Table 2. A summary of counts of Weddell seals along Victoria Land and the western Ross Sea, made using aerial photos beginning in the 1960s. A = Stirling (1969), B = Smith (1965), and C = Garrott et al., unpubl data. In several cases, the aircraft landed and ground counts were made for confirmation.

SITE OR SECTION OF COAST	LATITUDE ALONG VICTORIA LAND	DATE	TIME	COUNT	ESTIMATE
Cape Roget[A]	71 59	21-Jan-65		48	
Mourbray Bay[A]	72 11	20-Jan-65		650	
		29-Jan-68	1000	52	100
Edisto Inlet[A]	72 20	mid-Jan-67		600	
		31-Jan-68	1115	460	700
Cape Wheatstone[A]	72 37	11-Jan-65		800	
Borgrevink Ice Tongue[A]	73 21	23-Jan-67	0300	107	550
Bay, Edmonson Point[C]	74 20	14-Nov-07		124	
Inexpressible Island[A]	74 54	18-Jan-67	0130	61	300
Nordenskjold Ice Tongue-Prior Island[A]	76 11 - 74 41	17-Jan-67	1400	2147	2500
Cape Reynolds[C]	75 25	14-Nov-07		120	
	75 42	14-Nov-07		150	
	75 54	14-Nov-07		40	
	76 30	14-Nov-07		24	
Cape Roberts-Granite Harbor[A]	77 02 - 76 53	17-Jan-67	0245	235	1175
Dunlop Island & crack[C]	77 14	14-Nov-07		55	
Spike Cape[C]	77 18	27-Nov-07		52	
Marble Point[C]	77 26	27-Nov-07		277	
Butter Point[C]	77 39	27-Nov-07		16	
Strand Moraines[C]	77 45	27-Nov-07		16	
Strand Moraines-McMurdo Ice Shelf[A]	77 45 - 78 00	7-Feb-68	1630	866	
	Latitude, Longitude				
Franklin Island[A]	76 05, 168 19E	19-Jan-65		23	
Beaufort Island[A]	76 56, 166 56E	12-Jan-65		10	
Ross Island, Lewis Bay[C]	77 22, 167 35E	23-Nov-07		280	
Ross Island, Wohlschlag Bay[C]	77 22, 166 25E	23-Nov-07		10	
Ross Island, Royds - Hut Peninsula (Erebus Ice Tongue, center) [B]	77 42, 166 40E	1961-63 (Dec)		2670	
White Island	78 08, 48 35E	15-Nov-07		9	
TOTAL				9902	

The long-term data from the McMurdo Sound show some variances in the numbers that show up annually at pupping and haul out sites (Siniff et al. 2008; Fig. 1), but the overall population has been relatively stable (Cameron & Siniff

2004). Thus, while we do not have consistent and well designed aerial counts for Weddell seals along the entire Victoria Land coast, what we do have, as shown below, suggest that the assumption of relatively stable populations over the last few decades is not unreasonable, and thus we would expect that there are about 10,000 Weddell seals distributed from Cape Roget, Victoria Land, south to the Strand Moraines in McMurdo Sound. Certainly, however, there are additional seal haul out sites north of the Cape Roget (e.g., the extensive fast ice around Duke of York Island; P. Wilson, pers. comm., who saw large numbers of seals there on a penguin-aerial photo over-flight). Thus the number using the Ross Sea area for foraging is no doubt larger.

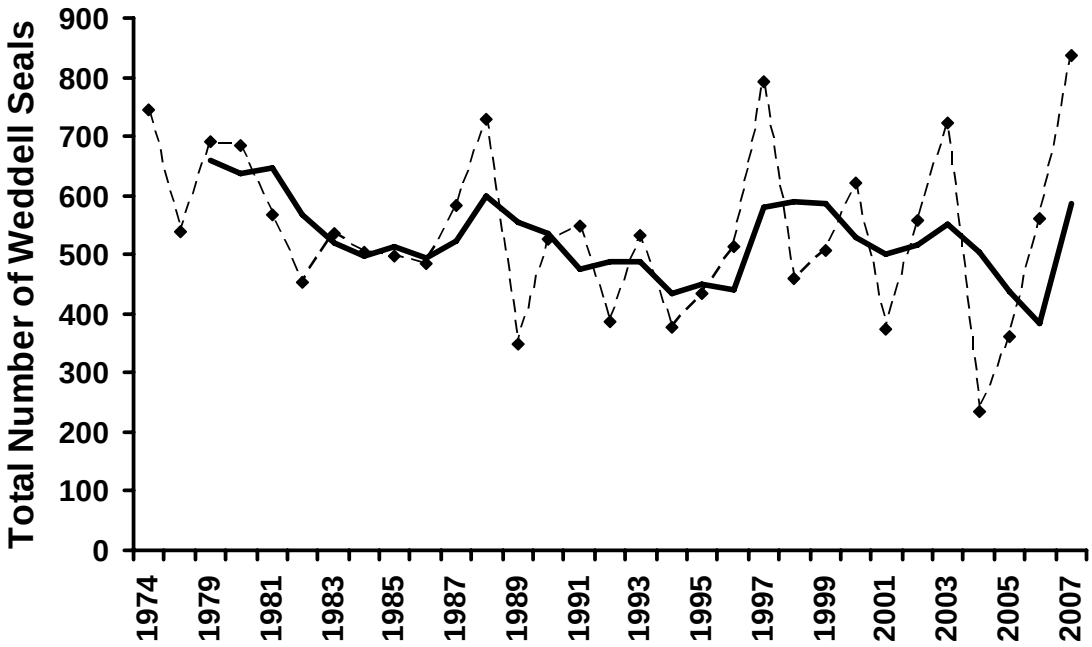

Figure 1. Counts of seals made at Innaccessible, Big Razorback, Little Razorback, Turks Head, Turtle Rock and Hutton Cliffs in Erebus Bay during the last week of November, 1974-2007. These are the sites common to those assessed by simultaneously by both aerial and ground counts in 2007, as shown in Table 1. The heavy line is a three-point moving average.

4 DISCUSSION

In a previous document we recommended that aerial counts be conducted during the last week of November when research has shown that ground counts show a plateau in breeding animals (Ainley et al. 2007: their figure 1). This is supported by patterns in the aerial counts made by Smith (1965: his figures 5 & 6). Therefore, we made our comparison of ground with aerial counts, as reported herein, during the last week of November 2007.

Smith (1965) conducted counts round the clock on two days from Scott Base, 17 February 1963 and 15 February 1964. These would have been of non- and post-breeding animals, which annually congregate at the transition between the

sea ice and the Ross Ice Shelf in that vicinity at that time of year. Smith found that the peak occurred at 15:00 to 16:00 hrs, the time when we conducted our aerial count in 2007 (see Fig. 2, Table 1). Because our ground count on 26 November 2007 required all day to complete, the diurnal pattern in haul out of seals likely increased the differences in our comparison. However, in November when females are tending pups, and males are territorial, the diurnal pattern in haul out is likely to be less dominant than in February. Regardless, our air and ground counts were close at the larger colonies (11-14%).

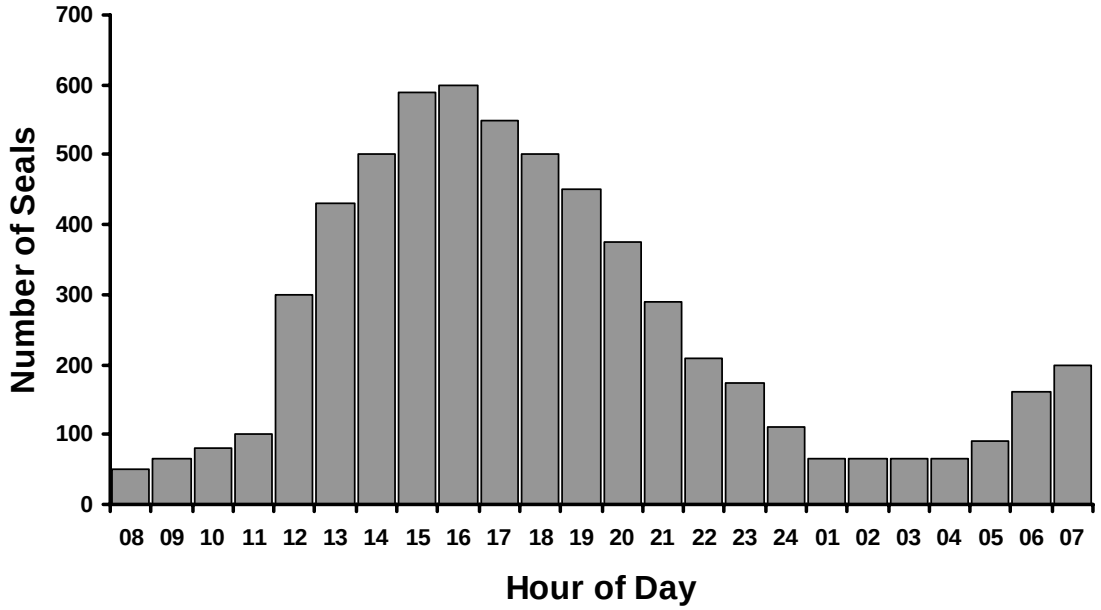

Figure 2. The number of seals hauled out off Scott Base on two days in February. The mid-point of the two counts, by hour, is shown here (17 Feb 1963, 15 Feb 1964); data from Smith (1965).

Smith (1965) corrected his counts using a statistical model that included temperature, solar radiation and wind. In sum, more seals haul out when the weather is sunny and calm, at least during the post-breeding period (February). Therefore, weather perhaps affected our comparison as well. At Cape Royds, which is immediately to the north of Erebus Bay (and the location where our flight originated), the weather on 26 November (ground count) was overcast all day and the wind ranged 8-24 kts; on 28 November (aerial count) there was no cloud cover and the wind ranged only 3-6 kts. In November, breeding and territoriality likely would dampen effects of weather, and thermoregulatory factors, on whether or not seals would haul out. In addition, temperatures are generally warmer in late November than late February.

Obviously, additional research and sophisticated statistical modeling, including perfection of some of the daily correction factors investigated by Smith (1965), might well explain some of the variability seen in the 1974-2007 counts of the six reference sites investigated in this report (Fig. 1). Regardless, even uncorrected counts appear to be sensitive to important environmental variability.

Considering a longer-time frame than just daily variation, the uncorrected counts exhibited peaks during the 1987-88 and 1997-98 El Niño events, consistent with the analysis of Testa et al. (1991), Hadley et al. (2007), and Proffitt et al. (2007). The latter studies reported correlations between aspects of Weddell seal population dynamics and body condition with the Southern Oscillation Index. Also apparent is the slight decline in numbers during the mid-1970s, exhibited also in Cameron & Siniff (2004) who used mark-recapture models to describe trends in the entire Erebus Bay population. The decline is possibly related to the dog-food seal-kill that occurred annually in southern McMurdo Sound until the early 1980s (see Introduction). Why the population declined or did not recover could also be related to a mid-1970s oceanographic regime shift, which affected the benthic and pelagic communities of the Ross Sea and throughout the Southern Ocean and which subsequently was found to be related to shifts in the Southern Annular Mode (Ainley et al. 2005; Stammerjohn et al. 2008). Finally, the wide swings in population size evident during 2001-2007, i.e. the period in which large grounded icebergs led to extensive multi-year fast ice in McMurdo Sound, correlate well with pup production during that period (2001-2006, r = 0.797; cf Siniff et al. 2008: figure 1). Therefore, it appears that counts, indeed, are sensitive to both local and remote factors, and thus are useful, whether they be aerial or ground efforts, as tools for monitoring ecosystem change in the Ross Sea and elsewhere in the Southern Ocean affected by finfish fishing.

When one considers the possible influence of the Ross Sea toothfish fishery, it is clear that removal of this species, even though the current level of take is considered conservative, is likely to have measurable impact on the ecosystem. Just based on how fish-eating pinnipeds in the region of the Antarctic Peninsula responded to historical depression in demersal fish stocks (see Ainley & Blight 2008), we have a very good indication of what to expect in the Ross Sea where commercial take of long lived, slow maturing fish species has been underway. Also in the Antarctic Peninsula region, Weddell seal numbers have declined as both sea ice and fish have disappeared (Siniff et al. 2008). Thus, it would seem very important that in the case of the Ross Sea that these lessons learned from past fish exploitation be considered and in the case of the Ross Sea measures to assess possible effects be put quickly in place.

5 RECOMMENDATIONS

1. An aerial survey program should be initiated to monitor Weddell seal numbers along the entire coast of Victoria Land, from Strand Moraines to Duke of York Island. The purpose of this effort would be to assess long-term trends in seal population size and distribution and particularly in regard to whether trends are consistent from site to site and are more or less steep closer to the continental shelf edge of the Ross Sea where the toothfish fishery is concentrated (see Hanchet et al. 2006). An initial survey should be conducted to identify the larger colonies at which the acquisition of annual images should become a priority; the larger colonies would exhibit less variation than the smaller ones, judging from results of our comparison in 2007. This initial survey would also allow

experimentation with the best aircraft approaches in order to photograph all individuals at a site. A survey manual, then, could be prepared that had details of location and flight procedure, as has been worked out by Landcare Research NZ for annual surveys of Adélie Penguin colonies along Victoria Land (e.g., Taylor et al. 1990).

2. The flight, perhaps by a P3 Orion, twin otter or C-130 (the latter is used for penguin counts), should be conducted close to the same date every year (last week of November), starting at about the same time of day at the same colony. This would reduce annual variance due to time of season and time of day. The above sorts of aircraft, unlike a helicopter which needs to stop repeatedly for fuel, likely could do the survey within a few hours, thus, further mitigating the factors that might cause variability.

3. Flight altitude (1000 ft, 305 m), as often used in the Arctic and the same as used for penguins, would work well for Weddell seals, especially using a large-format camera, with telephoto lens.

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