2010 Report on Davidson Seamount Marine Mammal and Seabird Surveys

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Abstract

In 2010, the Monterey Bay National Marine Sanctuary (MBNMS) and its partners conducted two aerial surveys and one ship-based survey of the surface waters surrounding the Davidson Seamount, an area typically regarded as having a higher abundance and diversity of marine mammals and seabirds. Each aerial survey occurred over one day in January and April, and covered 542 km and 400 km, respectively, of linear "on-effort" transects. The ship-based survey occurred over a three day period in July and covered 615 km of linear "on-effort" transects. Additional oceanographic and prey data were collected during the ship-based survey, including sea surface temperature, conductivity, salinity, plankton net tows, and echosounding. Rough marine mammal encounter rates (marine mammals per linear km) were calculated for each survey as follows: January aerial survey: 0.042 per km, April aerial survey: 0.788 per km, and July ship-based survey: 1.086 per km. Many years of future surveys are required to associate factors with any differences in encounter rates. Numerous factors include survey methods, inter-seasonal, and inter-annual variables.

Introduction

Davidson Seamount is an extinct volcano, submerged below the Pacific Ocean approximately 129 kilometers southwest of Monterey, California. The seamount is 13 kilometers wide, 42 kilometers along its main axis, and stands almost 2,280 meters tall, yet its summit is still 1,250 meters below the surface (Figure 1). This massive geological feature, sitting in a relatively flat and deep area of the seafloor, redirects deep water currents, sometimes deflecting it to the surface (CITATION). This cold water from the deep also carries with it higher nutrients, relative to surface water (CITATION). It is surmised that this process is what fuels a higher abundance of primary productivity within the immediate vicinity of the seamount. This productivity fuels the food web above it, including marine mammals. More available prey will typically increase the local abundance of marine mammals in the immediate area.

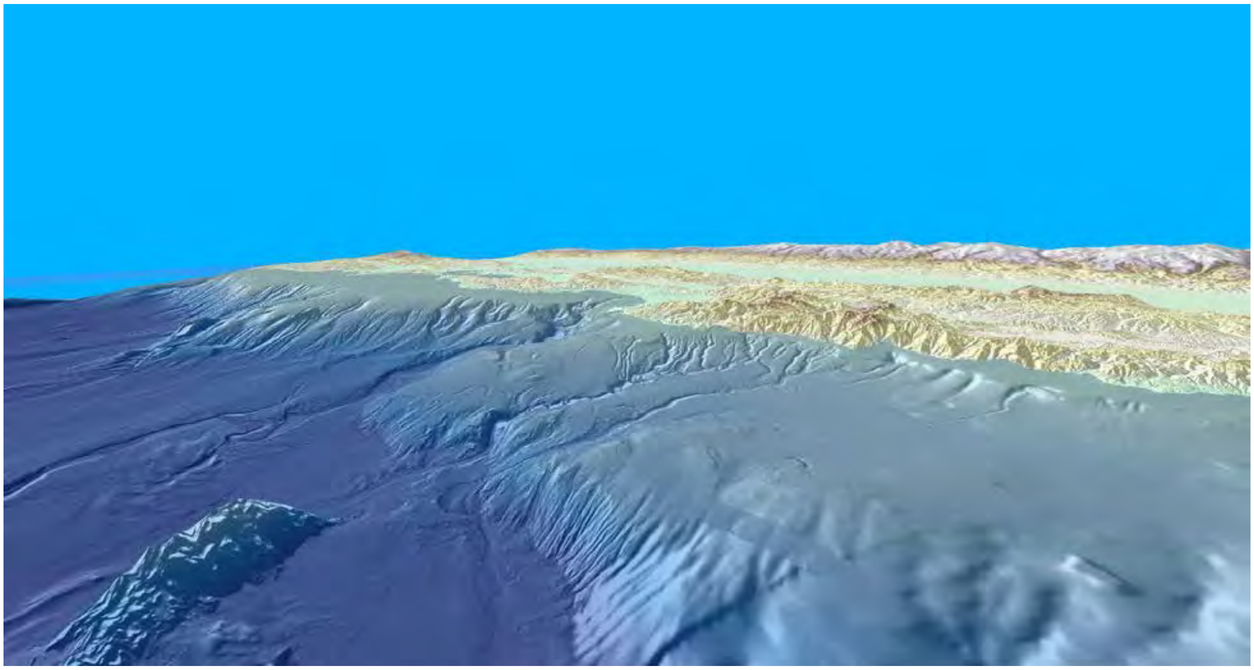

Figure 1. Three dimensional perspective looking north into MBNMS. The Davidson Seamount can be seen in the lower left, Monterey Bay in the middle of the figure.

The Monterey Bay National Marine Sanctuary has formed partnerships with scientists from Moss Landing Marine Laboratories, NOAA Fisheries, Channel Islands National Marine Sanctuary and UC Santa Cruz to conduct both aerial and ship-based surveys of the surface waters surrounding Davidson Seamount. Observations made in 2010 will serve as a baseline for future surveys, and over time a comparison of relative abundance, diversity, and distribution of marine mammals and seabirds by survey method and season will be established.

Methods

Aerial Surveys

In consultation with experts from NOAA's National Marine Fisheries Service, the following aerial survey methods were designed in early 2010 and will be used for all future aerial surveys.

A NOAA DeHavilland Twin Otter aircraft was used as the aerial observation platform for both the January 14 and April 19, 2010 surveys (Figure 3). The survey method takes into account the Twin Otter's ability to fly at low altitudes and consistent speeds, but due to the remote location of the Davidson Seamount, also takes into account a maximum safe flight distance of 500 nautical miles. However, the designs differed considerably between the January and April surveys.

The January survey consisted of a zig-zag (NW to SE) flight pattern of three lines in five distinct boxes over and around the Davidson Seamount. One box was over the seamount itself, while the other four were to the north, east, south, and west of the seamount (Figure 1).

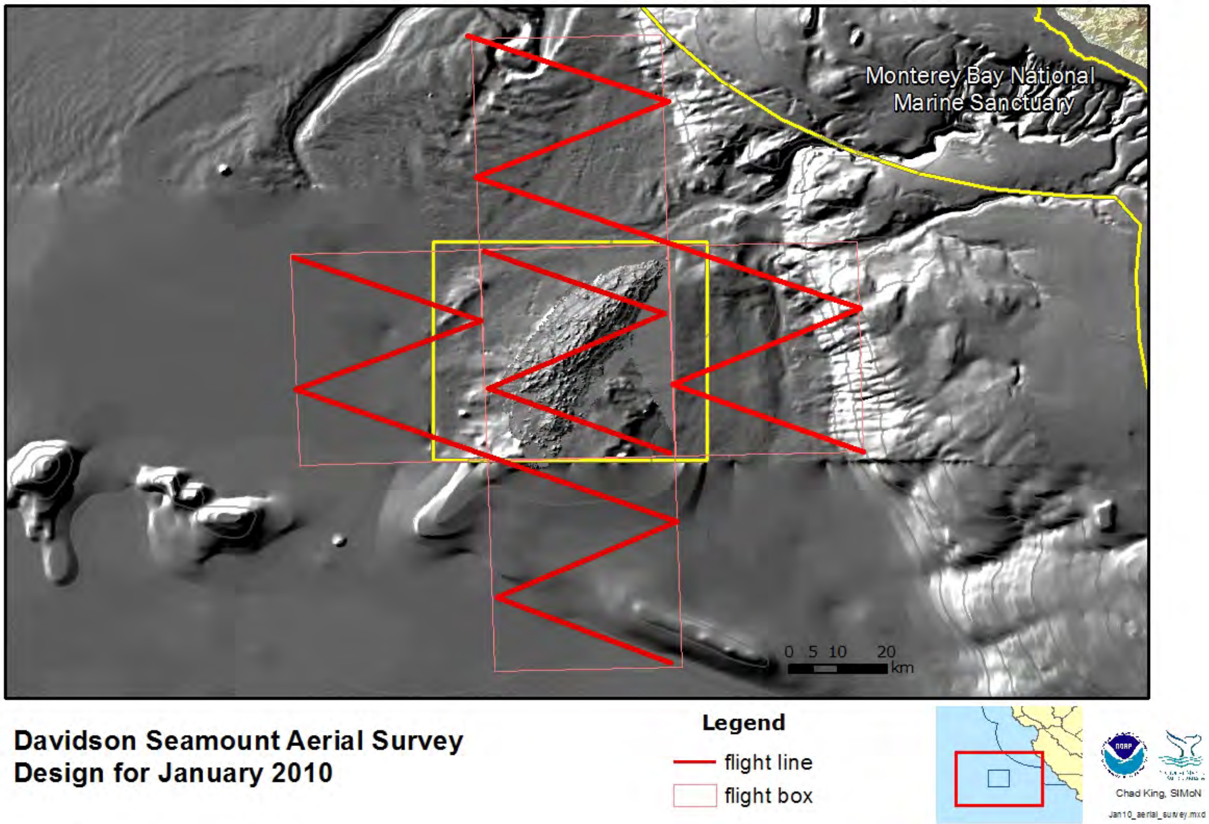

Figure 2. Aerial survey design for January 2010

As project management transitioned after the January 2010 survey, the design changed. To maximize the area surveyed, above and away from or surrounding the seamount, while optimizing the number of transects and maintaining flight efficiency, transects were selected perpendicular to the main axis of the seamount (Figure 4).

Figure 3. Monterey Bay National Marine Sanctuary staff and Moss Landing Marine Laboratories graduate students prior to an aerial survey for marine mammals near the Davidson Seamount aboard the NOAA DeHavilland Twin Otter N48RF on April 19, 2010.

The maximum survey footprint was designed to cover the entire axial length of the seamount (42.2 kilometer) and to include 44.4 kilometers of surface water perpendicular to each side of the axis of the seamount for a total potential area of 3,747 square kilometers (Figure 2). The observer "footprint" was 2.02 km wide (1.01 km on each side of the plane). This was calculated with a maximum observer angle of 12 degrees and a flying altitude of 210 meters.

Given the approximate width of the observer footprint, and to prevent overlap of parallel survey lines, 22 origination points fit within the 42.2 km axial length of the study area. These 22 points were placed at an equal distance from each other along the northwestern and southeastern ends of the study area (Figure 3).

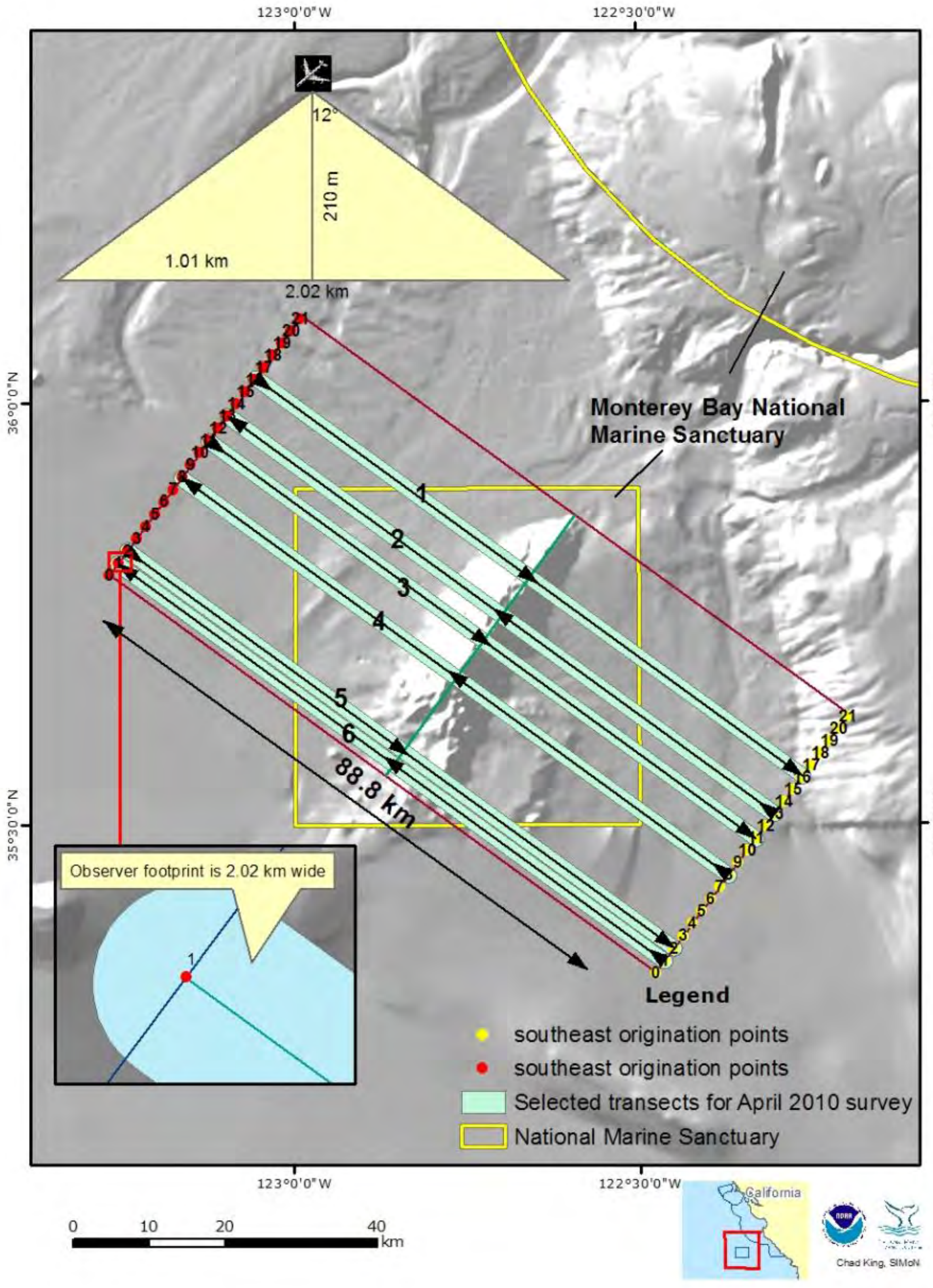

Figure 4. Aerial survey design for April 2010.

For each survey date, six random numbers with a value between 0 and 21 were selected, and were only selected once per survey date. Additionally, three must be even numbers (transects starting from the northwest) and 3 must be odd numbers (transects starting from the southeast). These points have corresponding latitude and longitude that are then acquired and put into the flight plan. When the Twin Otter was in the study area, it flew transects in descending order of point value, starting from the northwest at a heading of 126 degrees, then back at 306 degrees. This process is repeated for all coordinates selected, or when fuel was low, whichever came first.

Observations of marine mammals were made by trained and qualified individuals to ensure confidence in species identifications and counts. There was at least one observer on each side of the plane that sit in the most forward portion of the main cabin and use a large observation “bubble” (convex viewing port made of plexiglass) that extend away from the body of the aircraft to ensure an unobstructed view of marine mammals directly below and out to 12 degrees (Figure 5). A third observer accessed a plexiglass port in the back belly of the plane to observer marine mammals directly below the plane. Each observer also used a Suunto Tandem (inclinator and compass) to approximate the angle and distance of the marine mammal observed. All observers verbally relayed their counts and identifications to a fourth person who entered the data into custom-written software program on a laptop. This laptop was connected to the plane’s GPS system, enabling all observations to have a latitude and longitude automatically incorporated into the record. Variables recorded for each flight included: event code, effort, time, latitude, longitude, observer, viewing conditions, altitude, speed, weather, mammal sighting (marine mammal species code, see Table 1), re-sights, and turtle sightings. After the flight, this digital tabular file was imported into a GIS for spatial analysis and cartographic products.

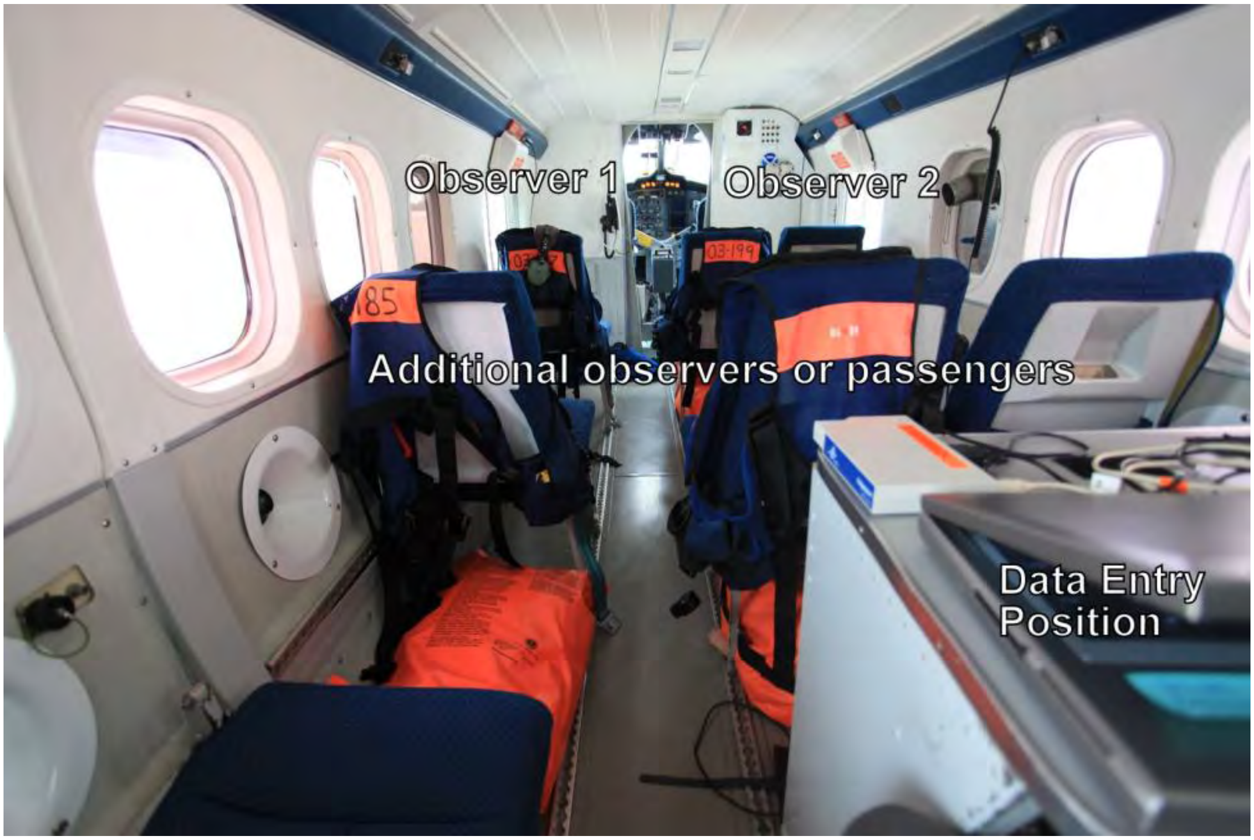

Figure 5. View of the Twin Otter's main cabin, looking forward. Observers 1 and 2 sit near the front of the cabin and view marine mammals through "bubble" widows. A data entry person sits near the rear of the plane and enters observations into a laptop. A third observer (position not seen here) lays down in the rear of the plane to view marine mammals through a plexiglass port in the belly of the plane.

Table 1. Species codes for aerial surveys

Large whales	**Medium-sized whales**
PM Sperm whale	BD *Berardius bairdii*
MN Humpback whale	ZI *Ziphius cavirostris*
BM Blue whale	UM *Mesoplodon* sp.
BP Fin whale	MC *Mesoplodon carlhubbsi*
ER Gray whale	UK *Kogia* sp.
EG Right whale	BA Minke whale
BB Sei whale	SW Unid. small whale
BE Bryde's whale	
UB Unid. baleen whale	
LW Unid. large whale	
Dolphins/Porpoises	**Pinnipeds/Fissiped**
PP Harbor porpoise	PV Harbor seal
PD Dall's porpoise	MA Elephant seal
DD *Delphinus* (unspecified)	EJ Steller sea lion
DS *Delphinus* (short-beaked)	CU Northern fur seal
DL *Delphinus* (long-beaked)	EL Sea otter
LB *Lissodelphis*	PU Unid. pinniped

LO ‘*Lags*’ / Pacific white-sided	US Unid. Seal
GG Grampus / Risso’s	[ZC CA sea lion - Not recorded]
GM Pilot whale	
OO Killer whale	
UD Unid. dolphin/porpoise	

Ship-board Surveys

From July 23-25, 2010, the R/V *MacArthur II* conducted marine mammal and seabird observations at the Davidson Seamount.

Visual Surveys

Line transect survey methods were used to collect cetacean abundance data. A daily watch for cetaceans occurred on the flying bridge during daylight hours (approximately 0700 – 1900) by six (6) mammal observers. Each observer worked in 2-hour rotations, manning each of the following three stations on the flying bridge for 40 minutes: a port side 7x 50 or 25x150 binocular station, a center-line data recorder position, and a starboard 7 x 50 or 25x150 binocular station (Figure 6). An “independent observer” sometimes kept a separate watch of animals sighted during the cetacean survey operations, to be compared later with the observer team’s data.

Visual surveys of seabirds were conducted from the flying bridge during daylight hours by two seabird observers. Seabird observers used handheld and 25x150 binoculars.

Figure 6. Observer using a binocular station (left) and observers using binoculars on flying bridge chairs on the R/V MacArthur II (credit: NOAA)

Ship Speed, Order of Operations

At the beginning of each day search effort started on the eastern waypoint of the trackline. The McArthur II traveled at approximately 10kt (through the water) along the designated trackline. While on search effort, if the ship’s speed through the water deviated from this by more than 1kt, the bridge personnel notified the mammal team on watch or the Cruise Leader.

On sighting a marine mammal school or other feature of biological interest, the Cruise Leader or marine mammal observer team on watch sometimes requested that the vessel be maneuvered to approach the school or feature for investigation. When the ship approached a school of dolphins, the observers made independent estimates of school size. Photography operations were directed by the Cruise Leader and Senior Marine Mammal Observers. Due to permit restrictions, the ship remained at least 100 yards away from all marine mammals unless the animals actively approached the vessel (ex. for bow riding).

When the observers have completed scientific operations for the sighting, the ship will resume the same course and speed as prior to the sighting. If the pursuit of the sighting has taken the ship more than 3nm from the trackline, the observers should be notified. The Cruise Leader or Senior Marine Mammal Observers may request that, rather than proceed directly toward the next waypoint, the ship take a heading of 20 degrees back toward the trackline or return to the position at which the ship diverted before resuming effort.

Ship Equipment Required

Observation computers (mammal and seabirds) were connected to the ship's GPS (for course, speed and position information). A log of observation conditions, watch effort, sightings and other required information was entered into a computer which was linked to the ship's GPS (for course, speed and position information).

Photography

Photographs of marine mammals were taken on an opportunistic basis. These photos are used to study social behavior and movement patterns of identified individuals, confirm species identification, and to study geographic variation.

Oceanography

Ship Speed, Order of Operations

A chronological record of oceanographic and net tow stations was kept by the ship (Marine Operations Log) with dates and times in GMT. The ship provided a copy of the electronic marine operations log (with the cruise Weather Log and SCS data) to the Chief Scientist at the completion of the cruise.

The collection of oceanographic samples and their processing was conducted by the oceanographer, ship's Survey Technician, and other designated scientists with assistance from the Deck Department as required. A thermosalinograph continuously collected surface water temperature and salinity.

CTD Stations

Two CTD stations were occupied each night after the end of the marine mammal and seabird observations (approximately 1900) at the designated CTD stations for the evening. CTD data were collected using the SeaBird 9/11+ CTD (Figure 7). The ship's Survey Technician was responsible for the CTD operations and maintenance. All casts were to 1000m, and cast descent rates were 30m per minute for the first 100m of the cast, then 60m/min after that. Each CTD cast was conducted at the designated station locations for the evening.

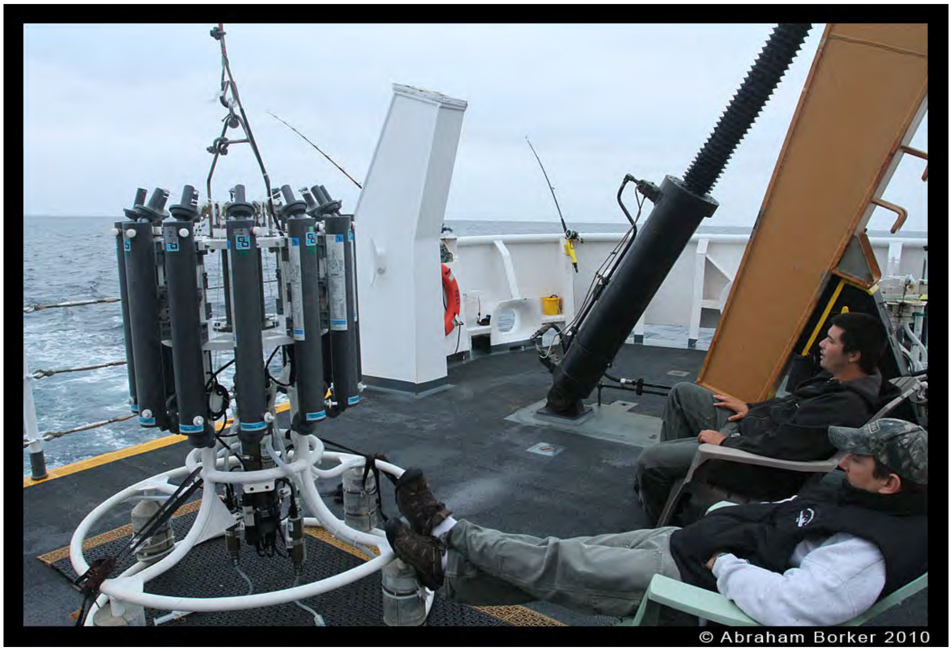

Figure 7. CTD on the aft deck of the R/V MacArthur II.

Prey Fishes

The scientific EK60 depth sounder was operated continuously at 38, 70, 120, and 200 kHz to remotely detect prey fishes below the vessel.

Net Sampling

Net tows were conducted by the scientific party as assigned by the Cruise Leader, with assistance from a winch operator. Three net tows per night were conducted no sooner than one hour after sunset and at the conclusion of the first CTD cast. An oblique bongo tow was conducted immediately following the first CTD station, at the middle station location, and before the second CTD at the third station location. Each bongo tow commenced 15 minutes after the evening CTD station, to a depth of 200 meters and for duration of 45 minutes. The bongo has 505-micron mesh on the starboard side, and 333-micron mesh on the port side (Figure 8). Samples were preserved in formalin or frozen, labeled and stored in containers.

Figure 8. Scientific crew preparing deployment of a bongo tow. Credit: NOAA.

Daily Operations Summary – (from Cruise Log: July 23 – 25, 2010)

Friday July 23, 2010

Began daytime operations at station 0E at 0700. All transect lines were to the NW or SE at a ship speed of 10 kts +/- 0.5 kts. Completed transect lines 0 and 4, and portion of transect 8 under overcast skies with very light wind and calm seas. We had to deviate from transect line 4 to avoid a large ship, however we remained "on-effort" searching for marine mammals and seabirds the entire time.

Nighttime operations took place between 2000 and 0200.We conducted CTD casts and Bongo net tows at stations 4W, 4M, & 4E. Squid jigging took place during the CTD cast at each station, but once again no squid were caught. At the completion of station 4E, the ship transited to the break-off point on transect 8.

Saturday July 24, 2010

Daytime operations began again at 0700 at the break-off point on transect 8 from Friday. We finished the remainder of transect 8, transect 12, and a portion of transect 16 prior to 1900. We went "off-effort" during transect 8 to identify and count a large school of Pacific white-sided and northern right whale dolphins. Each observer provided an independent estimate of the best/high/low numbers of animals in the school with the percentage of each species. A reasonable average was determined based on the estimates. Weather was again overcast with calm seas and light wind.

Nighttime operations commenced at 2000 and finished around 0300 Sunday morning. We occupied 4 stations (10E, 10M, 10W, & 16E) and conducted CTD casts and Bongo net tows at each station.

We caught no squid while jigging during each CTD cast. At the completion of Station 16E, the ship transited to the break-off point on transect 16.

Sunday July 25, 2010

Daytime operations began again at 0700 at the break-off point on transect 16 from Saturday. Weather was the same, overcast skies and calm seas, but with more wind (Beaufort 3 conditions all day). We finished the remainder of transect 16 and all of transect 20. We had extra time to survey, so we added 2 additional transects. Transect 24 is parallel to, and 4 miles north of, transect 20. We ended transect 24 at the axis of the seamount. We then made a 90 degree left turn to complete a transect down the axis of the Davidson Seamount. We went “off-effort” for approximately 2 miles from the turning point to avoid double counting any marine mammals or seabirds. The axis transect (transect 25) began at almost the same location as station 22M and continued along the axis until 1845 when the ship had to return to complete station 22M prior to departing the Davidson Seamount for San Francisco.

The ship reached station 22M around 2000 and conducted a CTD cast and Bongo net tow. One last attempt to jig for squid was unsuccessful. After the completion of the Bongo net tow at 2200 the ship departed the seamount and headed for San Francisco.

Results

Aerial Surveys

On January 14, 2010, approximately 542 kilometers of “on effort” transects were flown in five zig zag formations to the north, south, east, west and over the Davidson Seamount (Figure 9). Species identified during the survey included: California sea lion (*Zalophus californianus*), Cuvier’s beaked whale (*Ziphius cavirostris*), Grey whale (*Eschrichtius robustus*), Killer whale (*Orcinus* orca), Humpback whale (*Megaptera novaeangliae*), Sperm whale (*Physeter macrocephalus*), Laysan Albatross (*Phoebastria immutabilis*), Northern Fulmar (*Fulmarus glacialis*), Storm petrel (family *Hydrobatidae*), and the Ocean sunfish (*Mola mola*). Four groups of sightings included unidentified dolphins, unidentified bird, unidentified alcid, and unidentified whale, for a total of 13 distinctly recorded species groups. 139 individual animals (Table 2) for an individual encounter rate of 0.26 animals per kilometer, 0.20 seabirds per kilometer, and only 0.04 marine mammals per kilometer.

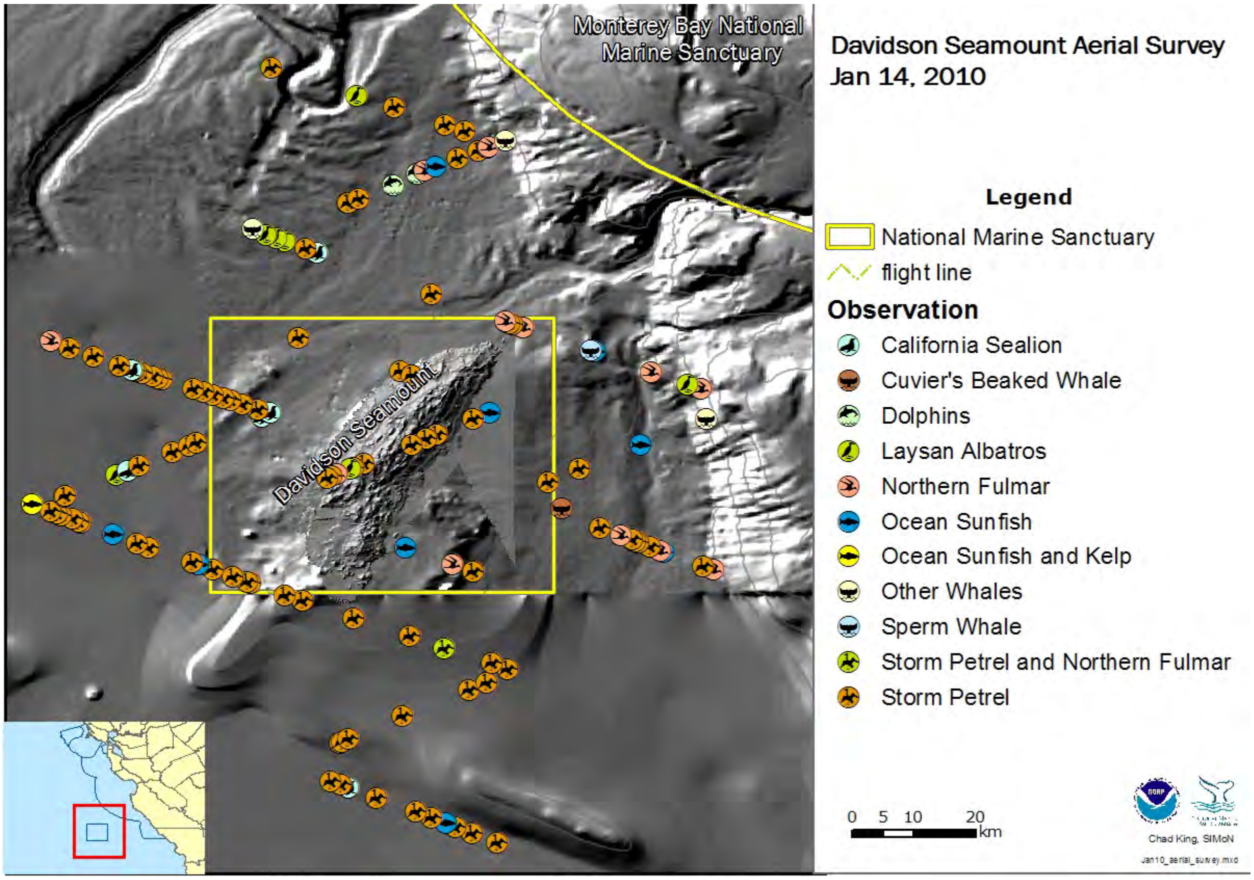

Figure 9. Marine mammal and seabird observations from the January 14, 2010 aerial survey of the Davidson Seamount.

Table 2. Number of species observed during the January 14, 2010 aerial survey of the Davidson Seamount.

Species	Total Individuals
California sea lion	6
Cuvier's beaked whale	1
Grey whale	2
Killer whale	1
Laysan Albatross	6
Northern Fulmar	16
Sperm whale	1
Storm-petrel	87
Sunfish	10
unid bird	1
unid dolphin	2
unid whale	5
Unidentified alcid	1
Grand Total	**139**

On April 19, 2010, five transects were flown perpendicular to the main axis of the Davidson Seamount, totaling approximately 400 kilometers of "on effort" transects (Figure 10). Species identified during the survey included: Blue whale (*Balaenoptera musculus*), California sea lion (*Zalophus californianus*), Humpback whale (*Megaptera novaeangliae*), Sperm whale (*Physeter macrocephalus*), and the Ocean sunfish (*Mola mola*). Two groups of sightings included unidentified dolphins and unidentified whale, for a total of eight distinctly recorded species groups. Seventy-eight (78) individual sightings were recorded, totaling 336 individual animals (Table 3) for an individual encounter rate of 0.84 animals per kilometer and 0.79 marine mammals per kilometer.

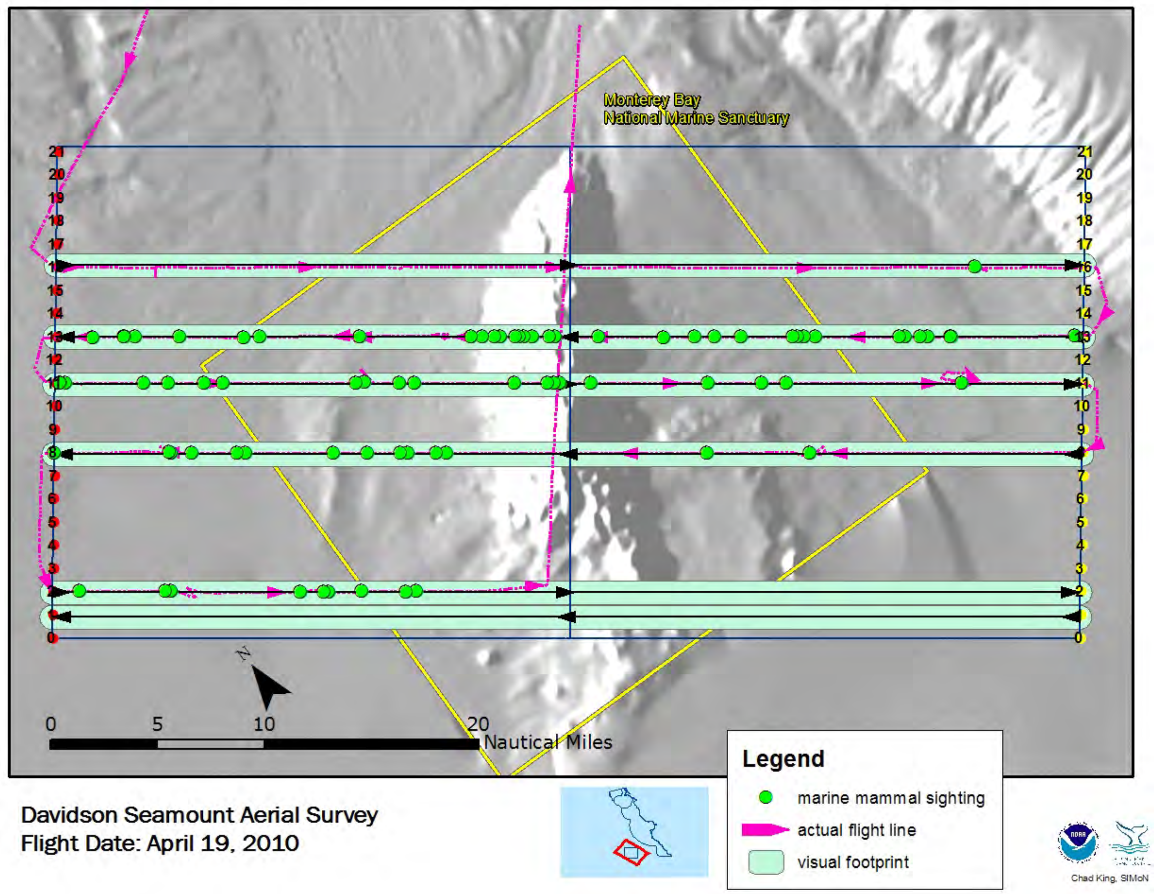

Figure 10. Map of aerial survey flight line and marine mammal sightings over the Davidson Seamount on April 19, 2010.

Table 3. Number of species observed during the April 19, 2010 aerial survey over the Davidson Seamount.

Species	Total Individuals
Blue whale	1
California sea lion	121
Elephant seal	1
Humpback whale	2
Sperm whale	2
Sunfish	21
unid dolphin	186
unid whale	2
Grand Total	**336**

Ship-board Surveys

Visual Surveys

Seven transects were made perpendicular to the main axis of the Davidson Seamount (585 total kilometers) and one transect traversed directly over the main axis of the seamount (30 kilometer transect length) (Figure 11). On-effort transect length totaled approximately 615 kilometers. Seventeen species of seabirds were observed in addition to unidentified Alcids and Terns, for a total of 316 sightings and 1,033 individuals (Table 4), an encounter rate of 1.68 seabirds per kilometer. Six species of marine mammals were observed in addition to groups of unidentified Pinnipeds, Otariids, Ziphiids, Fur Seals and Rorquals, for a total of 200 sightings and 668 individuals (Table 5), an encounter rate of 1.09 marine mammals per kilometer.

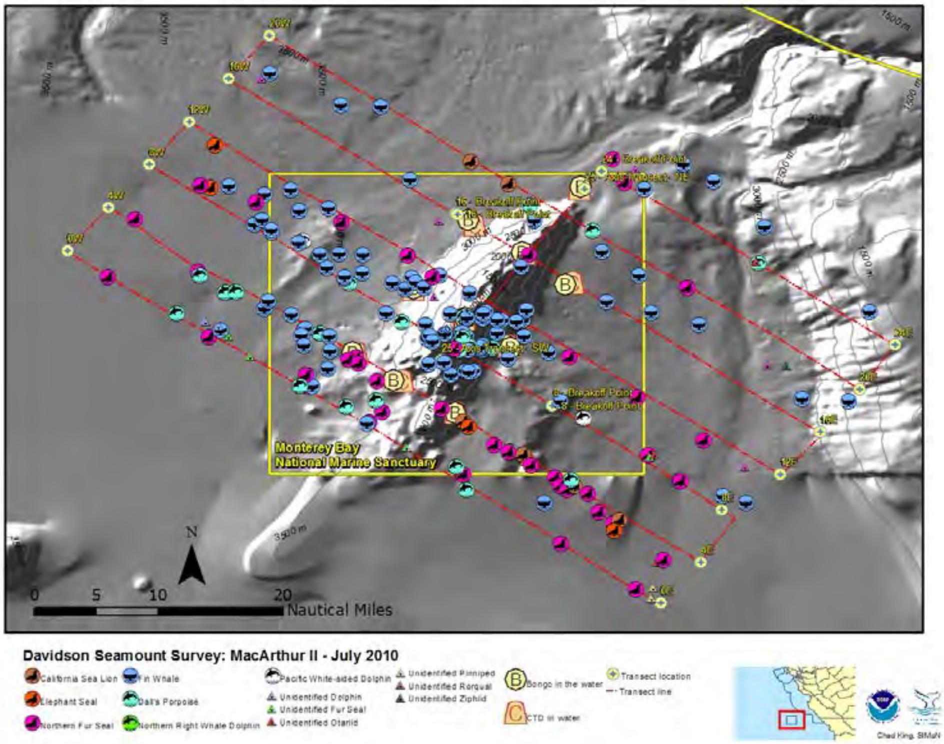

Figure 11. Map detailing scientific observations and measurements taken over and near the Davidson Seamount. Observations include those of marine mammals and seabirds. Oceanographic measurements by CTD. Bongo tows sampled plankton.

Table 4. Ship-based seabird observations by species and day.

	Day 1 - July 23, 2010		Day 2 - July 24, 2010		Day 3 - July 25, 2010		Overall Total	
Seabird Species	# Sightings	# of Individuals	# Sightings	# of Individuals	# Sightings	# of individuals	# Sightings	# of Individuals
Cook's Petrel	39	166	42	235	40	106	121	507
Leach's Storm Petrel	55	191	42	82	27	65	124	338
Red-necked Phalarope	6	33	5	52	1	1	12	86
Red Phalarope	9	11	3	11	5	9	17	31
Least Sandpiper	2	14					2	14
Arctic Tern	5	5	3	3	6	6	14	14
Short-billed Dowitcher	1	11					1	11
Xantus' Murrelet	3	4	1	1	3	4	7	9
Black-bellied Plover			1	6			1	6
Long-tailed Jaeger					3	3	3	3
Pink-footed Shearwater	1	1	2	2			3	3
Sooty Shearwater	1	1	1	1	2	2	4	4
Black-footed Albatross			1	1			1	1
Cassin's Auklet			1	1			1	1
Northern Fulmar	1	1					1	1
California Gull					1	1	1	1
Western Gull					1	1	1	1
Unid Alcid	1	1					1	1
Unid Tern			1	1			1	1
Total	124	439	103	396	89	198	316	1033

Table 5. Ship-based marine mammal observations by species and day.

	Day 1 - July 23, 2010		Day 2 - July 24, 2010		Day 3 - July 25, 2010		Overall Total	
Marine Mammals	# Sightings	# of Individuals	# Sightings	# of Individuals	# Sightings	# of Individuals	# Sightings	# of Individuals
22: Pacific White-sided	1	5	1	300*			2	305
74: Fin Whale	19	36	45	87	38	74	102	197
44: Dall's Porpoise	11	38	4	15	6	25	21	78
4: Northern Fur Seal	29	35	8	8	5	5	42	48
70: Unid Rorqual			4	6	3	3	7	9
1: California Sea Lion	4	4			2	2	6	6
3: Elephant Seal	3	3	3	3			6	6
11: Unid Fur Seal	4	4					4	4
49: Unid Ziphiid					1	4	1	4
6: Unid Otariid	3	3			1	1	4	4
77: Unid Dolphin	3	5					3	5
7: Unid Pinniped	2	2					2	2
Total	79	135	65	419	56	114	200	668

Oceanography

Net Sampling and CTD

Net Sampling and CTD were successfully deployed at 10 stations over and near the Davidson Seamount (Figure 11 and Table 6). Data summaries of plankton biomass and identifications were not available at the time of this report.

Table 6. CTD and Bongo deployments from July 22-26, 2010.

Date GMT	Time GMT	Date PDT	Time PDT	Button	Station	Decimal LAT	Decimal LON	TSG Water Temp C	Salinity	Conductivity
7/23/2010	6:41:55	7/22/2010	23:41:55	CTD in water	Station16W	35.8314	-122.7250	15.8752	33.2900	4.1861
7/23/2010	7:58:03	7/23/2010	0:58:03	Bongo in the water	Station16W	35.8385	-122.7343	15.8015	33.29	4.1789
7/23/2010	8:55:06	7/23/2010	1:55:06	CTD in water	Station16M	35.7932	-122.6598	15.8136	33.27	4.1778
7/23/2010	9:40:36	7/23/2010	2:40:36	Bongo in the water	Station16M	35.7949	-122.6626	15.773	33.26	4.17328
7/24/2010	3:28:23	7/23/2010	20:28:23	CTD in water	Station4W	35.6597	-122.8836	15.474	33.15	4.133
7/24/2010	4:14:28	7/23/2010	21:14:28	Bongo in the water	Station4W	35.6616	-122.8892	15.4601	33.16	4.13227
7/24/2010	5:21:29	7/23/2010	22:21:29	CTD in water	Station4M	35.6230	-122.8217	15.4671	33.18	4.13553
7/24/2010	6:41:27	7/23/2010	23:41:27	Bongo in the water	Station4M	35.6239	-122.8342	15.354	33.17	4.12335
7/24/2010	7:26:05	7/24/2010	0:26:05	CTD in water	Station4E	35.5807	-122.7515	15.3069	33.31	4.13449
7/24/2010	8:07:44	7/24/2010	1:07:44	Bongo in the water	Station4E	35.5809	-122.7522	15.2796	33.3	4.13143
7/25/2010	3:27:53	7/24/2010	20:27:53	CTD in water	Station10E	35.6700	-122.6797	15.005	33.34	4.11008
7/25/2010	4:23:17	7/24/2010	21:23:17	Bongo in the water	Station10E	35.6673	-122.6777	14.7927	33.36	4.09144
7/25/2010	5:14:20	7/24/2010	22:14:20	CTD in water	Station10M	35.7051	-122.7394	14.7554	33.36	4.0883
7/25/2010	5:58:38	7/24/2010	22:58:38	Bongo in the water	Station10M	35.7075	-122.7390	15.2448	33.36	4.13465
7/25/2010	6:49:24	7/24/2010	23:49:24	CTD in water	Station10W	35.7459	-122.8077	15.3966	33.3	4.14167
7/25/2010	7:31:16	7/25/2010	0:31:16	Bongo in the water	Station10W	35.7465	-122.8076	15.4007	33.29	4.14149
7/25/2010	9:18:14	7/25/2010	2:18:14	CTD in water	Station16E	35.7538	-122.5943	15.0404	33.31	4.10926
7/25/2010	9:58:06	7/25/2010	2:58:06	Bongo in the water	Station16E	35.7521	-122.6053	15.0622	33.31	4.11134
7/26/2010	3:23:00	7/25/2010	20:23:00	CTD in water	Station22M	35.8799	-122.5856	15.6761	33.27	4.16491
7/26/2010	4:25:02	7/25/2010	21:25:02	Bongo in the water	Station22M	35.8824	-122.5844	15.6318	33.28	4.16174

Survey Comparison

The three surveys conducted in 2010 serve as a baseline for future surveys. Although the ship-based survey yielded more marine mammals encountered per kilometer than either of the aerial surveys (Table 7), correlating non-temporal variables (seasonality, inter-annual, etc.) with encounter rates is not yet possible. Seasonality most certainly plays a large role in the relative density and species diversity of marine mammals; not just in terms of oceanographic patterns and prey availability, but also marine mammal annual migration patterns and feeding behaviors.

Table 7. Marine mammal encounter rates for three 2010 surveys over the Davidson Seamount (2 aerial, 1 ship).

Type	Date	No. Marine Mammals	km of transect	Marine Mammals per linear km
Aerial	1/14/2010	23	542	0.042
Aerial	4/19/2010	315	400	0.788
Ship	7/23-25/10	668	615	1.086

Another factor to consider is the relative survey footprint each survey design covers. It is estimated that every kilometer of linear aerial transect length corresponds to a visual footprint of 2.02 square kilometers. Footprint estimates have yet been made for ship-based surveys. However, a temporal encounter rate reveals that aerial surveys may be more efficient to observe marine mammals in terms of man-hours (Table 8). Hours of effort are not cumulative of total observer hours; they reflect hours the plane or ship was on transect.

Table 8. Marine mammal encounter rates per hour of survey effort for three 2010 surveys over the Davidson Seamount (2 aerial, 1 ship).

Type	Date	No. Marine Mammals	hours of effort	Marine Mammals per hr
Aerial	1/14/2010	23	4.25	5.41
Aerial	4/19/2010	315	3	105
Ship	7/23-25/10	668	36.75	18.2