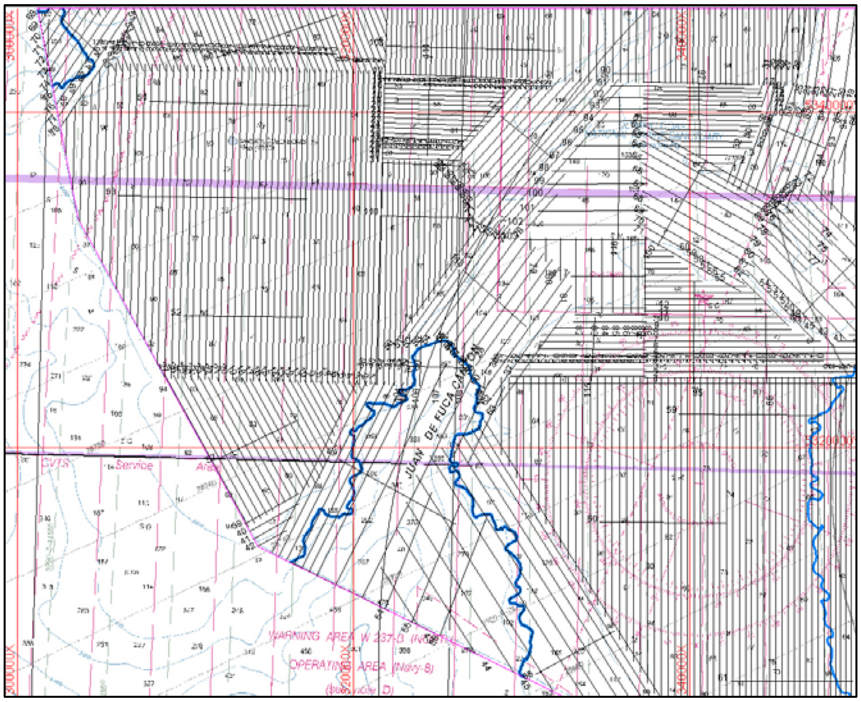
Marine Sanctuaries Conservation Series NMSP-06-11



Habitat Mapping Effort at the Olympic Coast National Marine Sanctuary – Current Status and Future Needs

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean and Coastal Resource Management
National Marine Sanctuary Program

December 2006

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The National Oceanic and Atmospheric Administration's National Ocean Service (NOS) administers the National Marine Sanctuary Program (NMSP). Its mission is to identify, designate, protect and manage the ecological, recreational, research, educational, historical, and aesthetic resources and qualities of nationally significant coastal and marine areas. The existing marine sanctuaries differ widely in their natural and historical resources and include nearshore and open ocean areas ranging in size from less than one to over 5,000 square miles. Protected habitats include rocky coasts, kelp forests, coral reefs, sea grass beds, estuarine habitats, hard and soft bottom habitats, segments of whale migration routes, and shipwrecks.

Because of considerable differences in settings, resources, and threats, each marine sanctuary has a tailored management plan. Conservation, education, research, monitoring and enforcement programs vary accordingly. The integration of these programs is fundamental to marine protected area management. The Marine Sanctuaries Conservation Series reflects and supports this integration by providing a forum for publication and discussion of the complex issues currently facing the National Marine Sanctuary Program. Topics of published reports vary substantially and may include descriptions of educational programs, discussions on resource management issues, and results of scientific research and monitoring projects. The series facilitates integration of natural sciences, socioeconomic and cultural sciences, education, and policy development to accomplish the diverse needs of NOAA's resource protection mandate.

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December 2006

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COVER

Cover image shows a sample of survey line planning for a multibeam bathymetry survey. Note the tighter line spacing required for surveying in shallower waters.

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ABSTRACT

With elevating interest to establish conservation efforts for groundfish stocks and continued scrutiny over the value of marine protected areas along the west coast, the importance of enhancing our knowledge of seabed characteristics through mapping activities is becoming increasingly more important, especially in a timely manner. Shortly after the inception of the Seabed Mapping Initiative instituted with the US Geological Survey (USGS), the National Marine Sanctuary Program (NMSP) assembled a panel of habitat mapping experts. They determined that the status of existing data sets and future data acquisition needs varied widely among the individual sanctuaries and that more detailed site assessments were needed to better prioritize mapping efforts and outline an overall joint strategy. To assist with that specific effort and provide pertinent information for the Olympic Coast National Marine Sanctuary's (OCNMS) Management Plan Review, this report summarizes the mapping efforts that have taken place at the site to date; calculates a timeframe for completion of baseline mapping efforts when operating under current data acquisition limitations; describes an optimized survey strategy to dramatically reduce the required time to complete baseline surveying; and provides estimates for the needed vessel sea-days (DAS) to accomplish baseline survey completion within a 2, 5 and 10 year timeframe.

KEY WORDS

Benthic, habitat mapping, side scan sonar, multibeam echosounder, multibeam side scan sonar, interferometric side scan and bathymetry, Olympic Coast National Marine Sanctuary, essential fish habitat

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION

With increasing interest in establishing conservation efforts for groundfish stocks and continued scrutiny over the value of marine protected areas along the west coast, the importance of enhancing our knowledge of seabed characteristics in a timely manner through mapping activities is becoming increasingly more important. As evidence, a marine mapping workshop was recently held in California to prioritize areas for seabed mapping (Kvitek and Bretz 2006), based on a variety of user needs, and a Request for Proposal (RFP) was subsequently drafted in less than four months, and called for complete mapping of California's northern central marine waters (<3 nautical miles from shore) between Monterey and Bodegas Bay (RFP 2006).

Additionally, the Washington State Ocean Policy Work Group (OPWG), established in August 2005 in response to a budget proviso requiring the Governor to institute an ocean policy agenda for the State, recently declared

> *"one relevant and plausible way the State can contribute to the conservation and enhancement of groundfish and other stocks is through benthic habitat mapping and characterization" (OPWG 2005).*

Over the past several years benthic habitat mapping has also become a major program focus for the National Marine Sanctuary Program (NMSP), as evident by inception of the Seabed Mapping Initiative and Memorandum of Agreement (MOU) instituted with the US Geological Survey (NOAA NOS 2002), and through the various ongoing seabed mapping activities occurring at several of the 13 sanctuaries, including the Olympic Coast National Marine Sanctuary (Intelmann 2006; Intelmann and Cochrane 2006a; Intelmann and Cochrane 2006b; and Intelmann 2006).

Shortly after the signing of the above MOU, a panel of habitat mapping experts determined the status of existing data sets and future data acquisition needs to vary widely among the individual sanctuaries and that more detailed site assessments were needed to better prioritize mapping efforts and outline an overall joint strategy (NOAA NMSP 2003). To assist with that specific effort and provide pertinent information for the Olympic Coast National Marine Sanctuary's (OCNMS) Management Plan Review, this report summarizes the mapping efforts that have taken place at the site to date; calculates a timeframe for completion of baseline mapping efforts when operating under current data acquisition limitations; describes an optimized survey strategy to dramatically reduce the required time to complete baseline surveying; and provides estimates for the needed vessel sea-days to accomplish baseline survey completion within a 2, 5 and 10 year timeframe.

CURRENT DATA HOLDINGS

Aside from a handful of side scan sonar "skunk stripes" collected in 1997 and 1998 by the USGS to describe surficial geology (Twichell et al. 2000) and a narrow band (3 km wide) geophysical survey designed to reconnoiter a potential underwater cable-lay route in 1999, there was virtually no useful contemporary data available for describing benthic habitats within the OCNMS prior to 2001. Available bathymetry data consisted of sparse soundings extracted from the National Geophysical Data Center's GEODAS (GEOphysical Data System), and were mostly a product of single-beam echosounding surveys barely capable of producing a low-resolution (90 meter grid) digital terrain model for the entire sanctuary boundary.

Multibeam Bathymetry

A significant first step was taken to reduce this data gap by successful request of ship-time through NOAA's fleet allocation plan. Between 2001 and 2004, OCNMS received 10 days-at-sea (DAS) during the month of October from the NOAA hydrographic survey ship *RAINIER*. With a variety of multibeam echosounding capabilities onboard, the *RAINIER* provided the ability to simultaneously survey both nearshore (Intelmann et al. 2006) and offshore areas within OCNMS. Additionally, a transfer of significant FY03 site base funds to NOAA's Office of Coast Survey (OCS) helped provide assistance with survey equipment requisitions that in turn resulted in OCNMS receiving unlimited access to a *RAINIER* multibeam survey launch (solely operated by OCNMS staff) for a period of 6 weeks during the summer of 2003.

Over 468 nm^2 of the sanctuary were surveyed during the four-year period of *RAINIER* surveys (Table 1). An important consideration with respect to survey planning is evident in Figure 1, namely the correlation of multibeam swath width to water depth. In survey sheets A and F, the two shallow water survey areas, the ratio of area covered to acquisition time was much smaller compared to any of the other offshore areas. The relatively small survey area A (31.87 nm^2) required over 119 hours to complete while survey area P (78.43 nm^2) took just over 51 hours of acquisition time.

Table 1. Multibeam bathymetry data acquisition statistics from the *NOAA SHIP RAINIER* hydrographic surveys in OCNMS (2001-2004). Acquisition time is actual minutes of logged data and does not reflect down time for line turns or for acquiring sound velocity measurements. $^+$Survey area conducted from *RAINIER* survey launch by OCNMS site staff during the summer of 2003.

Survey Area	Acquisition Time	Area_nm^2	Linear (nm) Tracklines
A	119:18:00	31.87	944.59
B	9:32:44	5.35	88.83
C	23:24:47	38.12	202.34
D	41:29:40	65.89	448.21
F^+	85:52:36	26.46	717.92
P	51:33:19	78.43	453.10
S	66:47:03	115.66	358.40
T	83:17:22	106.25	659.56
Total	**481:15:31**	**468.01**	**3,872.95**

Water depths were under 50 meters throughout sheet A, and between 150-300 meters in sheet P (Figure 2). Thus it is obvious that using multibeam echosounders requires more survey time in shallow water due to the tighter line spacing required to achieve full bottom coverage.

Despite persistent annual ship-time requests, OCNMS has not been successful at receiving hydrographic survey vessel time through the Office of Marine and Aviation Operations' (OMOA) fleet allocation process since 2004. As such, no further bathymetry data has been collected by acoustic methodology since that time.

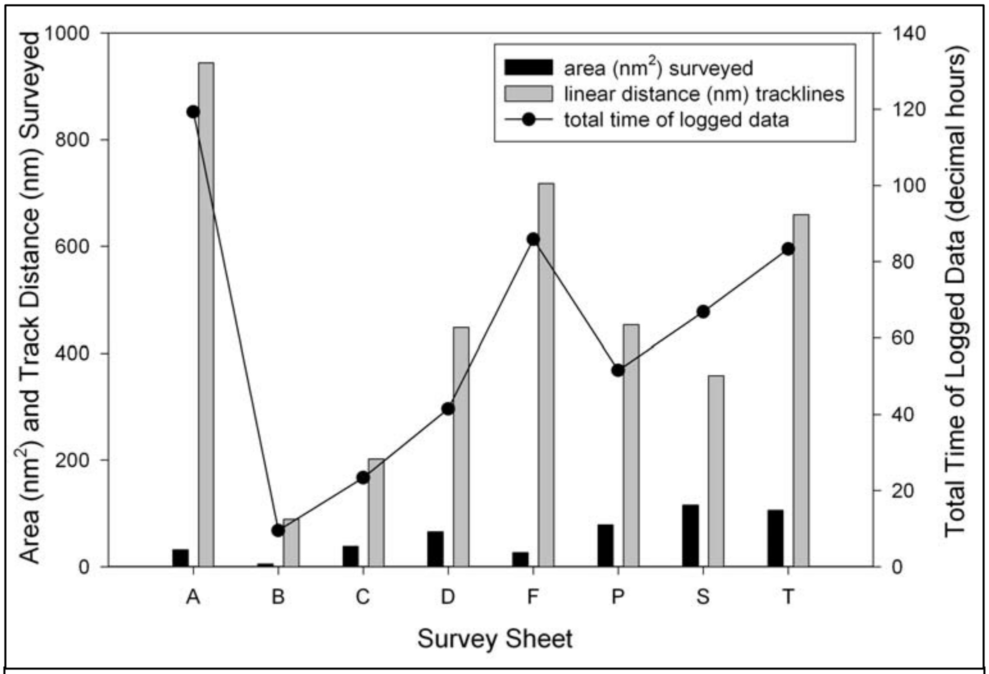

Figure 1. Graphical representation of *NOAA SHIP RAINIER* hydrographic survey effort (2001-2004) by specific area in OCNMS. Bar graph corresponds to left y-axis and line-scatter plot corresponds to right y-axis. Geographical location of survey sheets are shown in Figure 2.

It should be noted that two other small blocks of multibeam bathymetry data were available from the Washington Department of Fish and Wildlife (WDFW) but were not useful to OCNMS. Only the extracted XYZ data were made available to OCNMS from an offshore dataset collected in 1998 (Jagielo et al. 2003) and unfortunately was of poor quality. Had the raw sonar packets from the Reson 8101 been made accessible, better data cleaning and refraction editing could possibly have salvaged the data set. Furthermore, their nearshore dataset collected in 2000 was acquired with a lower frequency Elac 1180 multibeam echosounder in unfavorable sea conditions. Even though the raw sonar data were tracked down and converted to Caris Hips format for this particular survey, noise due to excessive vessel movement and low sounding densities rendered that data unuseable.

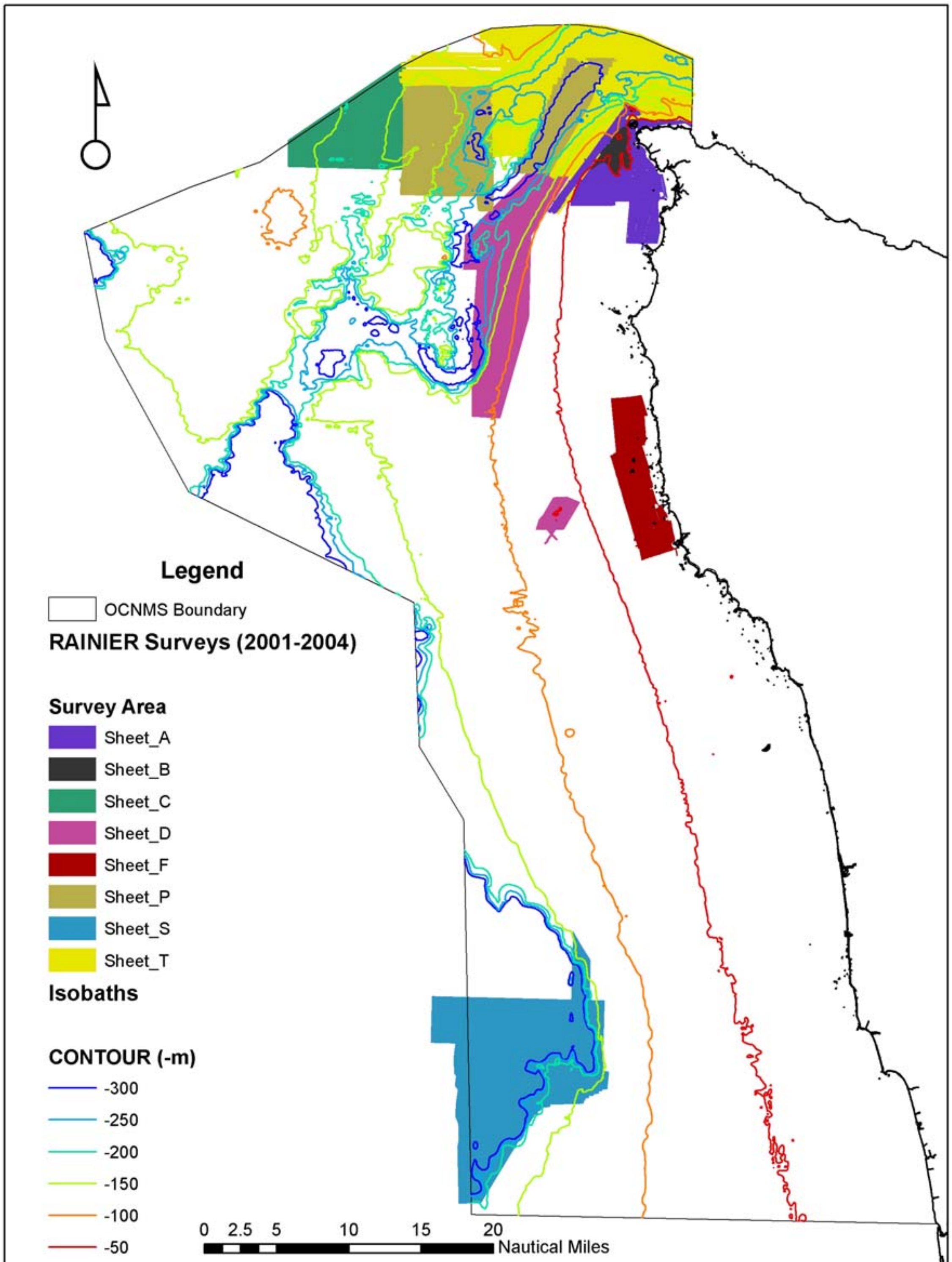

Figure 2. OCNMS Sheet locations from *NOAA SHIP RAINIER* multibeam bathymetry surveys (2001-2004).

LIDAR

In April 2005, a SHOALS 1000T LIDAR system was used as an efficient alternative for safely acquiring data to describe the existing conditions of nearshore bathymetry and the intertidal zone (Figure 3) over an approximately 40.7 km^2 (11.8 nm^2) portion of hazardous coastline near Cape Flattery (Intelmann 2006). The particular LIDAR system used did not have the functionality of capturing seafloor reflectance at the time the survey was conducted therefore only XYZ data were produced.

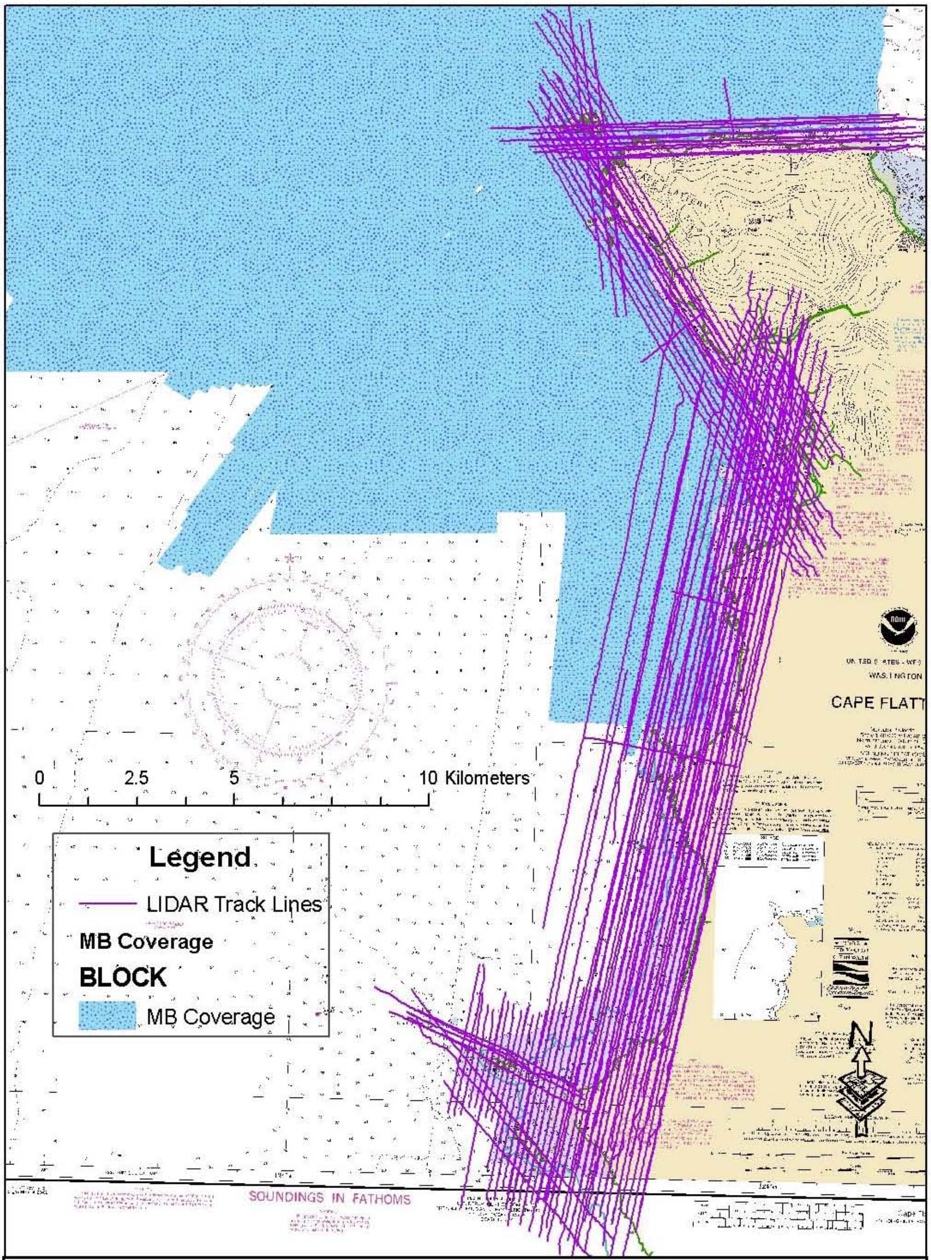

Figure 3. Cape Flattery LIDAR flight track lines, Koitlah Point to Cape Alava, shown with existing area of multibeam bathymetry sounding data (blue polygon).

Side Scan Sonar

Significantly more side scan sonar data has been collected in OCNMS over the past few years than multibeam bathymetry data (Figure 4). This is primarily due to the fact that we have been successful at receiving vessel time through the OMAO fleet allocation process on the *NOAA SHIP McARTHURII* but unsuccessful at receiving ship-time on any of the West Coast hydrographic survey vessels that are multibeam capable since 2004. Mobilizing a vessel for a successful multibeam bathymetry survey requires far more attention and resources than for a side scan sonar effort. Furthermore, the USGS has graciously provided OCNMS access to a suitable oceanographic winch to mobilize on the *McARTHURII* surveys, which dramatically reduces survey costs for conducting deep-towed side scan work. Additionally, OCNMS has developed and acquired capabilities for collecting side scan sonar data from the site based *Research Vessel TATOOSH.* Since 2003, this capability has subsequently permitted annual in-house acquisition efforts at minimal cost. Table 2 provides description of the current extent of side scan sonar data holdings at OCNMS. A handful of existing data sets were excluded from this list due to either limited coverage (USGS Corliss surveys by Twichell et al. 2000) or low image resolution (WDFW Jagielo et al. 2003), both of which create difficulties when the data are being utilized for habitat characterization purposes.

Table 2. Details of side scan sonar and multibeam backscatter acquisition within OCNMS since 1999. Time represents actual amount of logged sonar data without reflecting down time for transit between lines.

Year	Source[+]	Location	Sonar[++]	Time (h:m:s)	Area (nm^2)	Length (nm)
1999	CSUMB	Cape Alava	272	5:00:00*	1.14	11.89
2000	OCNMS	Shelf	Dowty	68:31:32	37.69	227.53
2001	Fugro	PCL Cable	SIS	85:00:00*	15.56	343.98
	OCNMS	Sheet A	BS	40:24:27	7.89	354.80
2002	OCNMS	Cape Alava	1000	22:06:01	2.34	52.48
	OCNMS	Sheet A	BS	21:52:49	5.64	170.1
	CSUMB	Sheet F	BS	35:57:08	12.18	310.65
	OCNMS	Shelf	1000	83:25:50	79.94	309.56
	USGS	Makah Bay	3000	92:31:00	34.36	367.90
2003	OCNMS	Sheet A	BS	48:00:11	12.40	351.59
	OCNMS	Sheet F	BS	49:55:28	14.28	407.27
	OCNMS	Sheet F	272	9:19:43	1.40	26.14
2004	OCNMS	Shelf	3000	54:03:52	39.79	177.50
	OCNMS	Sheet B	272	23:01:03	6.15	69.73
2005	OCNMS	Straits	272	6:17:17	1.75	10.07
	OCNMS	Shelf	3000	82:29:39	68.91	286.08
	OCNMS	Cape Flattery	272	20:46:05	8.08	69.17
2006	OCNMS	Shelf	3000	136:21:40	99.22	436.16
	OCNMS	Cape Alava	3000	15:47:11	6.86	82.72
Total				**900:50:56**	**416.75**	**4,065.31**

[+]CSUMB (California State University Monterey Bay). [++]272 (EG&G 272 100 khz analog side scan sonar; Dowty (analog side scan sonar); SIS (Benthos 1000D interferometric multibeam/side scan sonar); BS (backscatter from Seabat Reson multibeam echosounders; 1000 (Edgetech DF1000 digital side scan sonar); 3000 (Klein System 3000 digital side scan sonar. *Estimated acquisition time.

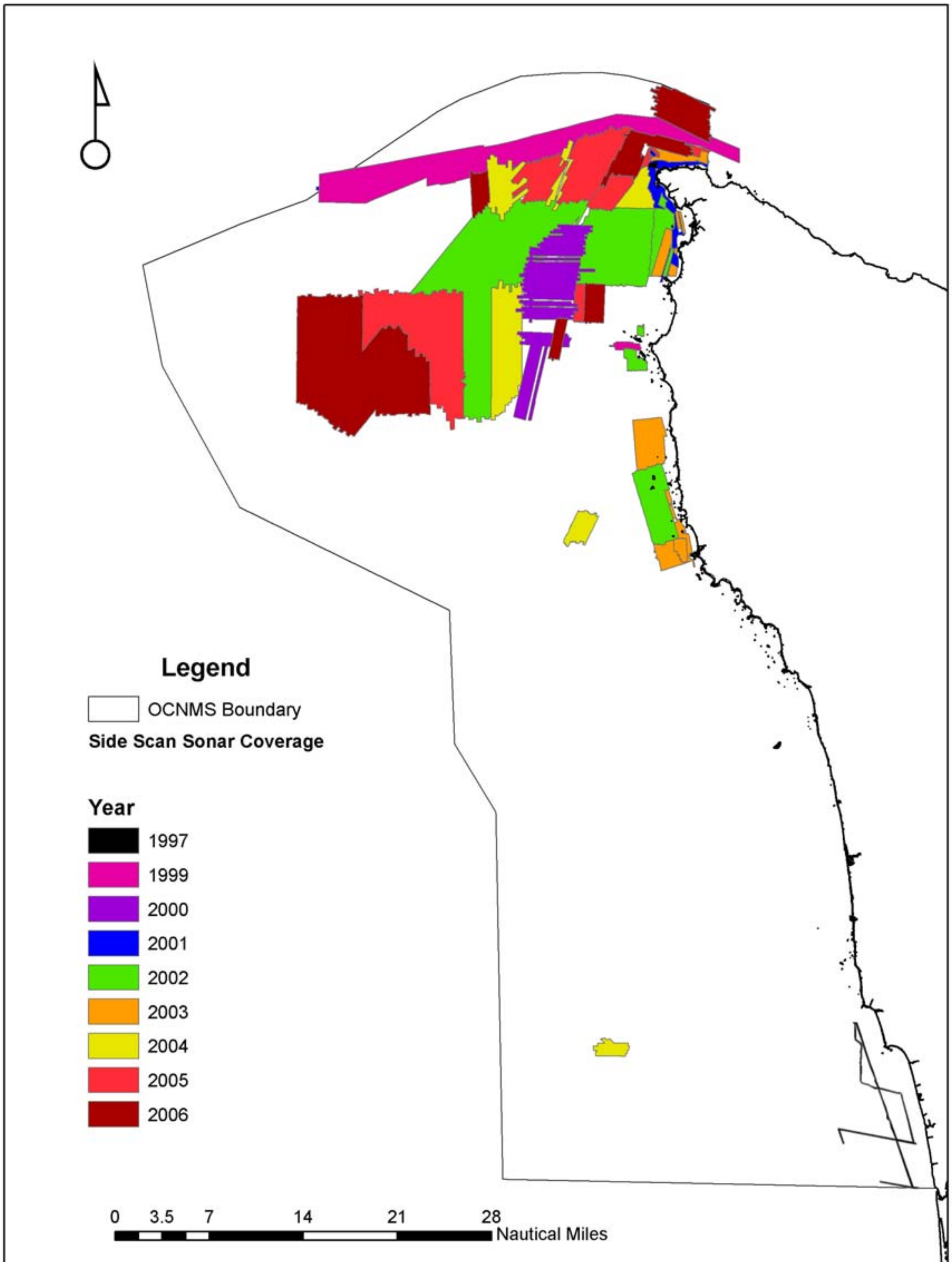

Figure 4. Side scan sonar and multibeam bathymetry backscatter acquisition effort by year at OCNMS.

TIME ESTIMATES TO COMPLETE DATA ACQUISITION ASSUMING CURRENT RATE OF ANNUAL VESSEL TIME

Realistic survey line plans were created in Hypack Max to provide estimates for the time required to complete a 100 percent data coverage first pass, using: a). single beam side scan sonar; b). multibeam echosounders; c) and an optimized strategy, which utilizes a combination of technologies to cover various portions of the sanctuary more efficiently.

Single Beam Side Scan Sonar

Line plans were first drafted by assuming use of a single beam side scan sonar, such as a Klein System 3000 (the side scan sonar most often used to date at OCNMS), to complete the remaining mapping work. Three different line spacing schemes were used to accommodate the various range scale settings, which dictate swath width, needed for mapping throughout the sanctuary and were largely depth and slope dependent (Table 3).

Table 3. Range scale and line spacing schemes used for various depth ranges.

Depth (m)	Range Scale (m)	Line Spacing (m)
20-150	150	250
150-350	200	350
150-350+	300	500
> 350	Excluded	Excluded

+A 300 meter range scale was assumed for high slope canyon areas.

For this analysis, a 150-meter range scale was chosen as the smallest setting used between the 20 meter and 150 meter isobaths. To insure equipment safety no side scan sonar data would be collected in waters more shoal than 20 meters. Assuming that a constant speed of sound in water is 1,500 meters per second, with a 150-meter range scale setting the sonar will ping 5 times per second, permit up to 30 meter altitude towfish flying (for safety), and allows for a 250-meter line spacing plan that provides 50 meters of overlap between lines. By lowering to a 100-meter range scale setting, the sonar would ping just 2.5 times more per second, provide only slightly better resolution, but also require the towfish to be flown up to 10 meters closer to the bottom. This required reduction in towfish altitude could be hazardous in the nearshore rocky environment in OCNMS. Also, the line spacing would have to be reduced to roughly 150 meters to maintain significant line overlap, thereby reducing area of coverage per unit time. For these reasons, the nearshore survey plan was based on 250 meter line spacing.

For the majority of the seafloor between the 150 and 350 meter isobaths, a 350 meter line spacing was used by assuming that a 200-meter range scale would be set on the sonar. With a 200-meter range scale setting the sonar will ping 3.75 times per second, permit up to 40 meter altitude towfish flying, and allow for a 350 meter line spacing plan that provides 50 meters of overlap between lines. Line overlap is necessary to allow for some degree of cross track navigation error, especially when there are high winds or swells that make it challenging to stay on survey line. Additional overlap also permits the ability to filter the outer edges (without losing coverage) of each ping to remove artifacts of signal attenuation that a time varied gain (TVG) often cannot accommodate for during post-processing.

The seafloor around the canyons creates greater challenges for planning survey work due to the high slopes, which make it difficult, if not impossible, to safely tow side scan sonar. Prior field calculations of winch drum speed determined that a Klein 3000 outfit with a KwingII depressor and towed using the USGS Dynacon winch off the *McARTHURII* (the primary configuration OCNMS has used for deep-water surveying to date) at survey speed, can be brought up in altitude at a maximum rate of approximately 80 meters per minute depending on currents. Using a 300-meter range scale setting in these steep areas provides the ability to tow the sonar up to 60 meters above the seafloor. With this configuration, survey lines must be run in a down slope direction only in the high slope areas where the winch speed cannot accommodate for the bathymetry rising faster than 80 meters per minute when traveling at survey speed. Surveying these areas strictly in a down slope direction also improves image quality since paying cable out creates less movement in the towfish than drawing cable in. The impact of surveying lines in one direction results in increased time at sea due to greater transit times between individual lines and significantly more time spent at winching. The slower ping rate (2.5 times per second) associated with a 300-meter range scale is still useful for delineating hard rocky areas from mixed substrate and soft muddy bottom, as evident from yet to be published data collected by OCNMS.

A wide range of depths requires several different vessels to be used for side scan sonar imaging throughout the sanctuary. The OCNMS side scan sonar winch has just 300 meters of steel-armored digital data transmission cable, which limits data acquisition to inside the approximate 100 meter isobath. Also, with the *Research Vessel TATOOSH* being only 39' feet in length, the vessel is restricted to daytime operations that do not require greater than 2 hour one-way transits to the survey grounds (in order to maximize the time of data collection). Because only two ports exist in the OCNMS, surveying from the *Research Vessel TATOOSH* in the southern portion of the sanctuary is not feasible (Figure 5). The region south of the green buffer zone and inside the 100 m isobath, as shown in Figure 5, will have to be surveyed with either a ship such as the *McARTHURII*, will have to wait until the site receives a larger boat, or will have to be done through contract award. The area beyond the 100 m isobath will need to be done off a larger vessel such as the *McARTHURII*, which can support much larger oceanographic winches (e.g., USGS Dynacon winch).

This effort analysis does not include acquiring side scan sonar data in water depths greater than 350 meters. For safety reasons, side scan sonar cannot be towed upslope in these canyon areas nor can it be flown down-slope because the seafloor will simply drop away from the sonar faster than cable can be paid out. Even if cable could be paid out at a fast enough rate, cable length would soon become problematic. Towfish positioning would also degrade when having multiple kilometers of cable paid out. Even if image resolution were compromised by flying the towfish at altitudes high enough to avoid collision with the canyon walls, the extreme layback would require acoustic tracking with assistance from a chase boat to operate the receiver and then transmit the telemetry back to the tow ship via wireless modem. Ideally situating the chase boat directly above the towfish would increase positional accuracy since most acoustic tracking systems are downward focused. This type of operation would greatly increase survey costs and would still not overcome the problem of the canyon slope being greater than the winches performance limitations. These high slope canyon areas would be best surveyed using either an autonomous underwater vehicle (AUV) or remotely operated vehicle (ROV) outfitted with either a multibeam echosounder or side scan sonar payload.

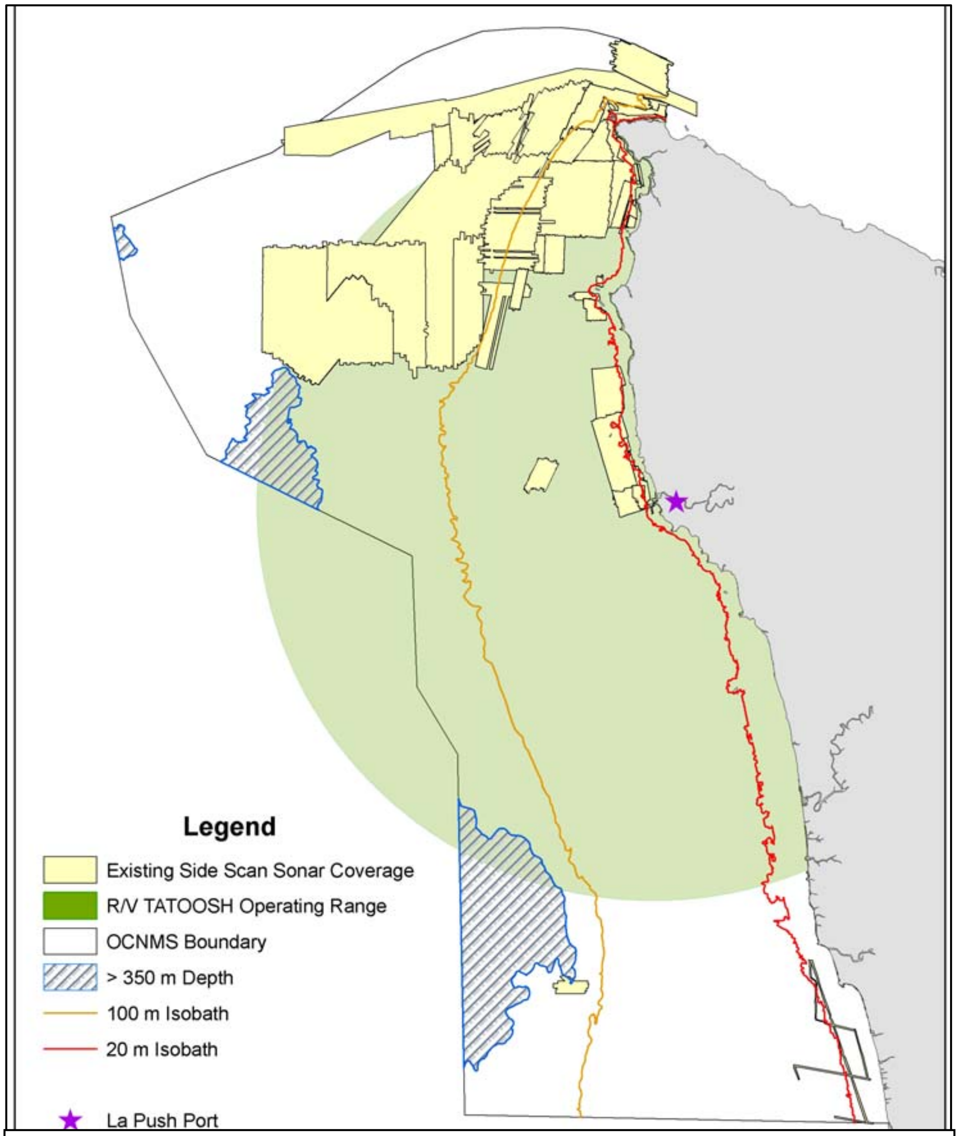

Figure 5. Illustration of current side scan sonar data coverage (yellow polygons) shown with regions of the sanctuary to be surveyed by small vessel such as the *R/V TATOOSH* (between the 20 meter curve shown in red and the 100 meter curve shown in orange) and by larger vessel such as the *NOAA SHIP McARTHURII* (beyond the 100 meter curve). Hashed polygons outlined in blue represent canyon areas deeper than 350 meters, which are excluded from the effort analysis because they should not be surveyed with towed side scan sonar. The green buffer represents the operating range of the *R/V TATOOSH*, based on a maximum one-way transit time of 2 hours traveling from LaPush at 15 knots, which is the approximate maximum speed achievable on this vessel while carrying an 800 pound side scan sonar winch, crew, other gear and fuel.

Past survey work (Intelmann and Cochrane 2006a; Intelmann and Cochrane 2006b) has suggested that sea conditions generally do not permit much faster data acquisition speeds than about 3.2 knots for continually recording sonar records used for habitat classification at OCNMS. Thus, our acquisition rate with a single beam side scan sonar would be 1.64 meters per second. For the deep-water ship-based surveying it was assumed that turn times would average 20 minutes for most lines, although several adjustments to turn and line transit time were made in areas where lines can only be run in one direction, such as the high slope canyon areas, and the regions around the vessel traffic lanes. In some of these areas turn/transit times were estimated to be up to 2 hours. An average of 10 minutes was assumed for making the turns in the shallow water survey areas using a smaller vessel such as the *Research Vessel TATOOSH*.

Acquisition time (which includes turns and winch time at the beginning and end of each line as described above) was assumed to be 7-hours per day from a small vessel, such as the *Research Vessel TATOOSH*, running daytime operations. This allows several hours to transit from port to and from the survey grounds each day. Acquisition time was assumed to be 21-hours per day from a larger ship such as the *McARTHURII*. This allows up to three hours per day for equipment troubleshooting and potential need for transiting out of sanctuary waters for sewage dumping. The four shallow water line plans in the southern portion of the sanctuary, which are out of range for conducting day operations off the *Research Vessel TATOOSH,* were treated as though acquisition was being conducted from a ship or from a larger vessel than the *Research Vessel TATOOSH* that could double staff to support 24-hour survey operations (e.g., 21-hours of acquisition per day).

These particular calculations also limit annual acquisition of at-sea survey days per year from a ship such as the *McARTHURII* to 10 at-sea survey days per year, as well as 10 at-sea survey days per year from a smaller vessel such as the *Research Vessel TATOOSH*. This was based on the average number ship days that have annually been allocated for habitat mapping work at OCNMS through both the OMAO fleet allocation process and through competition with other site projects for small vessel time on the *Research Vessel TATOOSH* over the past 5 years.

Results

With these realistic assumptions, it is estimated that 10,810.2 nautical miles (nm) of tracklines remain to be surveyed between the 20 and 350-meter isobaths in order to complete 100 percent side scan sonar coverage at OCNMS (Table 4). The 11 nearshore (inside 100 meter isobath) line plans, as shown in Figure 6, consist of 4,834.9 nm of tracklines and will require 1,762.6 hours of acquisition time, including turns. Based on 7-hours of daily acquisition time, this will take 251.8 at-sea days (DAS) to complete. Assuming we are limited to 10 DAS per year, it will take 25.2 years to complete the remaining nearshore work. The four nearshore line plans that are beyond the range of daytime operations for the *Research Vessel TATOOSH,* delineated by the red box in Figure 7, will require 853.8 hours to complete (2,333.2 nm of tracklines). These lines will take 40.7 DAS based on 21-hours of daily acquisition, thereby equating to 4.1 years assuming 10 DAS per year. Likewise, the 10 deep-water survey line plans to be conducted off a large ship consist of 3,642.1 nm of tracklines, and are estimated to require 1,370.9 hours of acquisition time. With 65.3 DAS survey time, this deep-water survey work would be completed in 6.5 years. Again, these figures do not account for the survey work that remains in water depths greater than 350 meters.

Table 4. Estimated effort required to complete 100 percent single beam side scan sonar coverage at OCNMS surveying with a combination of small and large vessels operating at 3.2 knots and assuming 10 at-sea days (DAS) per year. Statistics cover the remaining portion of the sanctuary remaining to be surveyed between the 20 and 350-meter isobaths. Nm=nautical miles, Hours=decimal hours, DAS=Days-at-sea.

Vessel	Line Plan	Nm	Hours	DAS
R/V TATOOSH	Tatoosh1	101.1	38.8	5.5
	Tatoosh2	109.5	41.5	5.9
	Tatoosh3	262.8	95.8	13.7
	Tatoosh4	340.8	126.4	18.1
	Tatoosh5	352.1	133.3	19.0
	Tatoosh6	608.7	217.7	31.1
	Tatoosh7	651.1	236.9	33.8
	Tatoosh8	687.6	247.7	35.4
	Tatoosh9	550.2	200.9	28.7
	Tatoosh10	671.8	238.3	34.0
	Tatoosh11	499.1	185.2	26.5
	Total	**4,834.9**	**1,762.6**	**251.8**
			Years to Complete	***25.1***
McARTHURII	Ship1	192.2	100.6	4.8
	Ship2	180.9	110.1	5.2
	Ship3	463.7	169.1	8.1
	Ship4	478.5	171.8	8.2
	Ship5	439.5	156.2	7.4
	Ship6	755.3	261.9	12.5
	Ship7	253.9	90.0	4.3
	Ship8	350.8	121.1	5.8
	Ship9	174.0	63.6	3.0
	Ship10	353.3	126.5	6.0
	Total	**3,642.1**	**1,370.9**	**65.3**
			Years to Complete	***6.5***
SOUTH LINES	South1	473.7	173.1	8.2
	South2	594.9	215.7	10.3
	South3	519.0	195.7	9.3
	South4	745.6	269.2	12.8
	Total	**2,333.2**	**853.8**	**40.7**
			Years to Complete	***4.1***

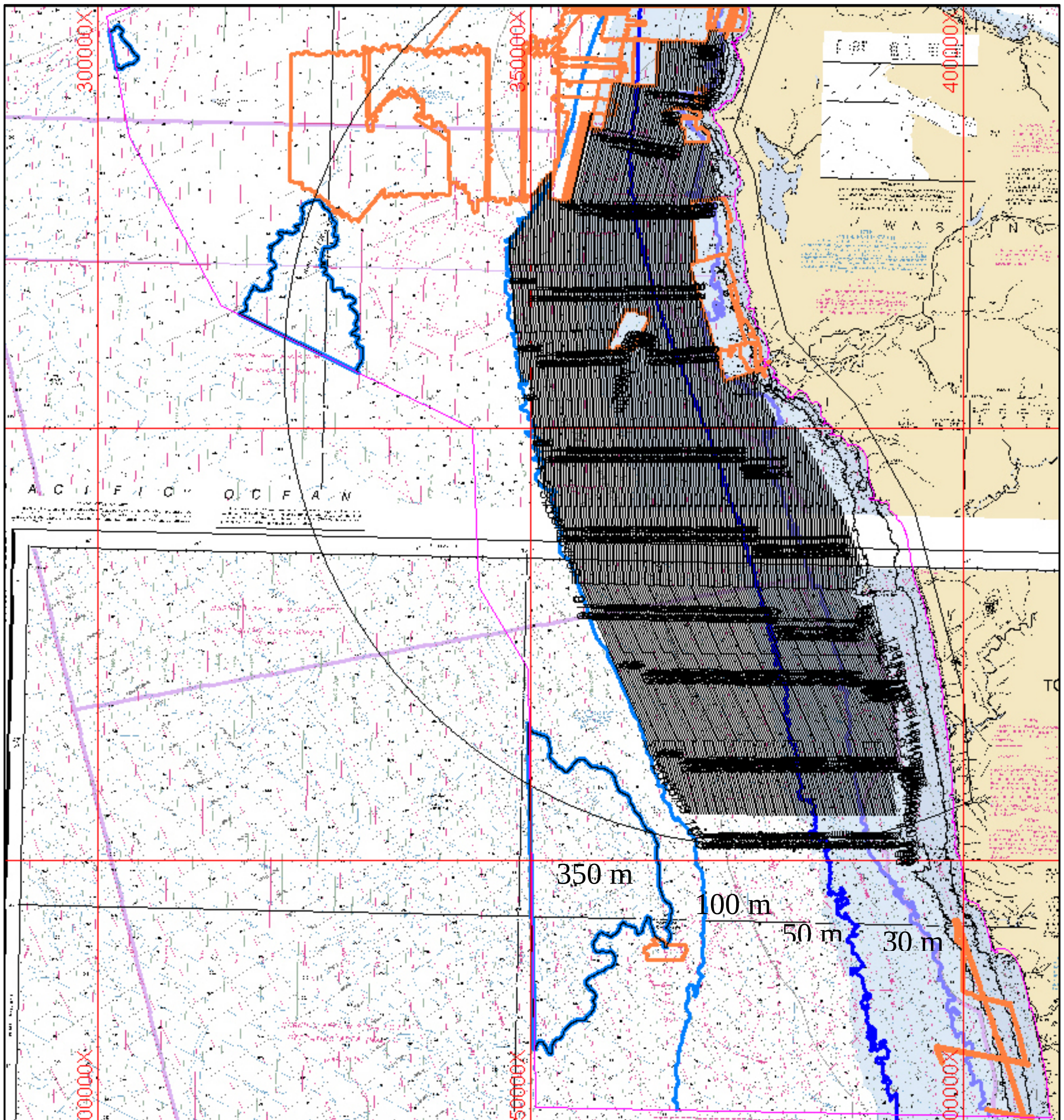

Figure 6. Shallow-water side scan sonar line plans designed for surveying from the *Research Vessel TATOOSH*. Line plans cover the area between the 20 and 100-meter isobaths. Orange polygons represent areas within the sanctuary that have already been surveyed with side scan sonar or have useful multibeam backscatter. Isobaths are as follows: 350m (dark blue), 100 m (light blue), 50m (royal blue), 30 meter (purple).

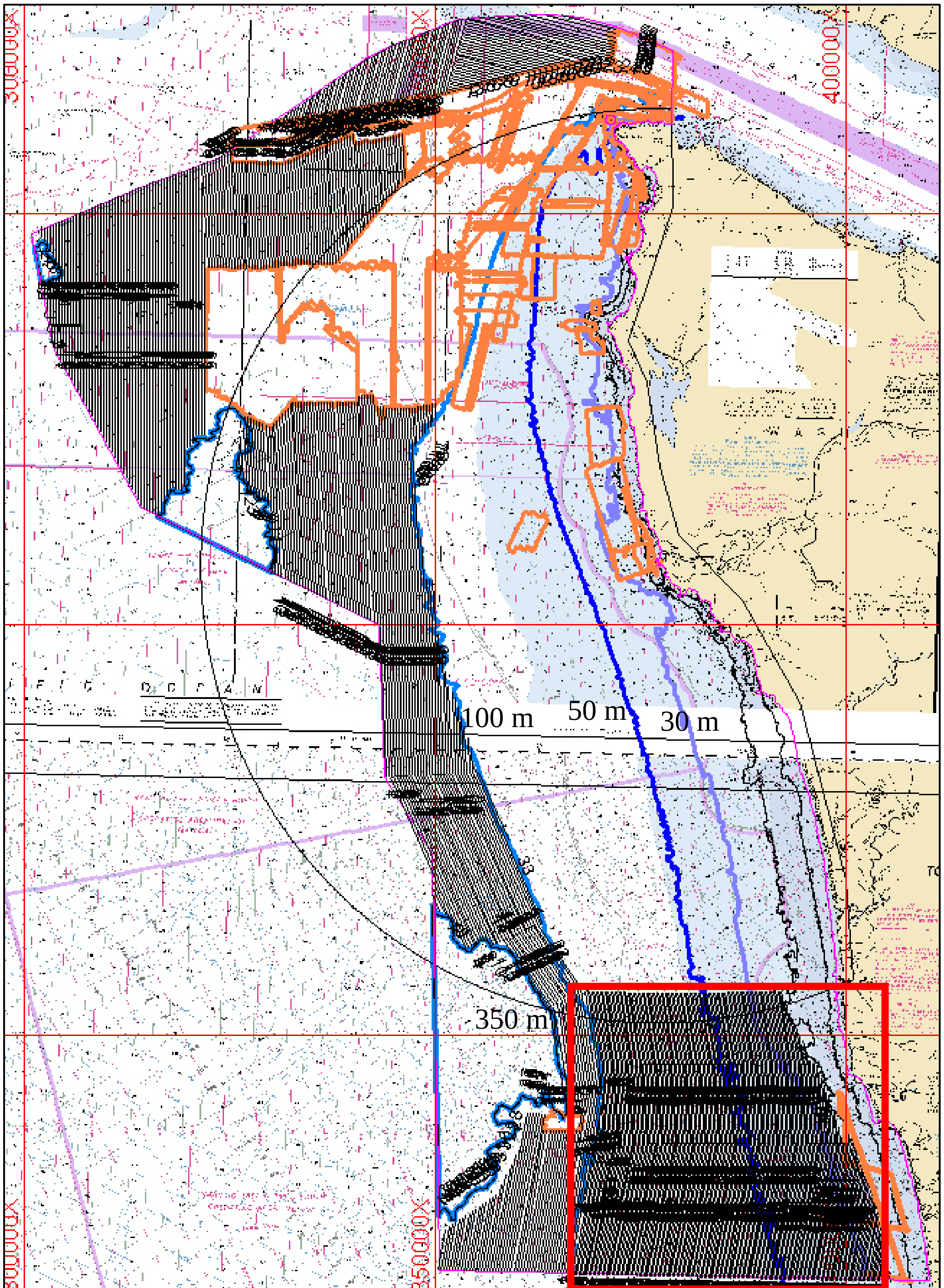

Figure 7. Deep-water side scan sonar line plans designed for surveying from the *NOAA SHIP McARTHURII*. Line plans cover the area between the 100 and 350 meter isobaths. Orange polygons represent areas within the sanctuary that have already been surveyed with side scan sonar or have useful multibeam backscatter. Isobaths are as follows: 350m (dark blue), 100 m (light blue), 50m (royal blue), 30 meter (purple). Red box defines the area that is out of operating range for the *R/V TATOOSH.*

Multibeam Bathymetry
Line plans were drafted by assuming that 100 percent seafloor coverage using multibeam echosounders was desired. Effort calculations assumed an 8 knot survey speed for both the deep and shallow water line plans with line spacing adjusted to 2.8 x water depth. Such line constraint would allow full bottom coverage with the ability to filter beyond 60 degrees from nadir to remove soundings most affected by refraction. Maintaining this 2.8 x water depth line spacing throughout the deeper water areas also produces higher sounding densities. Similar to past operations conducted in OCNMS on the *NOAA SHIP RAINIER*, it was assumed that higher frequency multibeam echosounder operations would be conducted by launches from roughly the 10 meter isobath to the 50 meter isobath. Lower frequency multibeam echosounders and ship based hydrographic operations would be implemented beyond the 50 meter isobath.

Effort calculations for the shallow water launch work assumed a daily acquisition rate of 6-hours. This allows 2 hours for deployment and retrieval of the launches from the ship, transiting to and from the survey area, and for obtaining necessary sound velocity (SV) measurements. Total hours of daily ship-based acquisition was calculated under two different scenarios, with and without daily launch tending. Under the first scenario a 12-hour daily acquisition was assumed, which would allow 12 hours for acquiring the necessary SV measurements and launch tending. With the latter scenario, an 18-hour daily acquisition was assumed in order to allow 6-hours for SV measurements. Average turn times of 15 minutes and 2 minutes were applied to the ship and launch line plans, respectively. Based on four previous OMAO allocations of hydrographic ship time to OCNMS, calculations further assumed a limitation of 8 annual DAS for survey work.

<u>Results</u>
An estimated 21,548.5 nm of tracklines remain to be surveyed beyond the 10 meter isobath in order to complete 100 percent multibeam bathymetry coverage at OCNMS (Table 5). The 13 launch-based line plans, as shown in Figure 7, consist of 14,095.4 nm of tracklines and will require 1,876.8 hours of acquisition time, including turns. Based on 6-hours of daily acquisition time, this will take 312.8 DAS to complete when using one survey launch, 156.4 DAS when using 2 survey launches, or 104.3 DAS if simultaneously using three survey launches. Assuming we are limited to 8 DAS per year it will take 39.1, 19.5, or 13.0 years to complete the remaining shallow water multibeam bathymetry survey work when using one, two, or three launches, respectively.

The 12 deep-water line plans to be conducted using ship based hydrographic surveying consist of 7,453.0 nm of tracklines (Figure 8) and are estimated to require 1,086.5 hours of acquisition time. By assuming the ship would essentially conduct 24-hour survey operations (18-hours of daily acquisition), this would require 60.4 DAS. But, if the ship was also required to undertake daily launch tending it would instead require 90.5 DAS. Thus being limited to 8 DAS per year, it would require 7.5 years to complete the deep-water survey lines when the ship is not tending launches and 11.3 years to complete when tending launches.

Table 5. Estimated effort required to complete 100 percent multibeam bathymetry coverage at OCNMS using a combination of ship and launch based surveying, operating at 8.0 knots and assuming only 8 at-sea days (DAS) per year. Statistics cover the remaining portion of the sanctuary that need to be surveyed beyond the 10 meter isobath. Nm=nautical miles, Hours=decimal hours, DAS^1=Days-at-sea assuming 18-hour daily ship acquisition and 6-hour daily launch acquisition, DAS^2=Days-at-sea assuming 12-hour daily ship acquisition.

Vessel	Line Plan	Nm	Hours	DAS^1	DAS^2
Ship	1	60.5	13.8	0.8	1.1
	2	595.2	90.1	5.0	7.5
	3	307.5	49.8	2.8	4.2
	4	321.1	54.6	3.0	4.5
	5	405.9	67.0	3.7	5.6
	6	470.1	66.4	3.7	5.5
	7	279.6	43.1	2.4	3.6
	8	610.7	85.0	4.7	7.1
	9	1,330.3	180.1	10.0	15.0
	10	1,275.5	178.8	9.9	14.9
	11	420.7	64.6	3.6	5.4
	12	1,376.0	193.3	10.7	16.1
	Total	**7,453.0**	**1,086.5**	**60.4**	**90.5**
			Years to Complete	**7.5**	**11.3**
Launch	13	207.4	30.2	5.0	
	14	801.2	110.0	18.3	
	15	709.7	95.5	15.9	
	16	770.2	101.1	16.8	
	17	1,179.9	1,565.9	26.1	
	18	1,041.9	140.5	23.4	
	19	1,178.7	157.7	26.3	
	20	1,852.9	244.3	40.7	
	21	1,801.4	236.2	39.4	
	22	1,422.2	187.8	31.3	
	23	929.2	125.5	20.9	
	24	1,142.1	151.8	25.3	
	25	1,058.6	139.3	23.2	
	Total	**14,095.4**	**1,876.8**	**312.8**	**1 launch**
				156.4	**2 launches**
				104.3	**3 launches**
			Years to Complete	**39.1**	**1 launch**
				19.5	**2 launches**
				13.0	**3 launches**

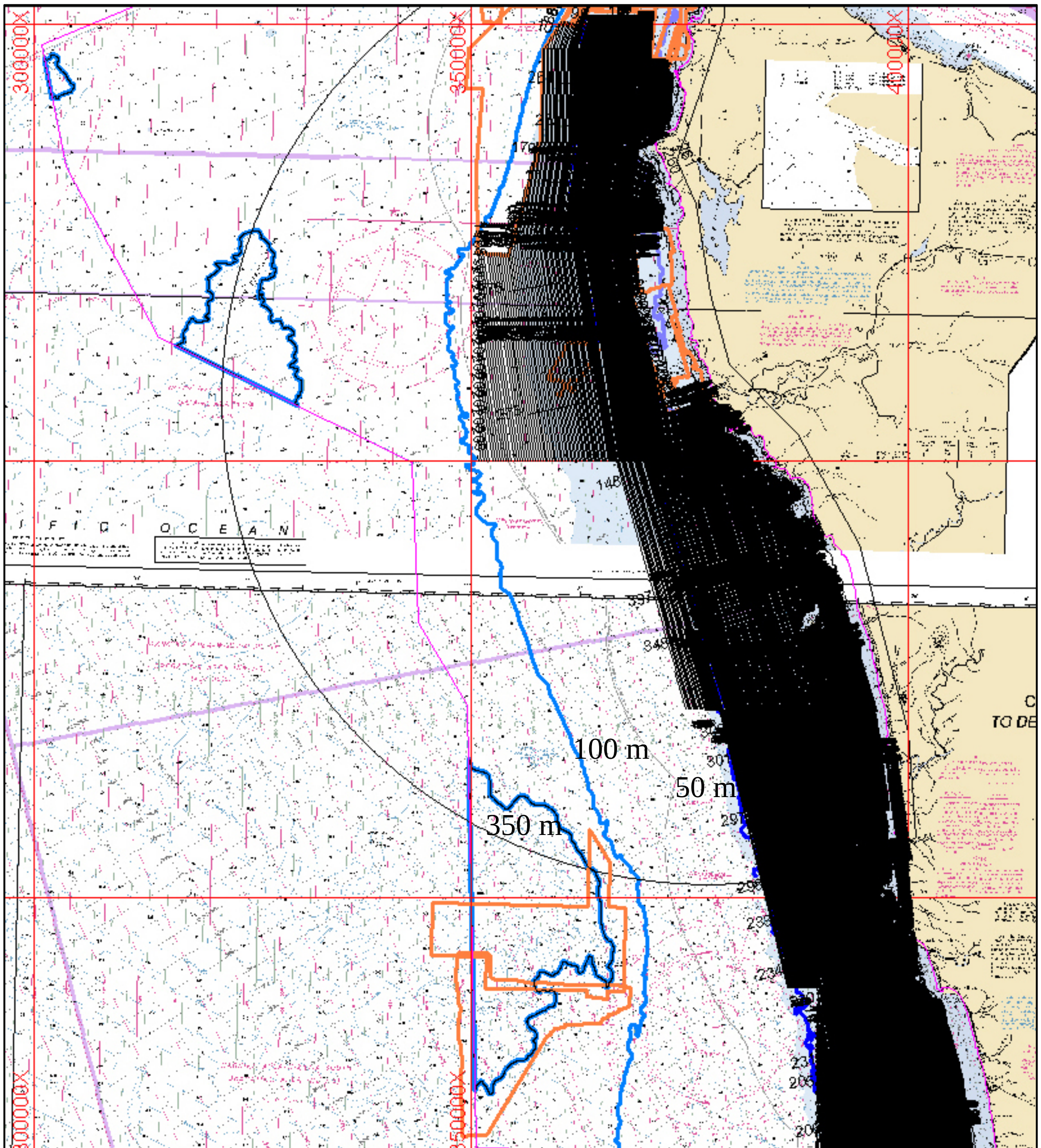

Figure 8. Shallow-water multibeam bathymetry line plans designed for surveying from *NOAA SHIP RAINIER* survey launches. Line plans generally cover the area between the approximate 10 m and 50 meter isobaths. Orange polygons represent areas within the sanctuary that have already been surveyed with multibeam bathymetry. Isobaths are as follows: 350 m (dark blue), 100 m (light blue), 50 m (royal blue), 30 m (purple).

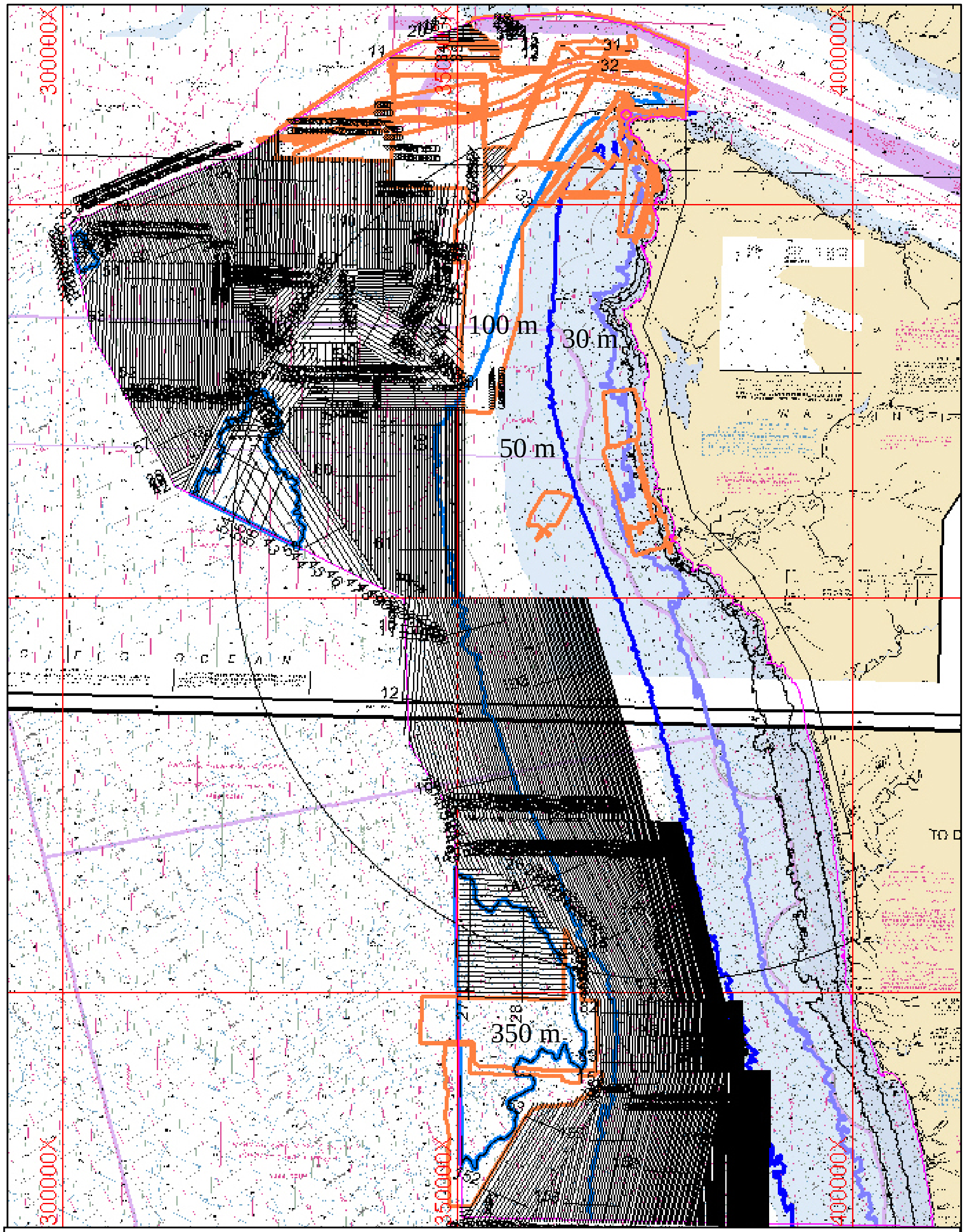

Figure 9. Deep water multibeam bathymetry line plans designed for surveying from *NOAA SHIP RAINIER* or similar vessel. Line plans generally cover the area beyond the approximate 50 m isobaths, except in the northern half of the sanctuary where they cover beyond the 100 m isobath. Orange polygons represent areas within the sanctuary that have already been surveyed with multibeam bathymetry. Isobaths are as follows: 350m (dark blue), 100 m (light blue), 50m (royal blue), 30 meter (purple). Note the fewer lines required to cover the deeper water.

Optimized Survey Strategy

Achieving 100 percent seafloor coverage in OCNMS using both multibeam bathymetry and side scan sonar (or multibeam backscatter) would, without a doubt, be a highly desirable means for producing habitat maps at the scale of the sanctuary because both high resolution depth and the textural properties of the seafloor would be made available. Acquiring this data across such a large area through both of these techniques would be an extremely time consuming endeavor, especially when limited by annual ship time as has been the case for OCNMS over the past 5 years. That said, when faced with the need to create habitat maps for site characterization purposes, time and resources would be best spent prioritizing the need for obtaining textural information of the seabed. Although depth information, produced from multibeam echosounders for example, does provide information that is useful for describing the roughness of the seafloor and can also be extremely valuable as a reconnaissance tool for designing safer towed side scan sonar surveys, it is not nearly as useful as the backscatter signatures for creating habitat maps. As such, efforts should be concentrated on gaining the best possible backscatter information, in the most efficient manner, to complete the benthic mapping efforts at OCNMS.

Using a combination of single beam side scan sonar, multibeam side scan sonar, multibeam bathymetry, and interferometric sidescan/bathymetry would significantly reduce the amount of time required to collect the appropriate information needed for producing useful habitat maps for the entire sanctuary. Single beam side scan sonar provides the ability to acquire data with large range scales but at limited speed. Multibeam side scan sonar permits high speed data acquisition but with limited range scale. Multibeam bathymetry allows high speed acquisition in the deep canyons without the troubles associated with significant cable out or towfish positioning but with reduced resolution. Interferometric sidescan/bathymetry provides the capabilities of wide swath, high speed acquisition (assuming an appropriate system were chosen, i.e. not alternate ping) in shallow water without worrying about obstacles to towing.

With this in mind, line plans were created assuming that traditional single beam side scan sonar would continue to be used for mapping the canyon areas less than 350 meters, the flat continental shelf between the 100 and 350 meter isobaths, and for areas between the 20 and 100 meter isobaths that are too financially risky for safely towing multibeam side scan sonar, such as the highly rugose areas on the continental shelf that are scattered with rock pinnacles. A multibeam side scan sonar, such as a Klein System 5000, would be used to image the wide flat continental shelf inside the 100 meter isobath. Although these systems do have a range scale limitation of 150 meters, with good seas high quality imagery can successfully be acquired at speeds approaching 10 knots, a marked improvement over the 3-3.5 knots needed by for single beam side scan sonar in this environment. An interferometric sidescan/bathymetry system would be the chosen method for surveying the shallow nearshore area inside the 20 meter isobath. Interferometric systems (sometimes referred to as swath sonars) produce side scan imagery that is precisely georeferenced to bathymetry, yet do not suffer from the angular dependency on water depth to the degree of multibeam echsounders. For example, where typical line spacing for a shallow-water multibeam bathymetry survey might be roughly

2.8 x water depth, the bathymetric and side scan range for an interferometric system can be anywhere from 9-12 x water depth, which allows much larger line spacing. Using an interferometric system that is not designed under an alternate ping architecture permits the ability to acquire survey data at similar speeds as with multibeam echosounders (e.g., 8 knots). Having greater line spacing plans would greatly reduce the overall amount of survey time required to complete the nearshore benthic mapping. The canyon areas that are deeper than 350 meters would be best approached by initially using a multibeam echosounder capable of producing quality backscatter. Information gleaned from this first pass backscatter data could then be used to strategize the potential areas and need for more costly and labor intensive AUV or ROV surveys for better imaging areas of added interest. Figure 10 illustrates an optimized survey strategy, delineating various regions of the sanctuary to be surveyed using the methods mentioned above.

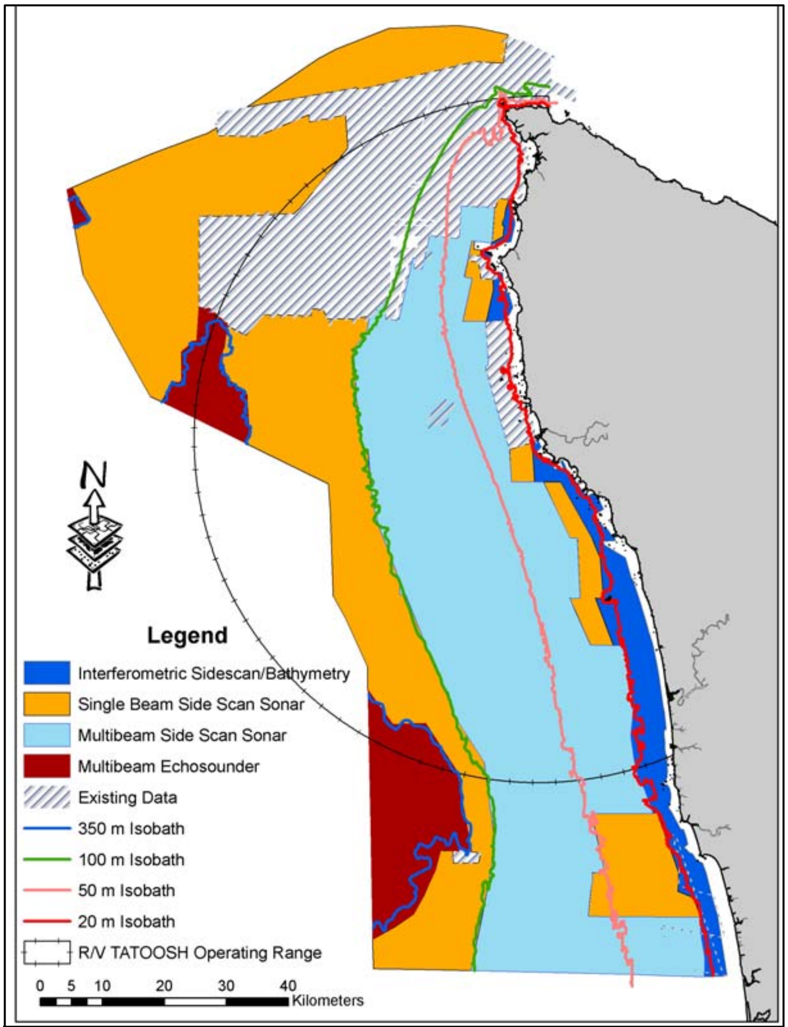

Figure 10. Representation of an optimized survey strategy incorporating multiple survey methodologies to more efficiently cover the remaining portion of the sanctuary for benthic mapping purposes. Regions requiring the different survey methodologies are uniquely colorized. Hashed polygons represent areas where data are presently available to adequately characterize benthic habitat at OCNMS. Ticked arc represents the survey operating range for the OCNMS research vessel *TATOOSH* when transiting from the LaPush port.

Results

Taking the approach of the optimized survey strategy, the region beyond the 100 meter isobath would require 4,071.6 nm of tracklines to complete (Table 6). That effort would require 2,074.7 hours of acquisition, including turns and winching, for a total of 104.4 DAS. Assuming OCNMS would receive the same number of allocated ship days per year, as in the past, this deep-water section of the sanctuary would be completed in 11.4 years.

The region inside the 100 meter isobath would require 9,105.5 nm of tracklines to complete using the optimized survey strategy (Table 7). That particular effort would require 1,595.0 hours of combined acquisition, including turns and winching, for a total of 187 DAS. Once again, assuming the shallow water research vessel would be limited to 10 DAS per year of acquisition, as in the past, this shallow-water portion of the sanctuary would be completed in 18.7 years. Although 18.7 years is a significant amount of time, it is a mere fraction in comparison to the effort required to map this same shallow water area using only a combination of single beam side scan sonar and multibeam echsounders (as has been the mode of data acquisition at OCNMS to date). It would require 43 years to complete 100 percent coverage of this same region inside the 100 m isobath when using single beam side scan sonar combined with multibeam echosounders only (Table 8).

Table 6. Estimated effort required to complete 100 percent seabed coverage using an optimized survey strategy that incorporates both multibeam bathymetry and single beam side scan sonar surveys to complete the region beyond the 100 m isobath (green curve in Figure 10). Nm=nautical miles; Hours=decimal hours; SBSS = Single beam side scan sonar; MBES = Multibeam echosounder; DAS[1]: assumed to be 21 acquisition/day (10 days/year) for SBSS and 18 hours/day (8 days/year) for MBES.

Method	Line Plan	Nm	Hours	DAS[1]
SBSS	Ship1	192.2	100.6	4.8
	Ship2	180.9	10.1	5.2
	Ship3	463.7	169.1	8.1
	Ship4	478.5	171.8	8.2
	Ship5	439.5	156.2	7.4
	Ship6	755.3	261.9	12.5
	Ship7	253.9	90.0	4.3
	Ship8	350.8	121.1	5.8
	Ship9	174.0	63.6	3.0
	Ship10	353.3	126.5	6.0
	Total	**3642.1**	**1,370.9**	**65.3**
MBES	Canyon1	14.4	5.0	0.3
	Canyon2	106.6	645.0	35.8
	Canyon3	308.5	53.8	3.0
	Total	**429.5**	**703.8**	**39.1**
	Grand Total	**4,071.6**	**2,074.7**	**104.4**
			Years to Complete	***11.4***

Table 7. Estimated effort required to complete 100 percent seabed coverage using an optimized survey strategy that incorporates single beam side scan sonar, multibeam side scan sonar, and interferometric sidescan/bathymetry surveys to complete the region inside the 100 m isobath (green curve in Figure 10). Nm=nautical miles; Hours=decimal hours; SBSS = Single beam side scan sonar; MBSS = Multibeam side scan sonar; ISB=Interferometric sidescan/bathymetry; DAS[1]: assumed to be 7 hours acquisition/day.

Method	Line Plan	nm	Hours	DAS
ISB	I_Boat1	51.2	7.4	1.2
	I_Boat2	7.2	1.3	0.2
	I_Boat3	78.0	11.5	1.9
	I_Boat6	85.4	12.3	2.0
	I_Boat7	118.7	17.1	2.8
	I_Boat8	194.0	27.1	4.5
	I_Boat9	265.5	35.4	5.9
	I_Boat10	326.1	42.7	7.0
	I_Boat11	320.9	42.7	7.1
	I_Boat12	175.8	23.9	4.0
	I_Boat13	163.8	22.4	3.7
	I_Boat14	160.1	21.9	3.7
	I_Boat15	166.0	21.9	1.0
	Total	**2,112.2**	**287.7**	**45.3**
SBSS	S_Boat1	23.7	10.1	1.4
	S_Boat2	19.0	8.5	1.2
	S_Boat3	56.6	20.3	2.9
	S_Boat6	48.0	17.6	2.5
	S_Boat7	60.8	24.1	3.4
	S_Boat8	69.4	24.1	3.2
	S_Boat9	64.9	22.7	3.2
	S_Boat13	240.1	84.5	4.0
	S_Boat14	244.9	89.2	4.2
	Total	**827.4**	**300.9**	**26.5**
MBSS	M_Boat1	65.6	11.0	1.6
	M_Boat2	90.5	14.7	2.1
	M_Boat3	180.9	31.2	4.5
	M_Boat4	340.8	60.2	8.6
	M_Boat5	352.1	60.5	8.6
	M_Boat6	549.9	86.1	12.3
	M_Boat7	589.9	96.0	13.7
	M_Boat8	613.5	98.7	14.1
	M_Boat9	458.7	74.3	10.6
	M_Boat10	671.8	101.2	14.5
	M_Boat11	442.5	72.5	10.4
	M_Boat12	465.9	75.1	3.6
	M_Boat13	354.6	59.1	2.8
	M_Boat14	260.7	46.7	2.2
	M_Boat15	728.1	119.0	5.7
	Total	**6,165.4**	**1,006.4**	**115.2**
	Grand Total	**9,105.5**	**1,595.0**	**187.0**
			Years to Complete	***18.7***

Table 8. Estimated effort required to complete 100 percent seabed coverage using a combination of single beam side scan sonar and multibeam bathymetry to complete the region inside the 100 m isobath (green curve in Figure 10). Nm=nautical miles; Hours=decimal hours; SBSS = Single beam side scan sonar; MBES = Multibeam echosounder. DAS[1]: assumed to be 7 hours acquisition/day for SBSS and 6 hours per/day for MBES.

Method	Line Plan	nm	Hours	DAS
SBSS	S_Boat1	101.4	38.8	5.5
	S_Boat2	109.5	41.5	5.9
	S_Boat3	262.8	95.8	13.7
	S_Boat4	340.8	126.4	18.1
	S_Boat5	352.1	133.3	19.0
	S_Boat6	608.7	217.7	31.1
	S_Boat7	651.1	236.9	33.8
	S_Boat8	687.6	247.7	35.4
	S_Boat9	550.2	200.9	28.7
	S_Boat10	671.8	238.3	34.0
	S_Boat11	499.1	185.2	26.5
	S_Boat12	473.7	173.1	8.2
	S_Boat13	594.9	215.7	10.3
	S_Boat14	519.0	195.7	9.3
	S_Boat15	745.6	269.2	12.8
	Total	**7,168.1**	**2,616.4**	**292.5**
MBES	M_Boat1	105.5	16.2	2.7
	M_Boat2	11.2	2.5	0.4
	M_Boat3	103.4	30.4	5.1
	M_Boat6	148.1	21.8	3.6
	M_Boat7	289.8	44.7	7.4
	M_Boat8	289.8	41.2	6.9
	M_Boat9	682.9	91.3	15.2
	M_Boat10	804.0	103.0	17.2
	M_Boat11	757.0	97.1	16.2
	M_Boat12	439.5	60.1	10.0
	M_Boat13	384.3	53.2	8.9
	M_Boat14	361.1	49.5	8.2
	M_Boat15	375.6	49.6	8.3
	Total	**4,752.3**	**660.7**	**110.1**
	Grand Total	**11,920.3**	**3,277.1**	**402.6**
		Years to Complete		***43.0***

VESSEL DAYS-AT-SEA NEEDED TO COMPLETE ACQUISTION EFFORTS ASSUMING 2, 5 and 10 YEAR SCHEDULES

Assuming the field season at OCNMS is limited between May 1-October 1, due to the inclement weather that usually prevails outside this period, allows roughly 155 possible days for vessel based activities within a calendar year. Further assuming that sea state is unfavorable for conducting hydrographic surveys 25 percent of this time leaves just 116 days per year to realistically acquire quality survey data. With this limitation in mind and also knowing the amount of effort required to complete the individual line plans, the total effort required for mapping the remaining area of the sanctuary to 100 percent coverage can easily be placed into any desired time frame to better understand the feasibility of accomplishing the mapping efforts.

For this analysis the three survey strategies described earlier, i.e. single beam side scan sonar, multibeam bathymetry, and the optimized survey strategy, were all placed into 2, 5, and 10-year timeframes to calculate the amount of at-sea-days required to complete the benthic mapping efforts at OCNMS in a timely manner. The same variables described earlier (ie. survey speeds, range scales, and turn times etc) that dictate the DAS required for completing each line plan were used to calculate these estimates.

<u>*Results*</u>

Single Beam Side Scan Sonar

Assuming survey work can only be conducted 116 days a year, with over 357 DAS required to complete the remaining mapping efforts, the work can not be completed within a 2-year time frame unless more than one small vessel is allocated to the nearshore line plans (Table 9). The region of the sanctuary between the 100 and 350 meter isobaths could be completed with single beam side scan sonar in 2 years if OCNMS were allocated approximately 32 DAS each year from the *McARTHURII* to strictly work on habitat mapping. Within 5-years, this same region could be completed by allocating approximately 50 DAS per year from the *Research Vessel TATOOSH* and just 13 DAS per year from the *McARTHURII*. However, an additional 8 DAS per year would be needed from the *McARTHURII* (or similar vessel) to complete the South Line Plan, unless the *Research Vessel TATOOSH* were replaced with a larger vessel capable of engaging in 24-hour operations.

Table 9. Number of required days-at-sea (DAS) to complete 100 percent single beam side scan sonar coverage between the 20 and 350 m isobaths at the OCNMS within 2-Year, 5-Year, and 10-Year time schedules. DAS Required is the number of days needed to complete each listed line plan. Shallow water line plans (<100 m isobath) would be conducted from a small vessel such as the *Research Vessel TATOOSH*. Deep water line plans (350 < x <100 m isobath) would be conducted from a large ship such as the *NOAA SHIP McARTHURII*. South Line plans are beyond the operating range of the *Research Vessel TATOOSH* and will have to be completed by a vessel capable of undertaking 24-hour operations. *Research Vessel TATOOSH* lines assume 7-hour acquisition days. All other lines assume 21-hour acquisition days. Survey speed is 3.2 knots for all lines.

Line Plan/Vessel	DAS Required	2-Year	5-Year	10-Year
R/V TATOOSH	251.8	125.9	50.4	25.2
McARTHURII	65.3	32.7	13.1	6.5
SOUTH LINES	40.7	20.4	8.1	4.1

Multibeam Bathymetry

The *NOAA SHIP RAINIER* could complete 100 percent multibeam bathymetry coverage at the OCNMS within a 2-year time frame assuming that three launches were working simultaneously for 52 acquisition days each year in order to complete the region within the 50 meter isobath (Table 10). In each year an additional 45 days of offshore hydrographic survey operations would be required from the ship to complete the survey work with a 2-year time schedule. By requiring a single launch to operate approximately 65 days per year, the shallow-water surveying could be completed within a 5-year time frame. However, an additional 12 DAS (annually) would be required from the ship for the offshore survey work, assuming no launch tending were required. Through simultaneous use of 3 launches, the nearshore region could be completed with just 10 DAS annually over a 10-year period. Under this 10-year completion goal, however, an additional 9 DAS per year would be required from the ship.

Table 10. Number of required days-at-sea (DAS) to complete 100 percent multibeam bathymetry coverage beyond the approximate 10 m isobath at the OCNMS within 2-Year, 5-Year, and 10-Year time schedules. Deep water line plans (beyond 50 m isobath) would be completed with a ship such as the *NOAA SHIP RAINIER*. Shallow water line plans (inside 50 m isobath) would be completed by survey launches such as those available on the *NOAA SHIP RAINIER*. *RAINIER*[1]=calculations based on the ship tending launches (e.g., 12-hour acquisition days). *RAINIER*[2]=calculations based on the ship not tending launches (e.g., 18-hour acquisition days). Launches 1-3=based on the number of launches simultaneously used to acquire the shallow water data. Survey speed is 8 knots.

Line Plan/Vessel	DAS Required	2-Year	5-Year	10-Year
RAINIER[1]	90.5	45.3	18.1	9.1
RAINIER[2]	60.4	30.2	12.1	6.0
1 Launch	312.8	156.4	65.6	31.3
2 Launches	156.4	78.2	31.3	15.6
3 Launches	104.3	52.2	20.9	10.4

Optimized Survey Strategy

The optimized survey strategy is clearly the most time efficient means for completing the data acquisition efforts at OCNMS. In fact, this strategy could permit the creation of a high quality habitat map for the entire sanctuary, including the deep canyons, with just 2 years of intense data acquisition efforts. Under the 2-year plan, if 90 DAS were allocated each year from the *Research Vessel TATOOSH* (or similar vessel), the entire sanctuary between the approximate 10 and 100 meter isobaths could be completely mapped if using a combination of single beam side scan sonar, multibeam side scan sonar, and an appropriate interferometric sidescan/bathymetery system (Table 11). This would obviously require the vessel to be outfitted with an interferometric sidescan/bathymetry system yet also have the ability to mobilize a winch with at least 300 m of steel-armored data transmission cable terminated for both a single beam and multibeam side scan sonar. With this same 2-year goal, OCNMS would also need to receive approximately 33 DAS per year from the *NOAA SHIP McARTHURII* to complete the remaining single beam side scan sonar survey work between the 100 and 350 meter isobaths. An additional 20 DAS each year would need to be tasked to the *NOAA SHIP RAINIER* to complete the multibeam bathymetry work in the canyons. This, however, would first require the *NOAA SHIP RAINIER* to be outfit with a new multibeam echsounder capable of producing quality backscatter. Of note, the *NOAA SHIP FAIRWEATHER* and *NOAA SHIP Hi'IALAKAI* presently carry multibeam echsounders capable of meeting this mission. But because these ships are not currently tasked with survey operations on the entire west coast, the chances are unlikely for utilizing these platforms for habitat mapping work in OCNMS.

Table 11. Number of required days-at-sea (DAS) to complete 100 percent coverage at the OCNMS using the optimized survey strategy within 2-Year, 5-Year, and 10-Year time schedules. SBSS line plans in water depths deeper than 100 m would be conducted using single beam side scan sonar with a ship such as the *NOAA SHIP McARTHURII.* SBSS line plans in water depths inside the 100 m isobath would be conducted using single beam side scan sonar with a small vessel such as the *Research Vessel TATOOSH.* MBES line plans were designed to be completed with multibeam echosounder using a ship such as the *NOAA SHIP RAINIER.* ISB line plans (<20 m isobath) would be conducted with an interferometric side scan/bathymetry system from a small vessel such as the *Research Vessel TATOOSH* or *RAINIER* launch. MBSS line plans would be completed with multibeam side scan sonar from the *Research Vessel TATOOSH*. MBES assumed 18-hour acquisition days at 8 knots; MBSS assumed 7-hour acquisition days at 10 knots; ISB assumed 6-hour acquisition days at 8 knots; SBSS assumed survey speed of 3.2 knots with 7-hour acquisition days from the *Research Vessel TATOOSH* and 21-hour acquisition days from the *NOAA SHIP McARTHURII.*

Line Plan/Vessel	DAS Required	2-Year	5-Year	10-Year
SBSS_*McARTHURII*	65.3	32.7	13.1	6.5
MBES_*RAINIER*	39.1	19.6	7.8	3.9
ISB_Launch	45.3	22.7	9.1	4.5
SBSS_*TATOOSH*	26.5	13.3	5.3	2.7
MBSS_*TATOOSH*	115.2	57.6	23.0	11.5

SUMMARY

Over the past 5 years, minimal availability of ship time has been the biggest hurdle for acquiring habitat mapping data at the OCNMS. Although OCNMS has been fortunate to receive some ship time through the OMAO fleet allocation process and has also slowly created in-house acquisition capabilities, the habitat mapping program has really been limited to a piece-meal approach, destined to take decades to complete a first pass base map if the effort remains status quo. With inclement weather creating a narrow window of opportunity for data acquisition, being further limited by available ship time severely lengthens the number of years needed to accomplish this important task.

It is obvious that high quality detailed maps of the seabed are a basic need for each sanctuary and they function as important tools for guiding resource management decisions. But these decisions are best made when based on the most accurate and timely data possible. Even though operating the mapping efforts under the status quo scenario seems more financially feasible at present, this approach overlooks the cost of investing in outdated data for the future. It makes little economic sense to be engaging in a 25-year plan to complete a first-pass base map for a sanctuary when the data can not help shape important broad scale management decisions today, such as the need to define essential fish habitat, for example. Making a significant investment now would allow for the completion of data acquisition efforts within a reasonable timeframe and help shape and guide the important management decisions currently facing us.

Useful investments could come in many forms. With under $1,500,000 investment, an high-speed multibeam side scan sonar, an intereferometric sidescan/bathymetry system, and other required miscellaneous sensors and software, could be purchased to allow the optimized survey strategy to be pursued. Although seemingly steep, $1,500,000 would easily be offset through the time saved at-sea by more efficient and productive surveying. Also, a small vessel specifically dedicated to habitat mapping should be acquired to offset ship time lost by other important ongoing research projects at the site that would suffer from diversion of vessel time from the *Research Vessel TATOOSH*. If a second vessel is not acquired for the site, then involving a research partner with similar data needs, such as Washington State for example, would be imperative for realistic engagement in increased benthic mapping efforts. Furthermore, as we are currently within the FY09-13 planning phase, an upgrade to the multibeam system on the *NOAA SHIP RAINIER* and crucially important ship time commitments from OMAO from the *NOAA SHIP RAINIER* and *NOAA SHIP McARTHURII* are timely additions that need to be highlighted within the Mission Support Goal of NOAA’s Planning, Programming, Budgeting, and Execution System (PPBES). All of these budgetary commitments would bring a 5-year time schedule for completing the habitat mapping data acquisition efforts at OCNMS into realistic grasp.

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