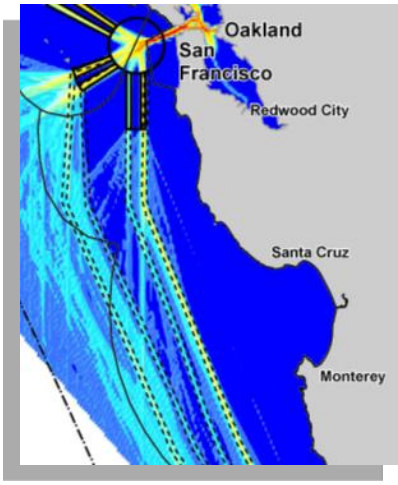
Monterey Bay National Marine Sanctuary (MBNMS)

Vessel Traffic Analysis 2009-2012

January 28, 2014



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Executive Summary

Monterey Bay National Marine Sanctuary (MBNMS) staff and stakeholders sought to have a better understanding of vessel compliance with the International Maritime Organization (IMO) recommended tracks within the MBNMS that were established in 2000. Three different analyses using Automated Information System (AIS) ship traffic data were completed to address this question. The Naval Postgraduate School (NPS) reviewed daily AIS data from September 2009-2012 and found that annually less than 8 individual cargo vessels deviated more than 3 nautical miles inshore of the northbound recommended track for vessels 300 gross tons and above and only one tanker was found deviating from that northbound track in that time-period. A further refinement of the analysis of the tanker traffic would be facilitated by access to data on the association and contents of each vessel because Western States Petroleum Association (WSPA) tankers carry crude oil, black oil, or other persistent liquid cargo in bulk and have agreed to stay more than 50 nautical miles offshore. The Southwest Fisheries Science Center of the National Marine Fisheries Service completed density maps for 2009 AIS data and found that tankers are using the recommended tracks, particularly those designated for vessels carrying hazardous cargo in bulk with an especially higher density using the southbound track. The 2009 data analysis by the Southwest Fisheries Science Center indicated higher densities of cargo vessels in the northbound recommended track for vessels 300 gross tons and above than in the other three tracks. MBNMS began conducting random daily reviews of AIS data on October 1, 2012 and staff contact the United States Coast Guard (USCG) when a deviation of more than 3 nautical miles inshore of the northbound recommended track for vessels 300 gross tons and above is noted. The USCG verifies the AIS data and contacts the vessel if they determine that the AIS data do reflect a deviation. These three AIS analyses do indicate that a great majority of the vessels that transit through the MBNMS are complying with the IMO recommended tracks.

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Introduction

Vessel traffic was identified as a major issue of concern during NOAA's Monterey Bay National Marine Sanctuary's (MBNMS) designation process due to potential impacts from a large spill should any vessels collide or ground along the coastline. For example, an oil spill could severely impact the sea otter population. The Sanctuary also hosts an abundance of whales and the National Marine Fisheries Service (NMFS) has identified vessel strikes as one of the threats that could impede the recovery of endangered whales, so it is vital to better understand vessel traffic in MBNMS.

In response to the raised concerns, the United States Coast Guard (USCG) and the National Oceanic and Atmospheric Administration (NOAA) established a working group of key stakeholders in the issue of vessel traffic, including representatives from federal, state and local governments, environmental groups and industry to review existing practices and risks, and recommend a package of strategies which would maximize protection of Sanctuary resources while allowing for the continuation of safe, efficient and environmentally sound transportation. The group's recommendations included implementing tracks offshore for container ships, bulk freighters, and vessels carrying hazardous materials to reduce the risk of groundings, and organizing those tracks into north-south lanes to reduce the risk of collision. These recommendations were ultimately approved by the International Maritime Organization (IMO), and implementation began in 2000 (See Figure 1).

In 2013, MBNMS resource protection staff working with a number of partners, including an environmental Non-Governmental Organization (NGO) stakeholder, made a decision to conduct an analysis on vessel use of the recommended tracks to determine if vessels were adhering to the recommended tracks. By using cargo and tanker navigation data that was made available through USCG and Naval Postgraduate School (NPS) and in partnership with other federal agencies, MBNMS was able to review and evaluate use of IMO recommended track lines over a four-year period from 2009 to 2012.

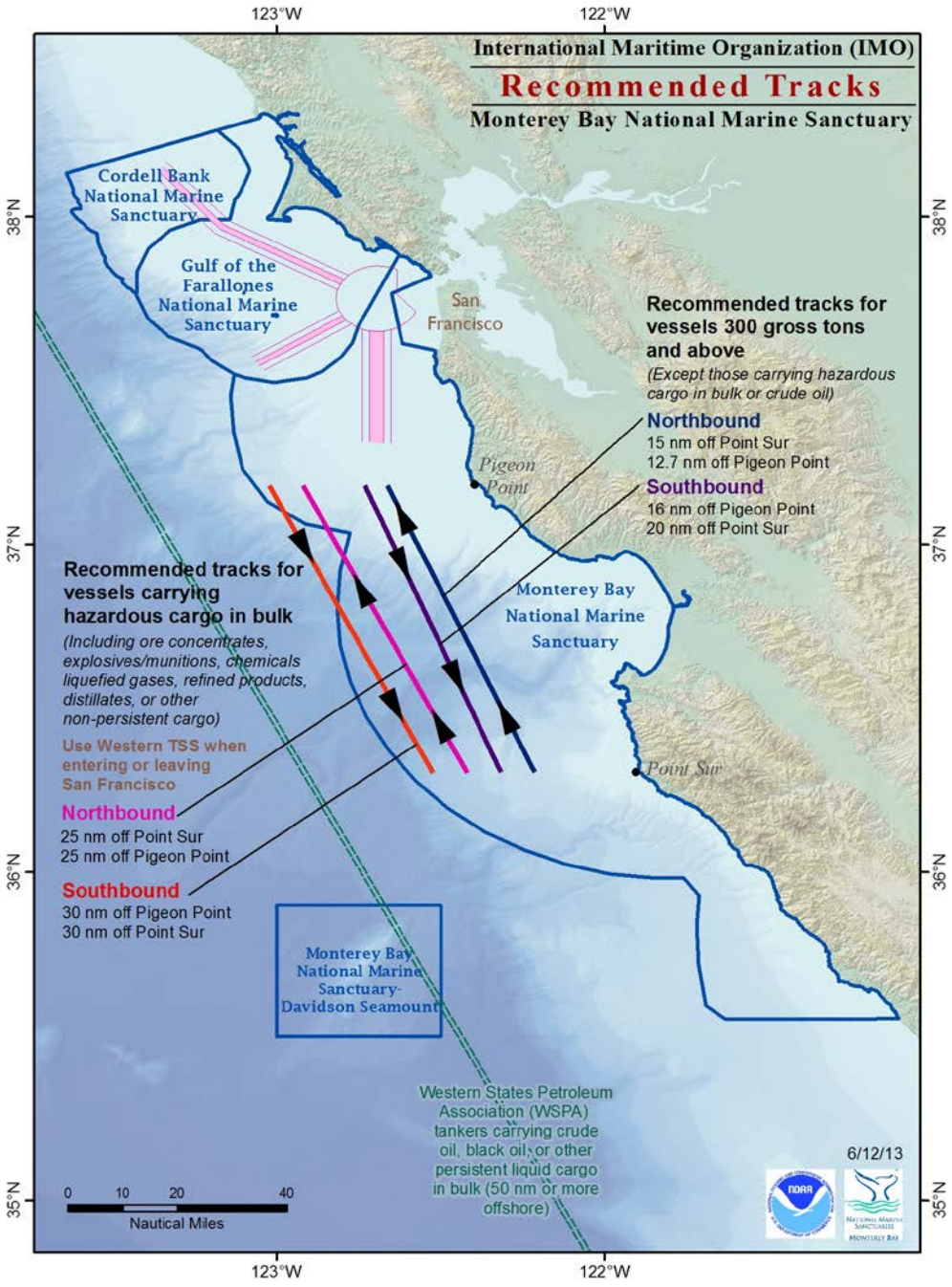

Figure 1. International Maritime Organization recommended tracks within Monterey Bay National Marine Sanctuary. The San Francisco Traffic Separation Scheme (TSS), shown in pink, was updated June 1, 2013 to reduce whale strikes by ships and improve navigational safety. The four recommended tracks are split between northbound and southbound lanes for vessels >300 tons (blue and purple lines respectfully) and vessels carrying hazardous cargo in bulk such as liquefied gases (pink and orange lines respectfully). The Western States Petroleum Association (WSPA) tankers agreed to transit 50 nm or more offshore (shown in dashed green line).

This report describes three approaches used to analyze vessel compliance with the IMO recommended tracks. All three methods rely on Automatic Identification System (AIS) data. AIS is an automatic tracking system used on ships and by vessel traffic services to identify and locate vessels in the surrounding area by exchanging electronic data with other ships and AIS base stations. The IMO requires that AIS be fitted aboard all passenger ships, aboard all ships of 300 gross tons, or greater, on international voyages, and aboard all cargo vessels of 500 gross tons, or greater, on non-international voyages (http://www.imo.org/OurWork/Safety/Navigation/Pages/AIS.aspx). It was originally developed to improve navigational safety and collision avoidance. However, AIS was also developed for other safety reasons, so using it to determine compliance with the recommended tracks is within the scope of its original intent. The three AIS analytical approaches were conducted by:

1. Naval Postgraduate School (NPS)- Christopher Miller;
2. Southwest Fisheries Science Center (SWFSC)- TJ Moore;
3. Monterey Bay National Marine Sanctuary (MBNMS) - Sophie De Beukelaer, Scott Kathey, and Karen Grimmer.

The SWFSC analysis focuses on an overall vessel density analysis but both the NPS and MBNMS analyses focus on daily vessel deviations. The term "deviation" was selected to characterize a vessel that was inshore of the easternmost recommended track.

Methods

Naval Post Graduate School AIS Analysis

Naval Post Graduate School (NPS) staff, Christopher Miller, analyzed ship traffic in MBNMS for September 2009 to 2012 using the AIS data from Volpe, The National Transportation Systems Center, data feed. NPS contributes data to VOLPE from AIS base stations located at Port San Luis (Avila Beach), Point Sur, the NPS (Monterey), and Bodega Bay. Miller also worked with Moss Landing Marine Laboratory to get an AIS receiver aboard the R/V POINT SUR automatically forwarded to the NAIS Volpe center, whenever they are underway, and their at-sea internet connection is operating.

The data feeds, both from the NPS receivers as well as the Government Use Only feed from the National AIS center / Volpe and are currently being archived as daily log files of time-tagged, raw AIS messages. Miller developed MatLab code to extract and decode the message traffic for analysis. MBNMS provided Miller with a deviation polygon (See yellow area in Figure 2), which included the area east (or inshore) of the northbound recommended track for vessels 300 gross tons and above that is south of Pigeon Point and north of Point Sur. The MatLab code returned

parsed data per day containing the name of the cargo vessel if it crossed the original deviation polygon. From the MatLab structure data, cargo vessel track data were exported into ESRI line objects (see the MPP Triumph as an example in Figure 2). NPS staff conducted this deviation analysis for all cargo vessels for AIS data from September 2009 to 2012. Tanker tracks were exported from the AIS data if the tankers crossed any MBNMS boundary lines, including Davidson Seamount Management Zone.

The original deviation polygon used to cull the AIS data by NPS was updated based on conversations between USCG and MBNMS staff that took into consideration the width of the TSS lanes. It was decided to provide a 3 nm buffer eastward from the northbound track for vessels 300 gross tons and above for the new deviation polygon. MBNMS used GIS to identify vessels that crossed this new deviation polygon (see results section).

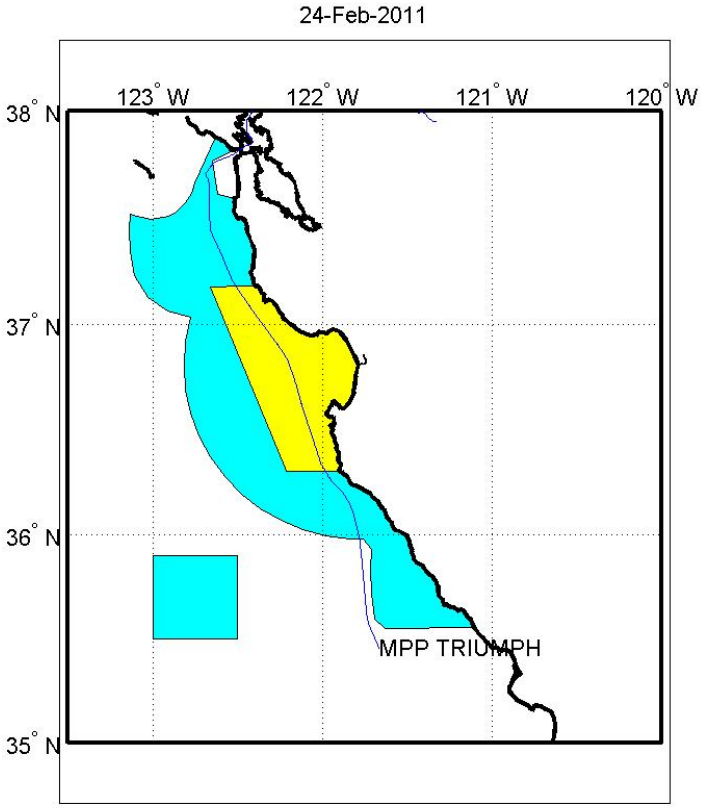

Figure 2. The yellow area signifies the original deviation box that alerted NPS computers to a deviation. The western boundary is the northbound recommended track for vessels 300 gross tons and above and is 15 nm off Point Sur and 12.7 nm off Pigeon Point. As an example, the MPP Triumph track line represents a ship transit which reflects a deviation from the recommended lanes.

National Marine Fisheries Service AIS analysis

The NMFS analysis is based on AIS data available from MarineCadastre.gov for the period of January – December 2009. The data for June of 2009 are limited to the first four days of the month (due to an incomplete record of data available from the source). The analysis was conducted with ArcGIS 10.x software, the ArcGIS Spatial Analyst extension, and the ArcPy site package for Python. Python scripting methods were used to extract, process, and analyze the data. The analysis includes data for tankers (AIS ship type 80-89), cargo vessels (AIS ship type 70-79), and large passenger ships (AIS ship type 60-69 and length >= 100 m). The study area includes the California coast from Fort Bragg in the north to Julia Pfeiffer Burns State Park along the Big Sur coast, which is in the southern region of MBNMS.

Various data validation processing was conducted on the data. For example, the nine-digit identifier called the Maritime Mobile Service Identity (MMSI) was required to be within a valid range for a ship (the three leading digits, called the Maritime Identification Digits, should be in the range 201 to 775). Other criteria included speed over ground (SOG) values greater than 0 and appropriate navigational status codes to filter out vessels that are not underway.

The annual vessel traffic density (in kilometers (km) traveled/square km) was calculated using the Line Density tool with a one kilometer grid cell size and a 500 meter search radius. The resulting numbers are not quite a count of vessel transits per grid cell but rather an estimate of the cumulative distance traveled through each grid cell. So, for example, one could have 22 vessel transits in a grid cell and 24.6 km transited for a grid cell. In most orientations of transits and grid cells with a large record of data, the estimated values of km traveled will approximate the number of transiting vessels because NMFS used 1 square km grid cells. However, transits along the diagonal or near a corner of a grid cell could cause the count of transits to deviate more from the estimated cumulative km traveled through the grid cell. The density modeling from this analysis may be somewhat of an underestimate of the actual ship traffic due to these considerations and other minor issues relative to methods, but should be a good representative overview of traffic density in the region during an annual period (2009).

Monterey Bay National Marine Sanctuary Analysis

Sanctuary staff uses three sources to conduct daily real time monitoring:

1. CeNCOOS: http://www.cencoos.org/sections/ais/aismap.shtml. The Central & Northern California Ocean Observing System (CeNCOOS) AIS data is a courtesy of the Naval Postgraduate School, Department of Oceanography. Sanctuary staff provided *.kml files for the San Francisco TSS and the recommended tracks to CeNCOOS staff to provide spatial references for the AIS data (see Figure 3). This CeNCOOS site is checked

when any possible deviations are witnessed using MarineTraffic (see below), as MarineTraffic.com doesn't include the tracks for spatial reference. A vessel is considered to be deviating if it is more than three nautical miles eastward from the northbound track for vessels 300 gross tons and above. Each vessel's unique signal allows its name and type as well as speed and direction to be reported. The red balloon marker shows the most recent position of the ship, with the previous trackline indicated by a line extending from marker. The trackline is color-coded based on the type of vessel, e.g. tanker tracks are black and cargo tracks are red. The map updates on every hour and at 20 minutes past each hour, showing the location of ships for the nearshore marine area from Pt. Arena to Pt. Conception as of those times.

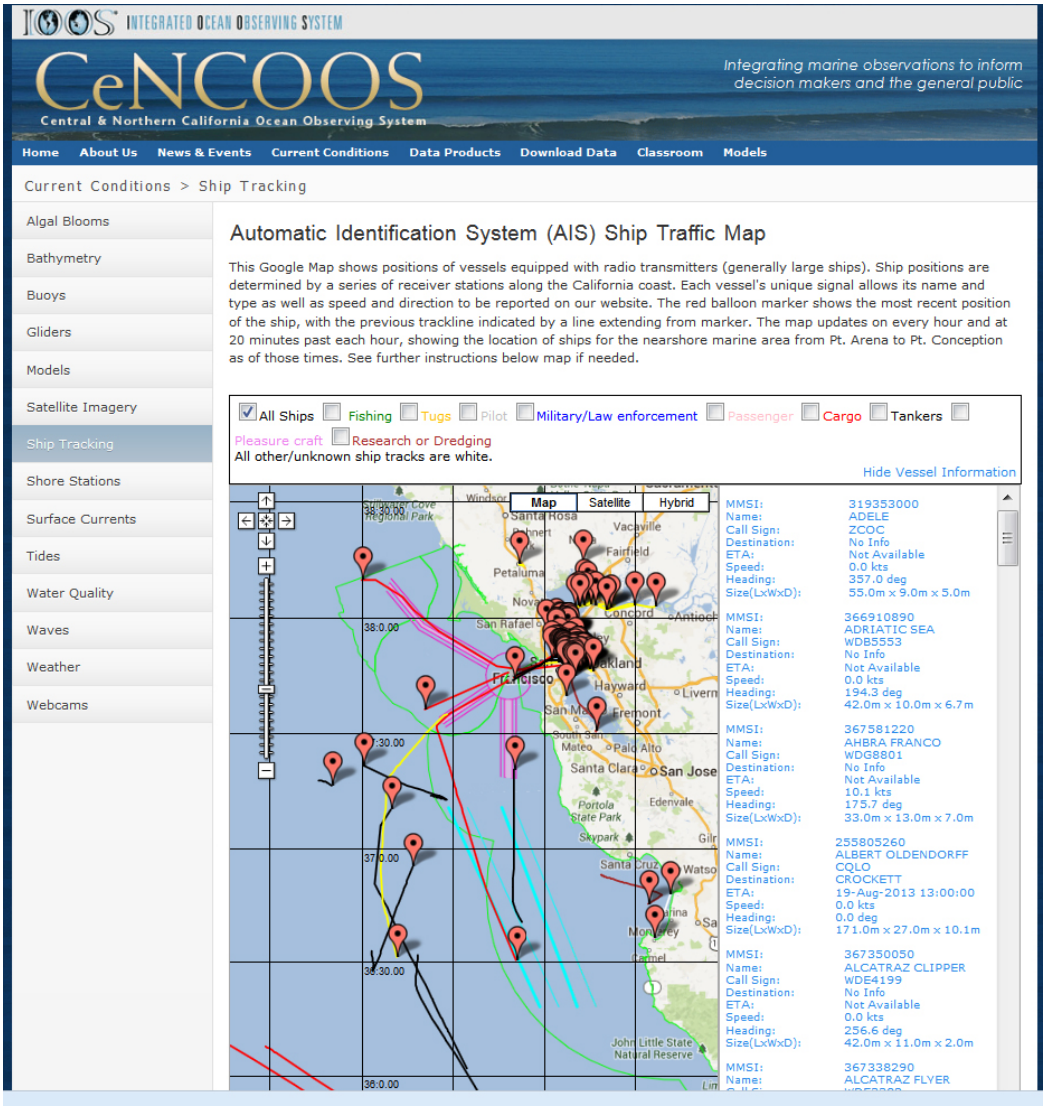

Figure 3. Screenshot of CeNCOOS's AIS data interface. The recommended tracks are shown in light blue, the San Francisco TSS in pink, Sanctuary boundaries in green and the red balloons are ship locations with track colors

indicating the type of vessel. For example, in the middle of the mapped region, a tanker (black track) crossed over the recommended tracks to enter the southern San Francisco TSS.

2. MarineTraffic: http://www.marinetraffic.com/ais/ NPS also contributes data to Marine Traffic but it is augmented with other land based AIS stations. MarineTraffic is updated every 99 seconds and easily opened in a web browser so this is usually the first site that the staff checks for the daily deviation review (see Figure 4). A user can click on a ship to get details such as the name, speed/course, destination and ETA and also select the "Show Vessel's Track" to see the vessels trackline. One can also use the "Distance to…" tool to select waypoints to measure the distance. For recommended track compliance, this tool is often used to check the distances to Point Sur and Pigeon Point. If a ship is deviating from the recommended tracks, the Sanctuary Staff will select "Vessel's Details" to copy the IMO and MMSI numbers to fill in the violations tracking sheet described below.

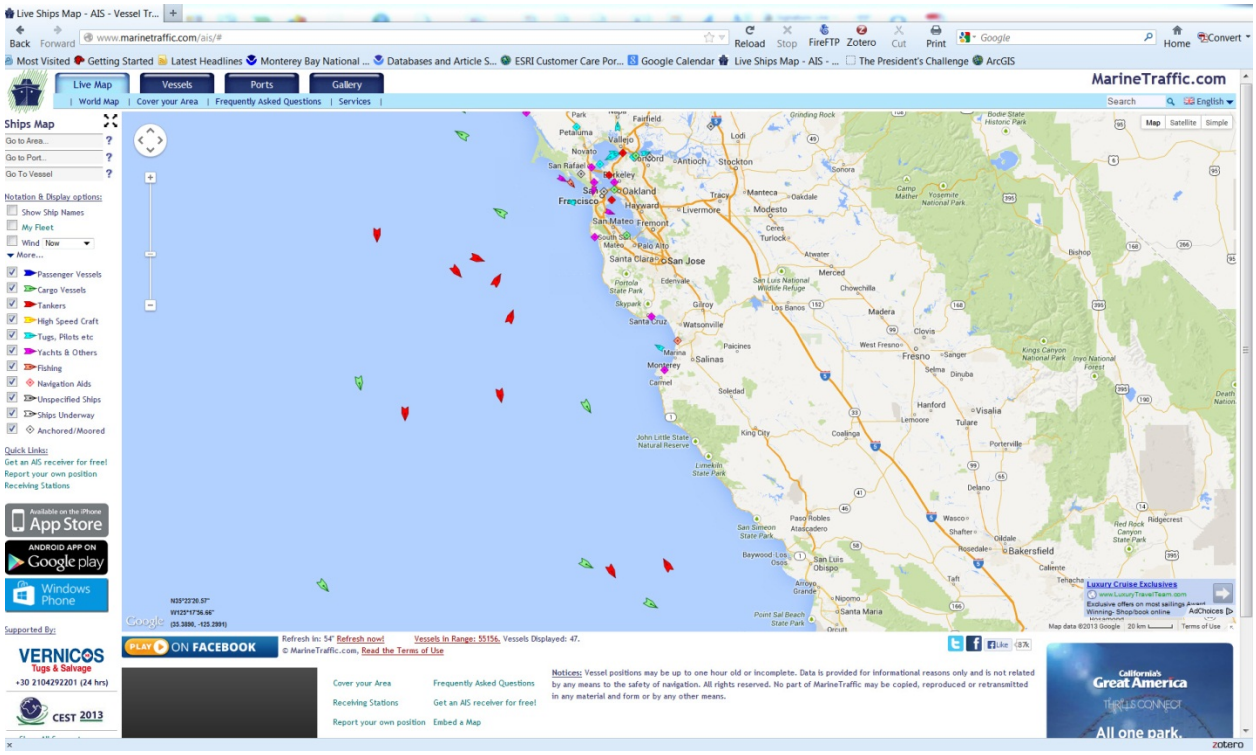

Figure 4. Screenshot of the MarineTraffic AIS data interface. Tankers are shown in red and cargo vessels in green. No marine spatial boundaries are available within this interface.

3. TV32: https://mssis.volpe.dot.gov/Main/home/ TV32 is client software for the Maritime Safety and Security Information System that serves as a common system interface and vessel tracking display used by government organizations. Since TV32 is an application, it is usually only employed when deviations from tracks have been confirmed on both

MarineTraffic and CeNCOOS's AIS sites. It requires a government login but contains the same information that is available through MarineTraffic in terms of the cargo type, destination, MMSI, speed, type, etc. although because it allows the user to import a NOAA chart as a background map, it allows a closer evaluation of the vessels use of the recommended tracks (see Figure 5).

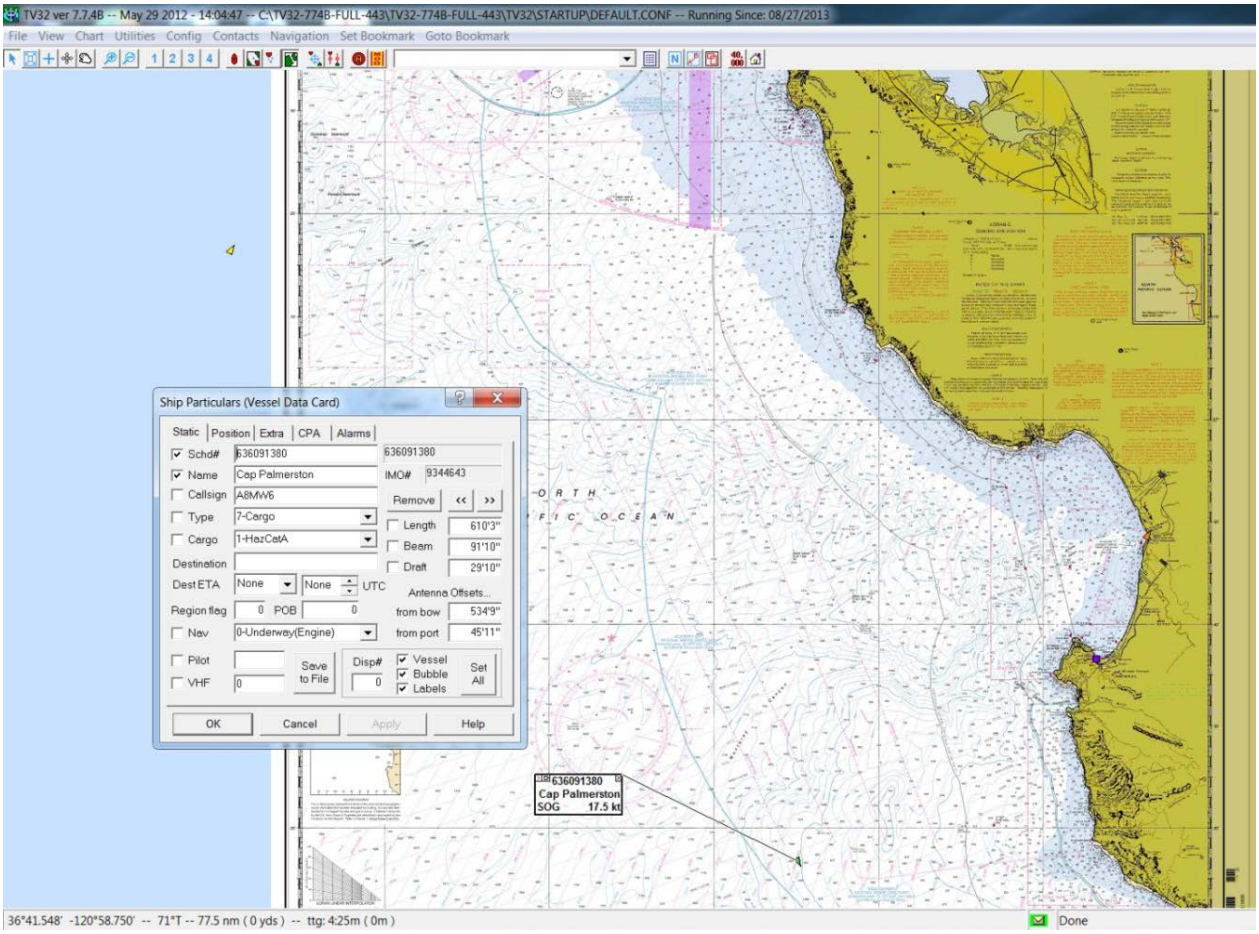

Figure 5. TV32 interface showcasing the nautical NOAA chart 18680 and vessels in the area. The screenshot captures the details for the Cap Palmerston which has indicated that its cargo is classified as "1-HazCatA" and she is heading south of the recommended track for vessels carrying hazardous cargo in bulk.

Monitoring details are described in a Google document that is shared with pertinent sanctuary staff and the USCG staff. The document has several tabs including one for reviews and one for deviations. The vessel log details include: date, time, software or site used for the review, staff that conducted the review, deviation description and comments. If a deviation was observed, then more details are filled in the "Deviations" tab. These details include: Date, Time, Vessel Name, Vessel Type, Cargo Type, Country of Origin, IMO number, MMSI number, Location of Deviation, Heading, Last known port, Destination Port, Speed (knots), Company, USCG letter

sent?, software or site used for the review, staff that conducted the review, if a screenshot was taken, image location (if online), if NPS captured the deviation in its analysis, and notes. When a deviation occurs, staff takes a screenshot of the AIS interfaces to document the deviation and stores it on a hard-drive.

Deviations are noted if a vessel is more than 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above. That means that a deviation occurs if a vessel is 12 nm or less from Point Sur or 9.7 nm or less from Pigeon Point. If a deviation is observed, the details are logged as described above and the USCG is contacted and provided with the details. The USCG then determines if there is indeed a deviation using their classified AIS data and then determines whether to contact the vessel operator and/or send a letter to the company that owns the vessel.

Caveats concerning interpretation of AIS data

Below is a list of conditions and considerations (caveats) that must be taken into account when analyzing AIS data for possible deviations from IMO ship track recommendations. One overarching point should be kept in mind when discussing the IMO ship tracks and vessel use of those tracks - the tracks are "recommendations only" and not enforceable by US law. The tracks themselves are beyond the 12-mile territorial sea of the United States, where freedom of navigation is observed by the international community as a matter of common law.

Conditions and Considerations (Caveats) for Interpreting Potential IMO Track Non-Compliance Using AIS Data

Design v. Use - AIS was designed for the purpose of ship-to-ship, ship-to-shore, and shore-to-ship communication of information pertinent to navigational safety, search and rescue, security, etc. AIS was not designed for purposes of various ship tracking applications or retrospective ship track analysis.

Signal Interference - AIS radio signals can be interrupted or shortened by atmospherics (RF propagation) - they are not uniform in broadcast strength or range and are not 100% consistent. Receiver arrays also vary in signal detection capability.

Signal Gap - AIS coastal receivers may be absent or non-functional in some areas, causing incomplete data for the region.

AIS Transmission Crash - Individual AIS transmitters may go off-line due to malfunction, power loss, or manual shut-down.

AIS Position Errors - AIS position information may be skewed due to problems with GPS systems or satellites.

Misleading AIS Profiles

Incorrect Operating Status - AIS cargo info is manually entered and is sometimes not updated before leaving port, giving a false status about onboard cargo. Similarly, "destination" and other manual entry profile data may be outdated.

Incorrect Vessel Type - AIS vessel type categories are designed to describe "operational status" (i.e. towing, cargo, fishing, etc.) - not vessel classification (i.e. research, tug, ferry, etc.). When R/V Fulmar deploys a tethered sonar, the boat displays on AIS as "towing" and could be interpreted as a tug and barge, rather than a research vessel. The code 27 could be used as a research vessel classification in AIS. The R/V RACHEL CARSON once appeared on AIS as a "dredge" barge.

False AIS Identity - Military or law enforcement vessels may purposely display false profiles for security reasons.

Shared AIS ID - Some shipping companies have used the same MMSI identifier in the past for multiple ships in a fleet to cut registration costs. For example, sometimes ships are transmitting MMSI of 1193046 which is the default MMSI after AIS installation and means that the MMSI wasn't updated after installation by the vessel operator. The result is that the ship tracks of several vessels appear as that of only one vessel, presenting a confusing and misleading transit pattern.

Data Processing Errors - Computer servers used to log AIS data may go off-line due to power outages or other problems, resulting in incomplete or corrupted data.

Potential Vessel Course Diversion

Traffic Diversion - Vessels may divert from IMO tracks to avoid other traffic or wildlife.

Sea State Diversion - Vessels may divert from IMO tracks to adjust for violent sea state and swell attack angles.

Emergency Diversion - Vessels may divert from IMO tracks due to emergencies, such as steering malfunction, on-board fire, medical evacuation, Coast Guard boarding, etc.

Non-WSPA Tanker - An oil tanker may be operating inshore of the voluntary 50-mile line because it does not belong to a WSPA member organization.

Empty Tanker - An oil tanker may be operating inshore of the voluntary 50-mile stand off line because it is empty (in ballast) and thus carries no oil cargo.

Results

Naval Post Graduate School Analysis

Cargo Vessels

Individual shapefiles representing the daily track of a vessel within the original deviation area were compiled in GIS to show an annual congregation of deviations for cargo vessels. Figure 6 shows tracks of all cargo vessels that were within the original yellow deviation area (See Figure 2) from 9/4/2009 to 12/17/2009. Many cargo vessels deviated from the northern end of the northbound recommended track for vessels 300 gross tons and above before entering the southern San Francisco Traffic Separation Scheme (TSS). However, these deviations were less than 3nm and not in the modified deviation area shown in pink in Figure 6.

For the three month period in 2009, three cargo vessels transited over 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above for the data collected in 2009 (See Table 1). There were a total of three deviations by these three vessels in 2009. Vessels transiting at 00:00 GMT were only counted once. For example, the cargo vessel Santa Cruz was transiting along the same path in the deviation area at 00:00 GMT between 10/4/2009 and 10/5/2009 so that was only counted as one deviation, not two.

Data were available for all of 2010, and five individual cargo vessels were detected more than 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above (See Figure 7 and Table 2). There were a total of 11 deviations by these five vessels in 2010.

During all of 2011, six individual cargo vessels were detected deviating more than 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above (See Figure 8 and Table 3). There were a total of seven deviations by these six vessels in 2011.

During all of 2012, eight individual cargo vessels were detected deviating more than 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above (See Figure 9 and Table 4). There were a total of 10 deviations by these eight vessels in 2012.

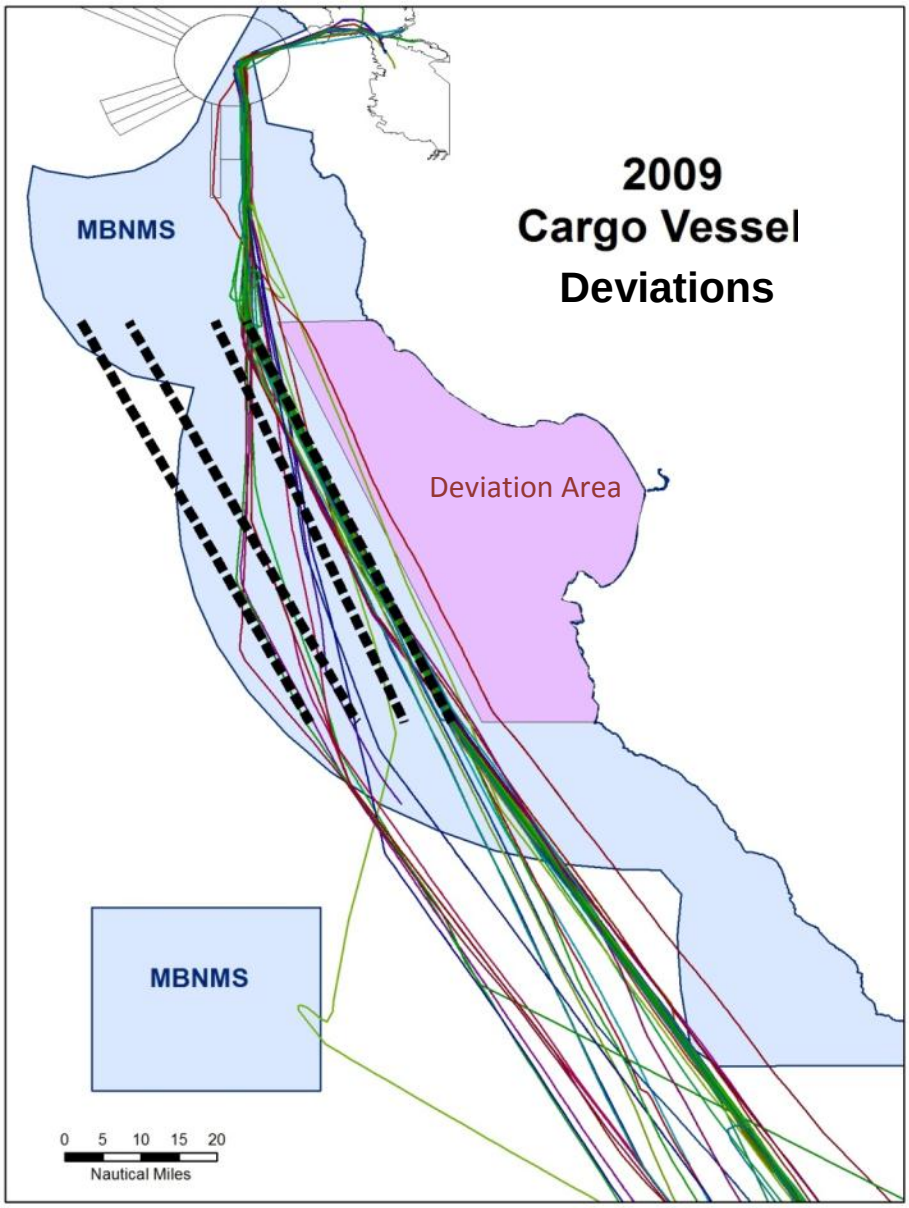

Figure 6. NPS AIS analysis for cargo vessel deviations for 2009. Only the tracks for cargo vessels that transited east of the northbound recommended track for vessels 300 gross tons and above (original deviation area) are shown. The recommended tracks are shown as dashed lines, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2009 is shown.

Table 1. 2009 Cargo vessel deviations. Cargo vessels more than 3 nm inshore of northbound recommended track for vessels 300 gross tons and above for AIS data collected in 2009 (9/4/09 to 12/17/09).

Date	Vessel Name
10/4/2009	Santa Cruz
10/5/2009	Santa Cruz
10/8/2009	YM Vancouver
11/7/2009	Maersk Dhahran
Total # Vessels	**3**
Total # Deviations	**3**

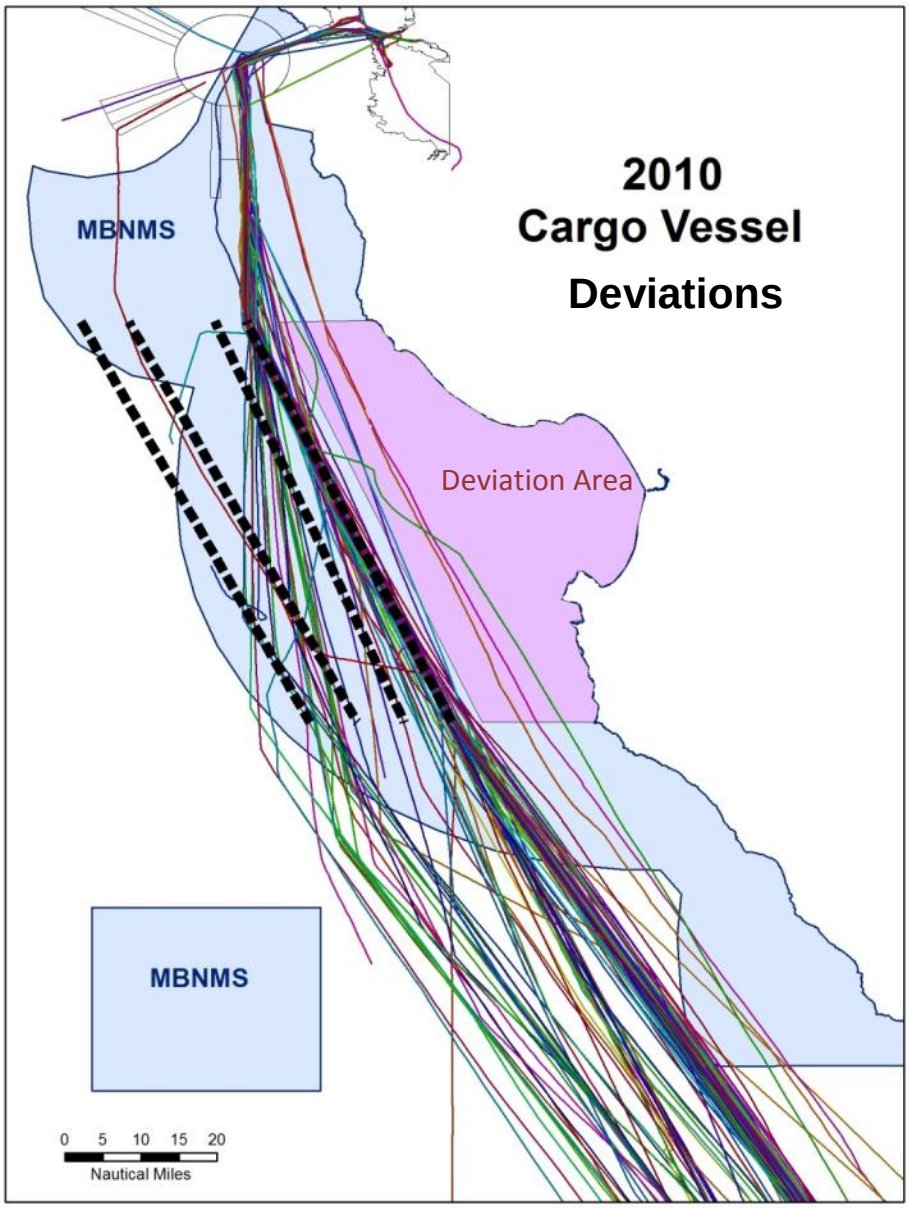

Figure 7. NPS AIS analysis for cargo vessel deviations for 2010. Only the tracks for cargo vessels that transited east of the northbound recommended track for vessels 300 gross tons and above (original deviation area) are shown. The recommended tracks are shown as dashed lines, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2010 is shown.

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Table 2. 2010 Cargo vessel deviations. Cargo vessels more than 3 nm inshore of northbound recommended track for vessels 300 gross tons and above for AIS data collected in 2010.

Date	Vessel Name
1/6/2010	Maersk Dhahran
3/11/2010	Maersk Dhahran
4/4/2010	Leda Trader
4/6/2010	Hyundai Singapore
5/13/2010	Maersk Dhahran
5/14/2010	Toby Tide
5/15/2010	Toby Tide
5/25/2010	Toby Tide
5/26/2010	Toby Tide
7/14/2010	Maersk Dhahran
7/19/2010	Horizon Falcon
9/16/2010	Maersk Dhahran
11/19/2010	Maersk Dhahran
Total # Vessels	**5**
Total # Deviations	**11**

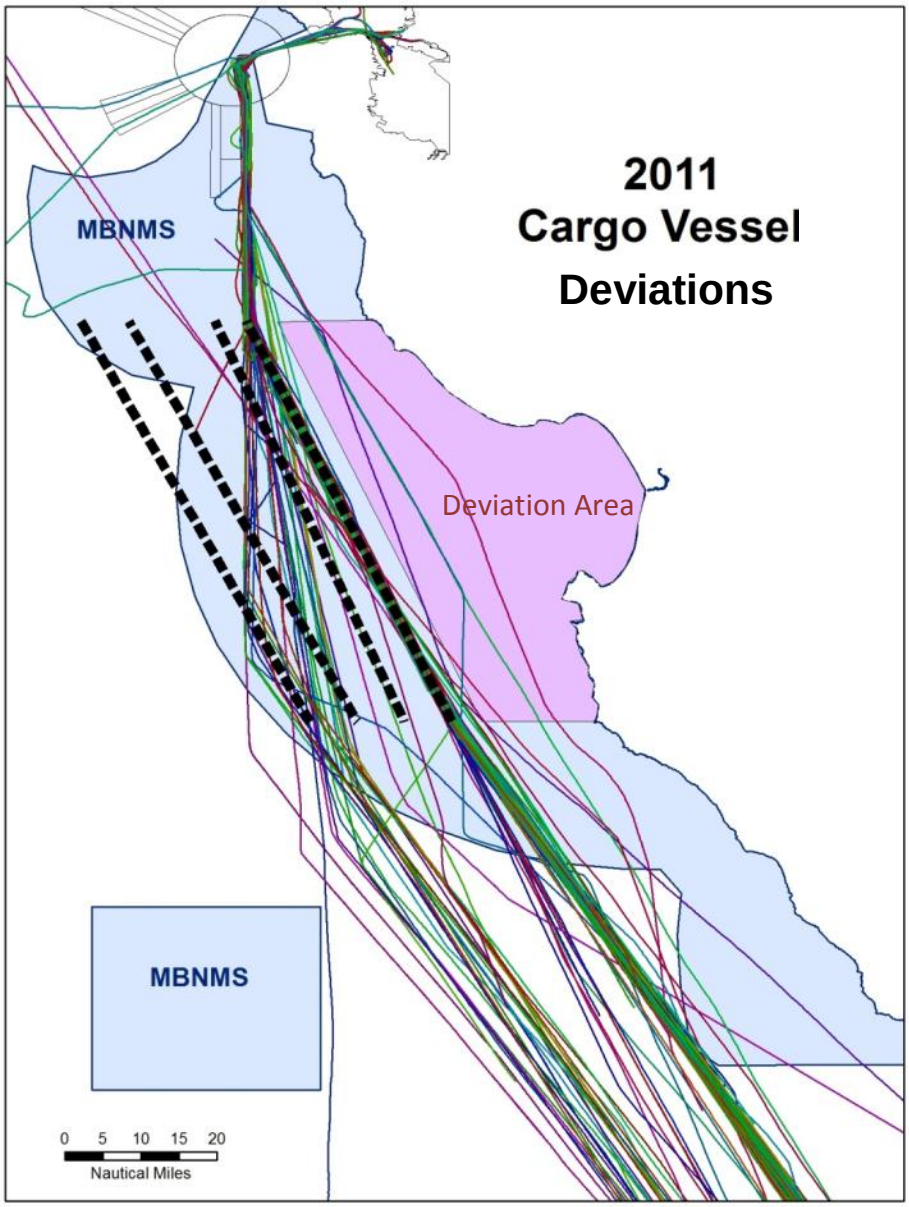


Figure 8. NPS AIS analysis for cargo vessel deviations for 2011. Only the tracks for cargo vessels that transited east of the northbound recommended track for vessels 300 gross tons and above (original deviation area) are shown. The recommended tracks are shown as dashed lines, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2011 is shown.

Table 3. 2011 cargo vessel deviations. Cargo vessels more than 3 nm inshore of northbound recommended track for vessels 300 gross tons and above for AIS data collected in 2011.

Date	Vessel Name
1/21/2011	Maersk Dhahran
2/24/2011	MPP Triump
5/8/2011	Kota Jasa
5/12/2011	Ocean Pioneer
5/24/2011	MV CSAV Venuzuela
6/17/2011	Kota Jasa
8/14/2011	NRC Quest
Total # Vessels	**6**
Total # Deviations	**7**

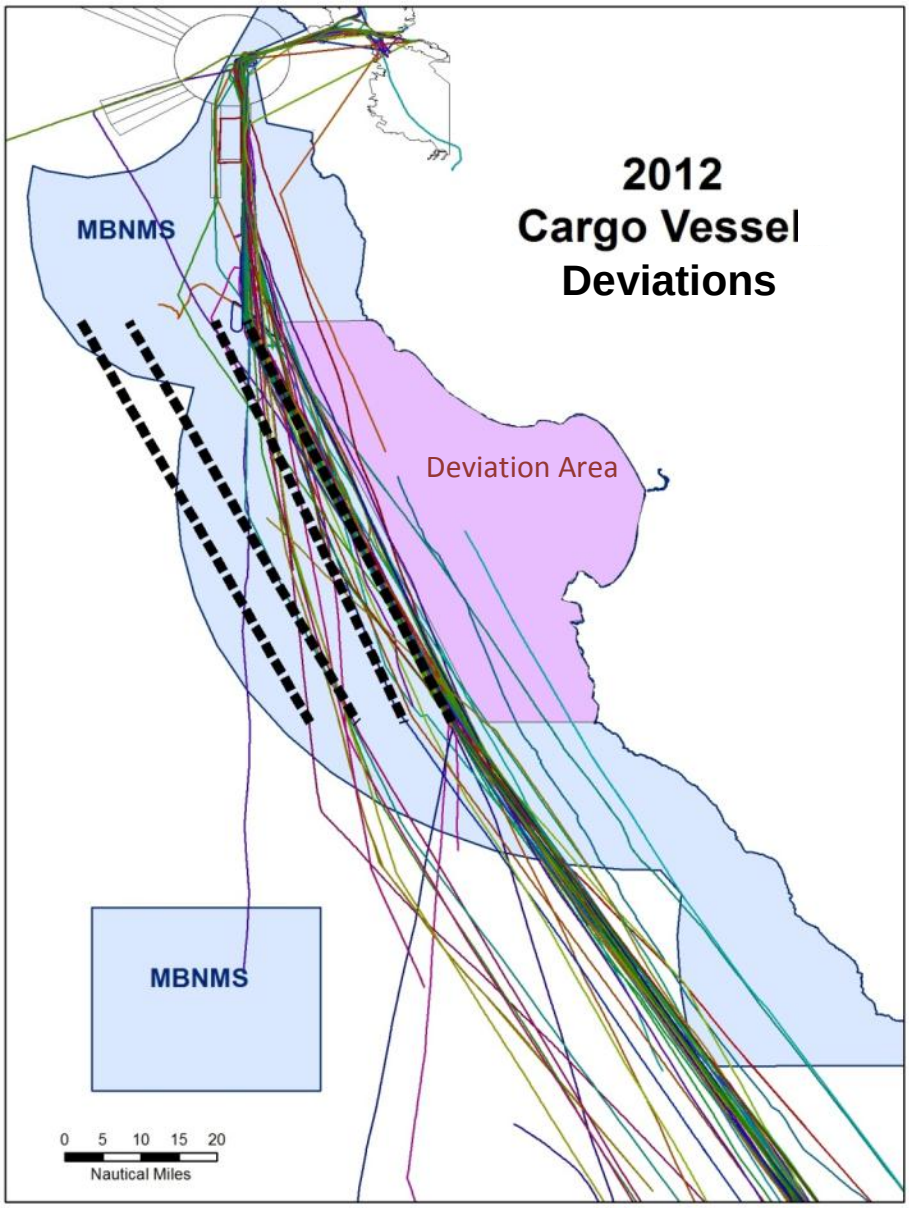


Figure 9. NPS AIS analysis for cargo vessel deviations for 2012. Only the tracks for cargo vessels that transited east of the northbound recommended track for vessels 300 gross tons and above (original deviation area) are shown. The recommended tracks are shown as dashed lines, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2012 is shown.

Table 4. 2012 Cargo vessel deviations. Cargo vessels more than 3 nm inshore of northbound recommended track for vessels 300 gross tons and above for AIS data collected in 2012.

Date	Vessel Name
2/27/2012	Mol Diamond
4/6/2012	Hanjin Hamburg
5/18/2012	Apl Thailand
6/14/2012	Cape Mayor
7/5/2012	Apl China
7/22/2012	War Admiral
8/23/2012	War Admiral
8/24/2012	War Admiral
9/14/2012	Adele Elise
10/10/2012	Adele Elise
10/13/2012	Ocean Pioneer
Total # Vessels	**8**
Total # Deviations	**10**

Tankers

Any tanker track that crossed the MBNMS boundaries, including Davidson Seamount Management Zone, was exported from Matlab and mapped in GIS. However, due to the lack of knowledge of their ballast, we focused on those deviating 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above. No tankers were detected more than 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above in 2009 (during 9/4/09 to 12/17/09), 2011, nor in 2012 (See Figure 10, Figure 12 and Figure 13

respectively.) In 2010, one tanker was detected more than 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above (See Figure 11 and Table 5).

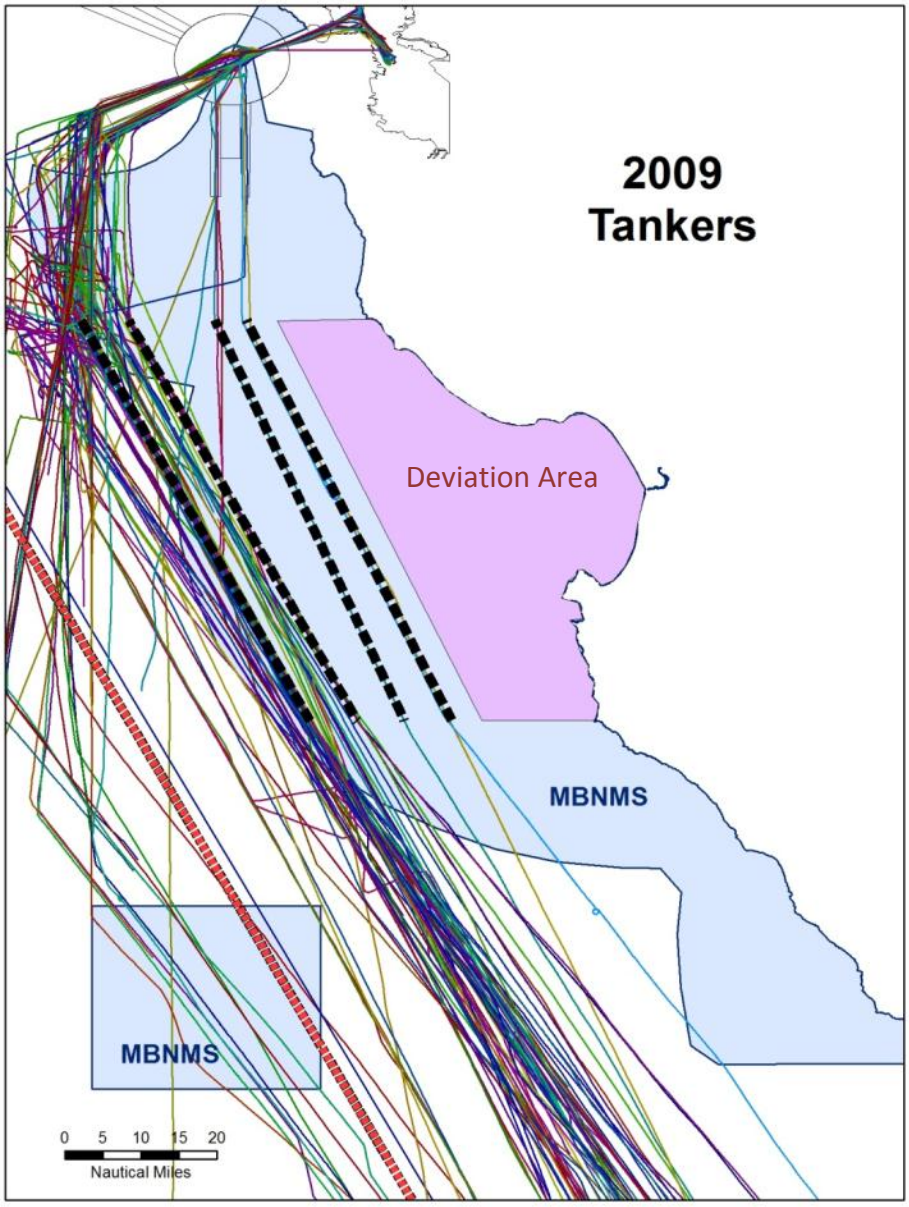


Figure 10. NPS AIS analysis for tankers for 2009 (9/4/09 to 12/17/09). Only the tracks for tankers that transited through the MBNMS are shown. The recommended tracks are shown as black dashed lines, the 50 nm rhumb line is shown as a dashed red line, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tanker tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2009 is shown.

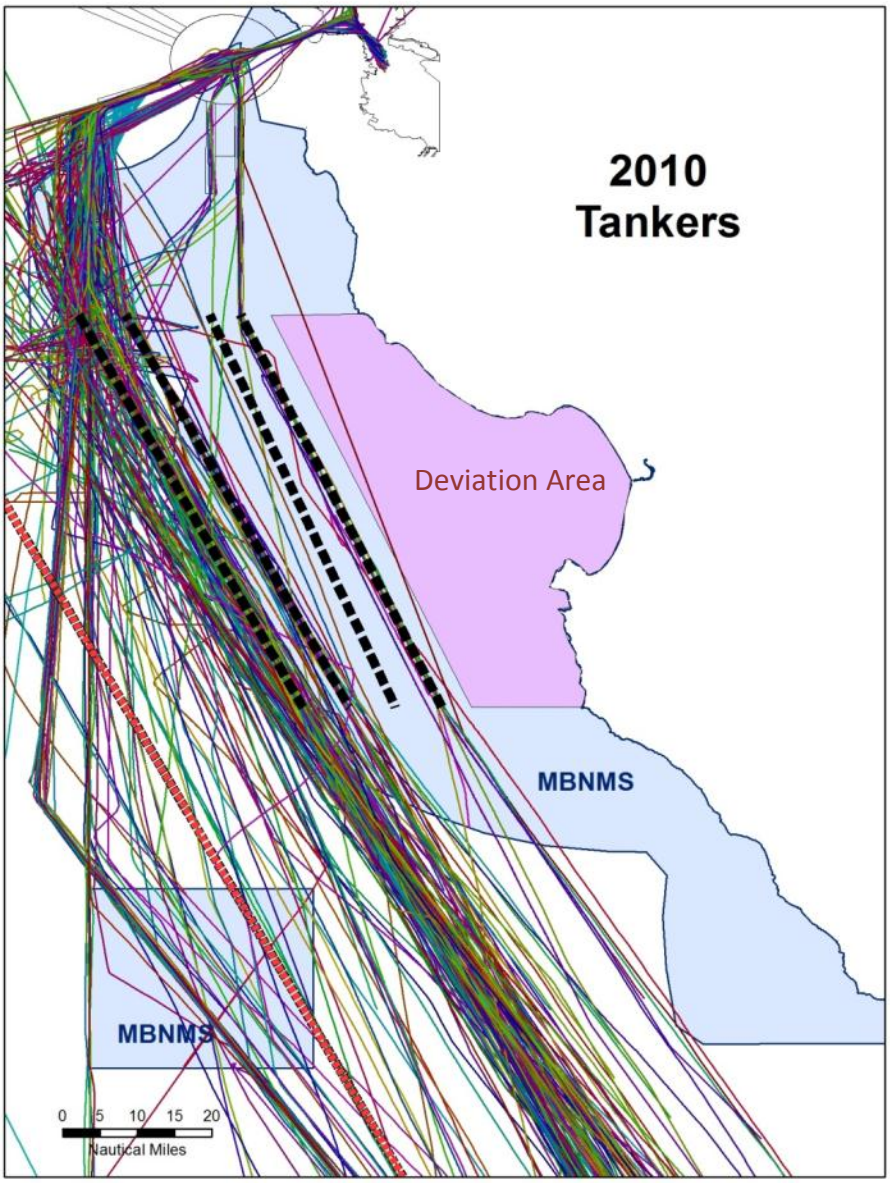


Figure 11. NPS AIS analysis for tankers for 2010. Only the tracks for tankers that transited through the MBNMS are shown. The recommended tracks are shown as black dashed lines, the 50 nm rhumb line is shown as a dashed red line, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tanker tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2010 is shown.

Table 5. 2010 Tanker deviations. Tankers more than 3 nm inshore of northbound recommended track for vessels 300 gross tons and above for AIS data collected in 2010.

Date	Vessel Name
4/19/2010	Gulf Stream
Total # Vessels	1
Total # Deviations	1

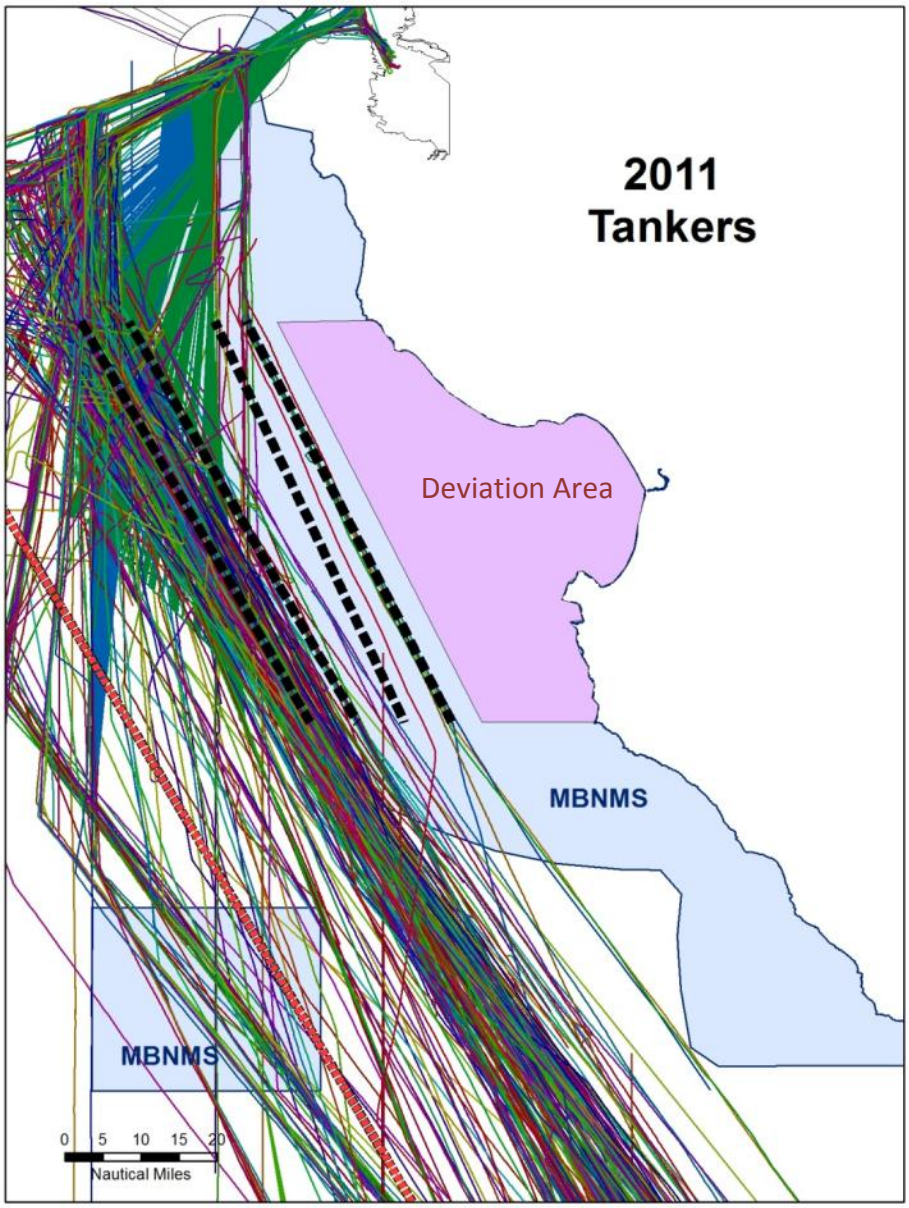


Figure 12. NPS AIS analysis for tankers for 2011. Only the tracks for tankers that transited through the MBNMS are shown. The recommended tracks are shown as black dashed lines, the 50 nm rhumb line is shown as a dashed red line, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tanker tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2011 is shown.

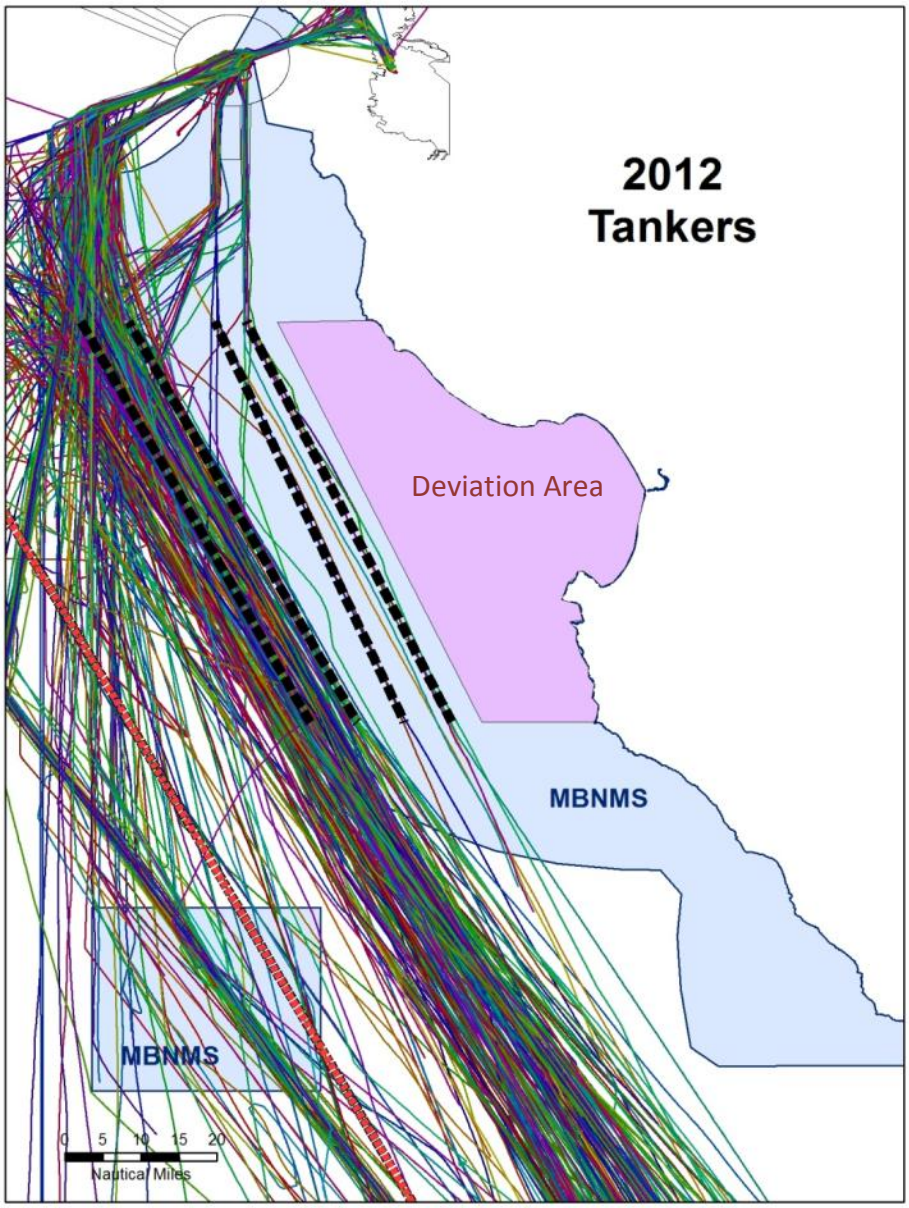


Figure 13. NPS AIS analysis for tankers for 2012. Only the tracks for tankers that transited through the MBNMS are shown. The recommended tracks are shown as black dashed lines, the 50 nm rhumb line is shown as a dashed red line, the 3 nm deviation area is shown in pink and Monterey Bay National Marine Sanctuary (MBNMS) boundary is shown in blue. Note: Colors for tanker tracks are arbitrary and were randomly selected and the San Francisco TSS that was in valid in 2009 is shown.

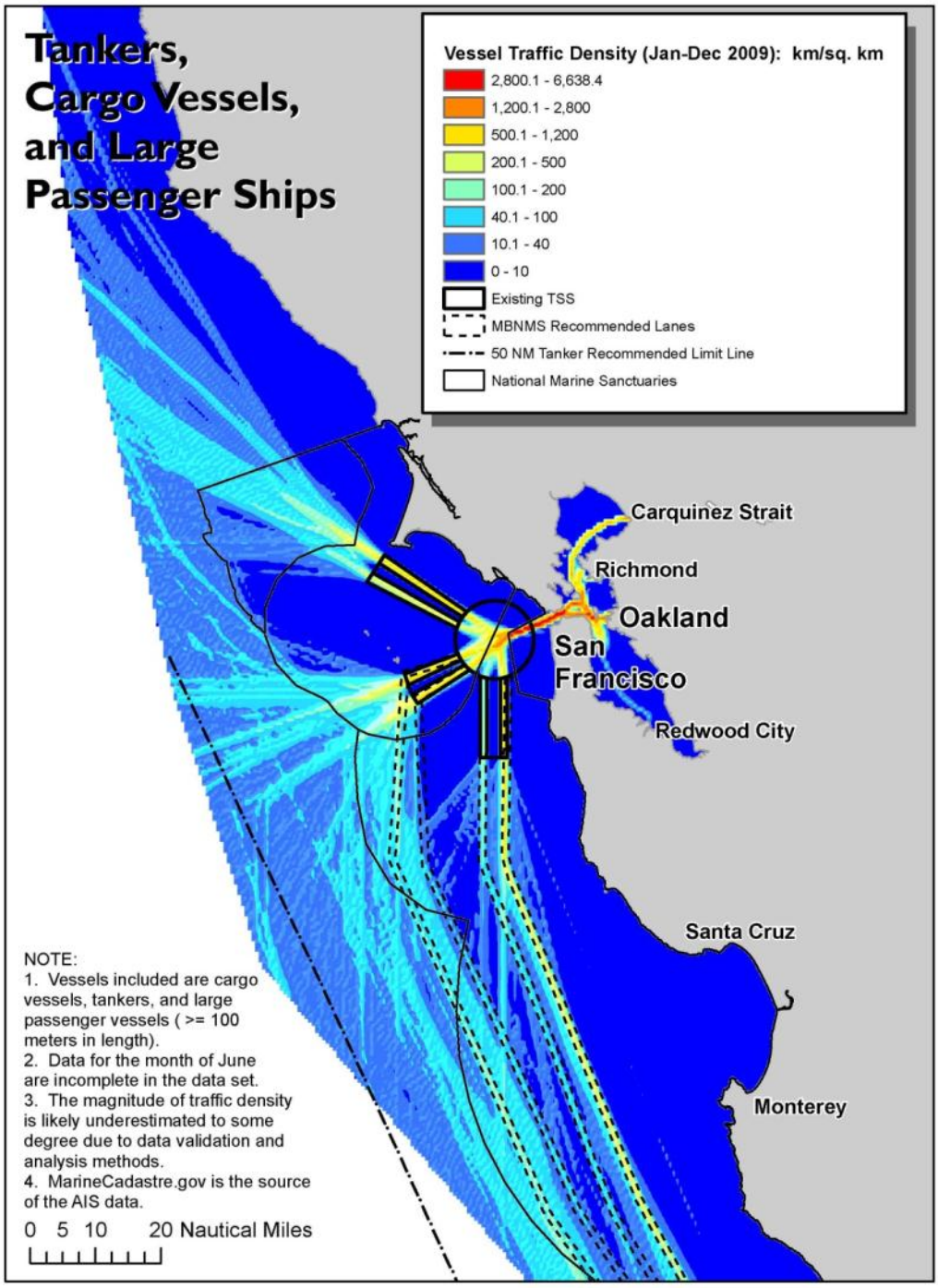
National Marine Fisheries Service Analysis

The analysis of all vessels combined (cargo, tanker, and large passenger ships) shows that the overall ship traffic is highest along the western San Francisco Traffic Separation Scheme (TSS)[1] (See Figure 14), followed by the northern TSS and then the southern TSS. There is parity in traffic arriving and departing via the western TSS. For the other TSS lanes, the ship traffic is high along the inbound lane of the southern TSS and the outbound lane of the northern TSS. So, the data show that far more vessels use the northern TSS to depart San Francisco than to arrive at the port. Likewise, the disparity between arrivals and departures along the southern TSS is even greater with much of the traffic in this southern corridor traveling toward the port.

The spatial pattern of the traffic distribution shows a pronounced fan pattern along the western approach to the western TSS, which includes some ships transiting from/to the south. The northern TSS also has a fan pattern in the area approaching the TSS, but it is far narrower. The southern approach has a very insignificant fan pattern with most traffic in this corridor following the northbound recommended track for vessels 300 gross tons and above, and a much smaller fraction of the traffic in this corridor using the recommended southbound track for vessels 300 gross tons and above. A small portion of the traffic in this southern TSS corridor does not follow the recommended tracks precisely, but rather continues on a heading due south (outbound) or north (inbound) when south of Pigeon Point. The outer recommended tracks for vessels carrying hazardous cargo in bulk appear to be used by some vessels. The outbound track appears to be frequented by more vessels than the inbound track for vessels carrying hazardous cargo in bulk.

The patterns discussed above can be visualized as a 3D surface (See Figure 15).

[1] The San Francisco Traffic Separation Scheme (TSS) was updated June 1, 2013 so the NMFS maps in this report show the old TSS that was in place in 2009. There are three approaches in the TSS: northern, western, and southern. The inbound tracks are on the right as vessels approach the port.



Figure

Figure 14. NMFS 2009 AIS analysis of vessel traffic density includes tankers, cargo vessels and large passenger ships (km/sq km).

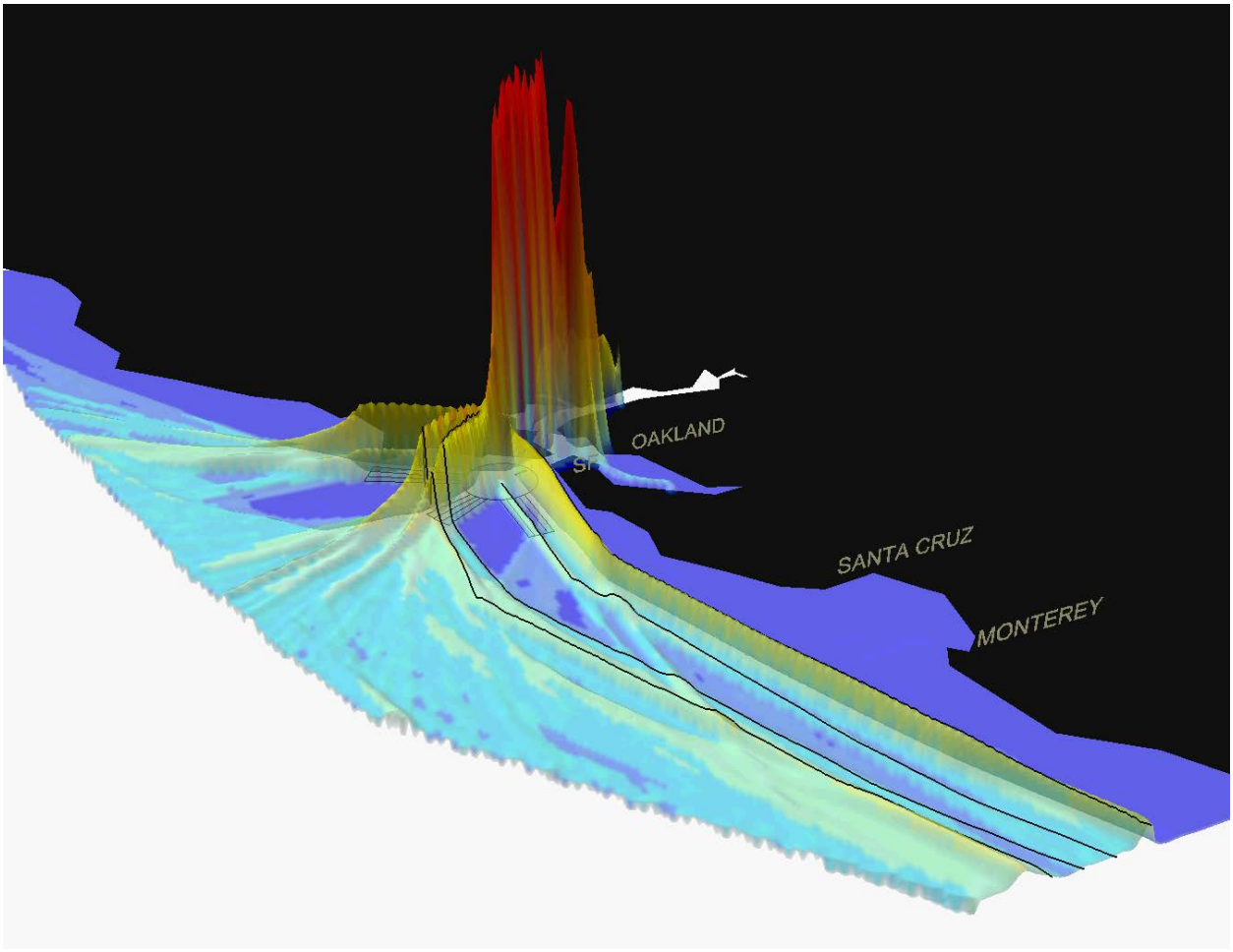


Figure 15. Snapshot perspective from the southwest of a 3D analysis of all 2009 vessels with MBNMS recommended lanes represented as black centerlines and draped over the ship traffic density surface. The taller red surface represents higher density of vessels converging in the precautionary area and in the SF Bay Area.

Of the three vessel types included in this analysis, cargo vessels are most frequently encountered (70.2% of the kilometers traveled in the precautionary area of the TSS) but tankers are also somewhat common in the region (28.1% of the kilometers traveled in the precautionary area). Large passenger vessels (>= 100 meters in length) are not common, but present (1.7% of the kilometers traveled in the precautionary area).

The map of cargo vessel traffic density (See Figure 16) shows similar patterns as described above for all vessels. This might be anticipated due to the large proportion of cargo vessels in this region.

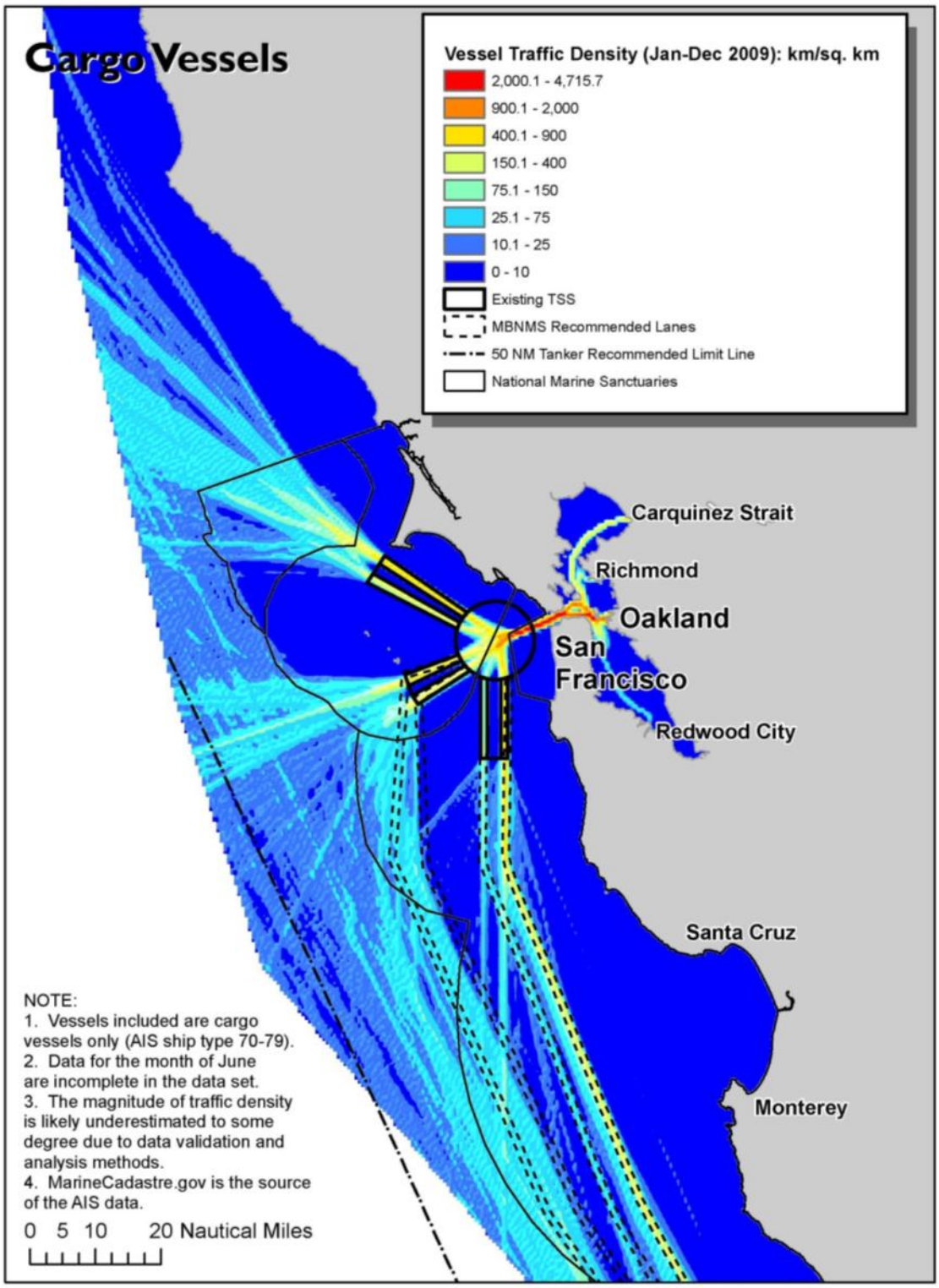


Figure 16. NMFS 2009 AIS analysis of vessel traffic density for cargo vessels (km/sq km). The dashed lines outlining the recommended tracks are connected to the TSS lanes to aid visual analysis of the density data. (See Figure 1 for actual recommended tracks.)

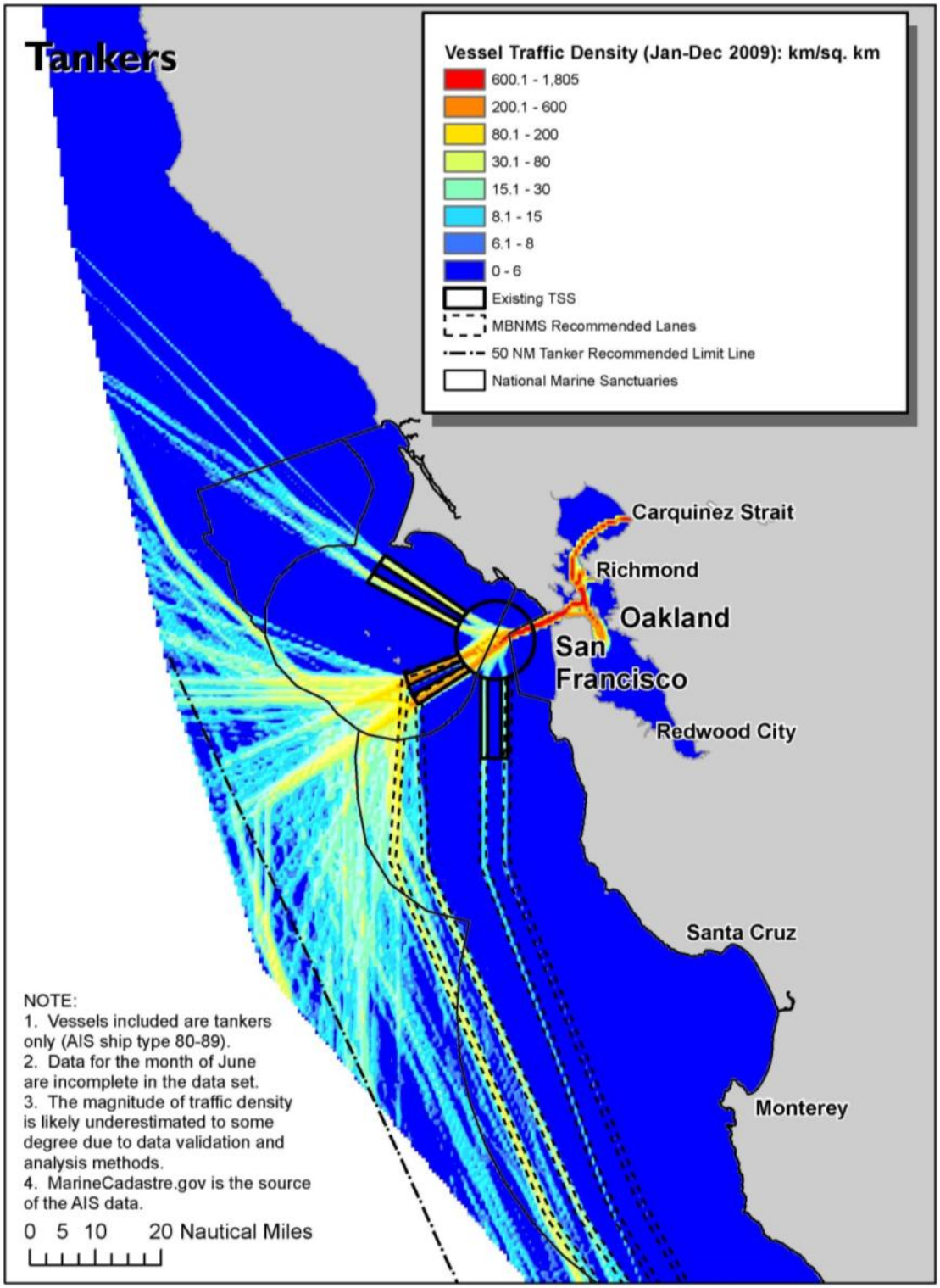


Figure 17. NMFS 2009 AIS analysis of vessel traffic density for tankers (km/sq km). The dashed lines outlining the recommended tracks are connected to the TSS lanes to aid visual analysis of the density data. (See Figure 1 for actual recommended tracks.)

The map of tanker traffic density (See Figure 17) shows significant use of the western San Francisco Traffic Separation Scheme (TSS) and some use of the northern TSS. The southern TSS is hardly used by these vessels. In terms of the recommended tracks through MBNMS, the tracks for large vessels 300 gross tons and above are hardly used (this is consistent with the lack of use of the southern TSS). The recommended tracks for vessels carrying hazardous cargo in bulk are used more frequently, with the outbound (southbound) track getting more use than the inbound (northbound) track.

Regarding tanker traffic arriving from the south or departing southward, some tankers arriving/departing via the western TSS appear to change their heading around the 50 nm tanker limit line (thus, appearing to avoid the region except for the approach to the western TSS). Another contingent using the western TSS appears to change their heading at the edge of the MBNMS western boundary. Finally, a third group appears to use all or part of the recommended lanes for vessels carrying hazardous cargo.

Unfortunately, the analysis did not include the area west of the 50 nm line to compare tanker densities offshore and within the tracks.

Monterey Bay National Marine Sanctuary Analysis

Daily reviews began on 10/1/2012 and, by 10/25/2013, 196 reviews had been conducted. A total of 21 deviations have been noted. Eighteen of those deviations were tankers that were less than 50 nm offshore. On 11/1/12 the tanker Claxton Bay was noted to be 30 nm off Point Sur, and Sanctuary staff contacted the USCG to provide the deviation information. The captain of the Claxton Bay was contacted and he relayed that the tanker was empty and therefore didn't need to be 50 nm or more offshore. Apl Thailand was notified on May 31, 2013 (see USCG letter in Appendix A) after two deviations were noted, one on 3/7/13 and one on 5/30/13. Both times Apl Thailand transited about 3 nm inshore of the northbound recommended track for vessels 300 gross tons and above. In response to the USCG, Apl Thailand owners stated that they were trying to avoid the National Data Buoy Center (NDBC) buoy 46042 (See Figure 18).

Discussion

Naval Post Graduate School Analysis

It appears that most vessels are following the recommended tracks within MBNMS. Table 6 shows deviations per year to aid in comparisons between vessel types and years. Total annual cargo vessel deviations fluctuated but the total number of individual vessels deviating increased slightly each year. Rising fuel prices and increased competition could have an impact on Industry decisions to stay closer to the coast to decrease transit time between California ports.

Based on Miller's 2011 paper, "Monthly distribution of shipping vessels within the Monterey Bay National Marine Sanctuary, January-December 2010," there were 5283 cargo vessels that passed through the MBNMS boundaries. Cargo ships totals were tallied by Miller from individual daily reports so the vessels transiting at 00:00 GMT were counted twice (once in each day's data in which they appeared). This was also true of the total vessel count (Miller 2011). If we use the same logic, we have to consider that 13 cargo vessels deviated in 2010 (Table 6see Table 2). Therefore, in 2010 approximately 0.25% of all the cargo vessels deviated more than 3 nm inshore of the recommended tracks for vessels 300 gross tons and above.

Table 6. Number of annual deviations by individual vessels more than 3 nm inshore of northbound recommended track for vessels 300 gross tons and above. (2009 AIS data only covers 9/4/09 to 12/17/09).

Type	2009	2010	2011	2012
Cargo	**3** (by 3 vessels)	**11** (by 5 vessels)	**7** (by 6 vessels)	**10** (by 8 vessels)
Tanker	0	**1** (by 1 vessel)	0	0

Available technology allows operators to store and replicate routes, which may explain repeat deviations by the same vessel. For example, Maersk Dhahran deviated once in 2009 (see Table 1), 6 times in 2010 (see Table 2), and once in 2011 (see Table 3). There could be other reasons for repeat deviations, as noted above.

National Marine Fisheries Service Analysis

The pattern for the density of all combined ship types suggests that ships arriving in the Port of San Francisco from the south tend to depart via the western TSS or northern TSS. There does not appear to be consistent, reliable use of the recommended tracks for vessels carrying hazardous cargo in bulk as the density shows the vessels traversing over a wide swath in the region. If the cargo type entered by the ships in AIS was more reliable and consistently filled in, it would enable a fine-tuned analysis to determine if vessels carrying hazardous cargo are using the outside lanes. A consistent and reliable use of cargo type would also aid the analysis for Western States Petroleum Association (WSPA) tankers as those carrying crude oil, black oil or other persistent liquid cargo in bulk have agreed to stay 50 nm or more offshore (see Figure 1). Further investigation of the potential use and reliability of cargo type classification and ship draft in AIS data should be explored.

Monterey Bay National Marine Sanctuary Analysis

Daily reviews are not time intensive but can have a significant impact on compliance through our collaboration with the USCG. When letters are sent by the USCG, the vessel owners and operators can be reminded that the recommended tracks were implemented not just for environmental safety but also for the vessel's safety. MBNMS staff also learn more about the reasons why ships deviate (see AIS caveats - Potential Vessel Course Diversion) and can address issues, such as the National Data Buoy Center's buoy being relocated too close to the northbound recommended track for vessels 300 gross tons or above (see more below).

As mentioned in the NMFS analysis discussion above, it would be useful to have more accurate information on specific product the tanker is carrying (crude vs refined), and if the vessel is full of persistent liquid cargo or in ballast. An unloaded cargo vessel needs to be stabilized so after the cargo, e.g. crude oil, is unloaded at port, a vessel takes in ballast water in its ballast tanks to counteract the effects of the weight above the water level. We understand that if a WSPA tanker is in ballast it is not required to be 50 nm or more offshore. MBNMS staff can contact the USCG who can contact the vessel's operator to determine if the ship is in ballast.

Comparing Analyses

Even though the three types of AIS analysis vary in temporal scope, they do indicate that cargo vessels or tankers do not often deviate inshore of the northbound recommended track for vessels 300 gross tons and above. This is consistent with the results of the NMFS traffic density analysis. The results of the daily AIS track reviews by MBNMS are similar to the patterns present over time as determined by the NPS and NMFS analyses. Tankers also seem to be abiding by the tracks and the 50 nm offshore agreement. However, more research on ship cargo type and draft in the AIS system, and investigation of other potential data sources, may be able to shed further light on these patterns. Cargo vessels deviate more than tankers, which may be due to a higher ratio of cargo vessels transiting through MBNMS. For example, in 2010, cargo vessels comprised 40-50% of all vessel traffic within MBNMS (Miller 2011). Both the NMFS and the NPS analyses indicate that cargo vessels tend to cut inshore at the north end of the northbound recommended track for vessels 300 gross tons and above to enter the San Francisco TSS thus bringing them closer to Pigeon Point as well as other environmentally sensitive areas such as the area around Año Nuevo. The southern San Francisco TSS lane was lengthened June 1, 2013 (see Figure 1) so this corner cutting might be reduced in the future.

Next Steps

Conduct Outreach

Outreach is always at the center of successful MBNMS resource protection strategies. As a priority, staff will be communicating with the Industry in order to discuss and present these findings and find additional ways to collaborate. In addition, we plan to make the final report available to the public through a variety of ways, some of which are described below:

- Disseminate the final report via website, presentations and listservs.
- Continue to review and ensure that the USCG Coast Pilot is up-to-date on MBNMS and recommended track information.
- Contact the Industry to present findings and encourage continued use of recommended tracks. If funding available, invite original stakeholder work group attendees from recommended track installation meetings for presentation and discussion of findings.
- If necessary, use “Local notice to mariners” for district 11 as appropriate to let mariners know of any changes with the recommended lanes.

- Keep Sanctuary vessel traffic website up-to-date (http://montereybay.noaa.gov/resourcepro/resmanissues/vessels.html).

- Present information at pertinent conferences and meetings, including the MBNMS Sanctuary Advisory Council.

Continue Annual NPS Analysis

Provide Christopher Miller with the updated deviation GIS shapefile that includes the boundary for the area 3 nm east of the northbound recommended track for vessels 300 gross tons and above. Continue NPS and MBNMS collaboration and coordinate with NPS to run deviation analysis in Matlab on tankers and cargo vessels annually, starting with 2013.

Explore AIS Data Handler

Bureau of Ocean Energy Management (BOEM) and NOAA have worked together to build a collection of tools and instructional material to help analysts process AIS data and derive products to understand marine transportation patterns. At the time of publication, AIS data from 2009, 2010 and 2011 were available. The tool they provide is called the AIS data handler and can be found on the website http://marinecadastre.gov/AIS/default.aspx . Sanctuary staff will continue to troubleshoot the Coastal Services Center's AIS data handler, a GIS extension, so that we can analyze AIS data in-house.

Satellite AIS (S-AIS) Data

Processed AIS data from satellites is available for purchase. For example, Olympic Coast National Marine Sanctuary (OCNMS) worked with Exact Earth to acquire satellite AIS data in 2012 to determine vessel compliance within their Area To Be Avoided (ATBA). The OCNMS vessel traffic monitoring program that's been going on since 2004 and reports can be found on their website: http://olympiccoast.noaa.gov/protect/incidentresponse/atba.html. An enterprise solution for S-AIS for ONMS is being considered by ONMS staff.

Buoy Relocation

MBNMS will follow-up with the National Data Buoy Center (NDBC) to relocate buoy 46042 if the program continues in 2014. The buoy is currently only 0.57 nautical miles west of the northbound recommended track for vessels 300 gross tons and above (see Figure 18). The close proximity of this buoy to the recommended track has been used as a reason for transiting east of the northbound track and thus triggering a deviation review and contact by the USCG.

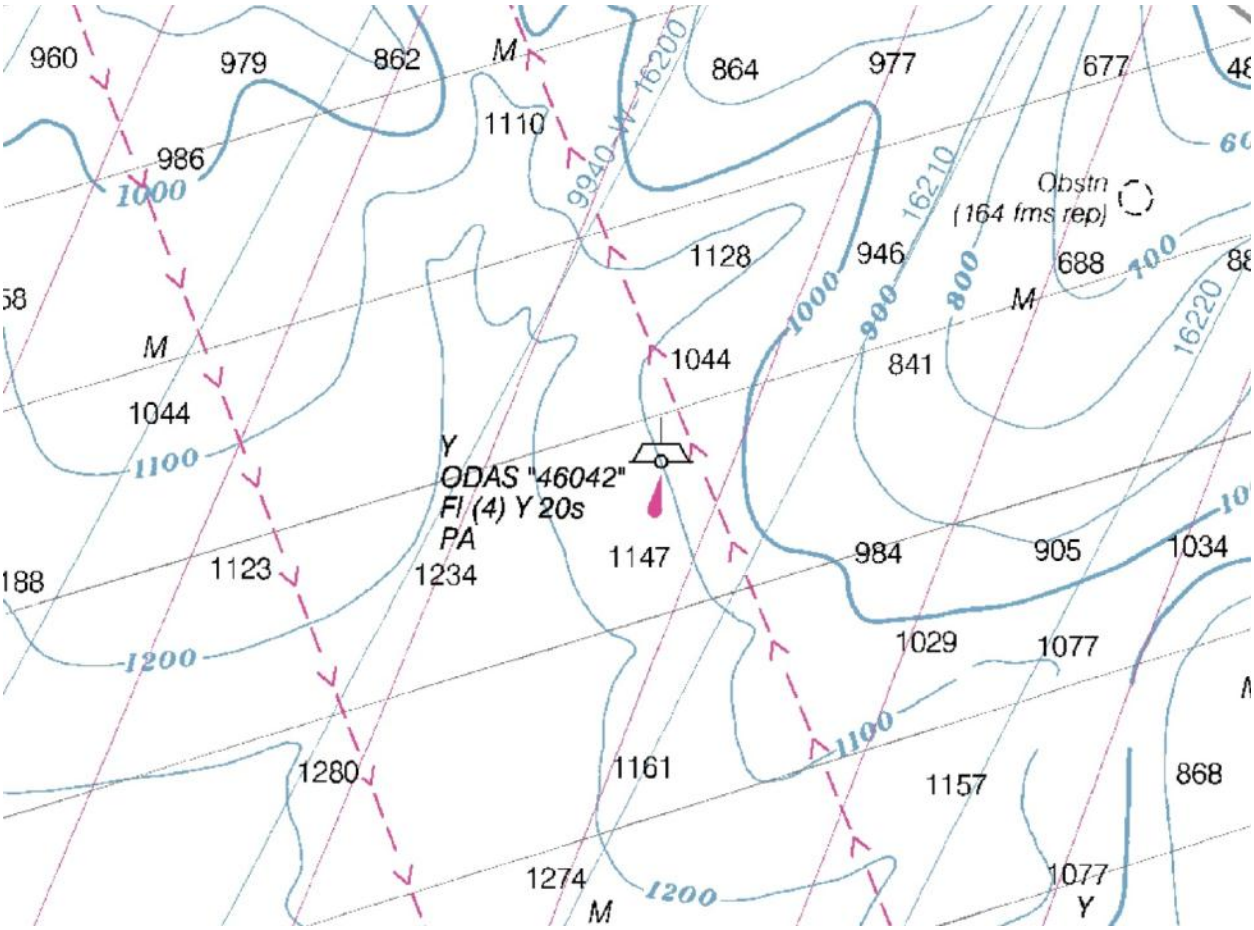


Figure 18. Location of buoy 46042 near the northbound recommended track for vessels 300 gross tons and above. NOAA Nautical Chart 18680 (June 2013).

Augmenting AIS Stations

Christopher Miller from NPS has been working with the Pacific Grove NOAA facility to get an antenna/receiver placed at Point Pinos for better coverage on Monterey Bay and the outside coastal areas currently blocked to the NPS receiver. There is also a tremendous opportunity to improve AIS coverage with the Liquid Robotics Wave Glider platforms, as they also have communication and AIS receivers on board. NPS has suggested that we continue discussions with Liquid Robotics to determine the costs of accessing their AIS data. NPS currently has 2 wave gliders so there might be an opportunity to use them as AIS receivers. Also, the NPS AIS station at Pescadero Point is in place, but has been offline for more than a year due to private property issues at the site. So, contact with the owner would be useful to explore options for getting this station back online.

Acknowledgements

- Michael Carver, Cordell Bank National Marine Sanctuary, for input, access to TV32 and ideas to implement,
- NPS for providing local AIS stations and data,
- USCG for following up on potential vessel deviations,
- The Otter Project/Monterey Coastkeeper for encouraging this analysis,
- The partnership behind the MarineCadastre.gov web site which includes the National Oceanic and Atmospheric Administration's Coastal Services Center and the Department of the Interior's Bureau of Ocean Energy Management. See more at http://www.marinecadastre.gov/MMC%20Pages/partnerships.aspx

References

Miller, C.W. (2011) Monthly Distribution of Shipping Vessels Within Monterey Bay National Marine Sanctuary, January-December 2010. Naval Postgraduate School Report prepared for the National Oceanic and Atmospheric Administration, Monterey Bay National Marine Sanctuary, 43pp.

Appendix A

USCG letter template

The purpose of this letter is to advise you the US Coast Guard has received a report that on XX/XX/XXXX, the vessel X was transiting shoreward of the Recommended Tracks through Monterey Bay National Marine Sanctuary established by the International Maritime Organization (IMO) on December 1, 2000. Using AIS data, Monterey Bay National Marine Sanctuary officials observed the vessel transiting approximately X nautical miles off shore from Monterey, California. The observed position of the vessel was approximately X nautical miles shoreward of the IMO recommended track for large commercial vessels transiting through the sanctuary.

The recommended tracks were established to enhance the safety of navigation by increasing order and predictability for offshore traffic patterns. They also increase protection for the resources of Monterey Bay National Marine Sanctuary. The sanctuary is home to an extraordinarily diverse array of marine mammals, sea birds, fishes and invertebrates, including many species that are particularly sensitive to the impacts of spilled oil or other hazardous materials.

I have enclosed a chart that depicts these recommended tracks. Although they are not mandatory, vessels are encouraged to comply with these recommendations that have been sanctioned by IMO. Please contact X at (XXX)XXX-XXXX if you have any questions concerning this letter.