Commercial Fishing Vessel Tracking in California State Managed Fisheries:

Best Practices in Design and Implementation with Considerations for the California Commercial Dungeness Crab Fishery

The Nature Conservancy

April 2024

Acknowledgement
We would like to thank the Ocean Protection Council for funding this work, the California Department of Fish and Wildlife for providing insights and feedback, Lisa Damrosch for providing industry perspective, and Huff McGonigal at Fathom Consulting for report development.

Table of Contents

Executive summary

As climate change continues to drive changes in ocean temperature, chemistry, and species distribution, the need for reliable, timely data is becoming increasingly important. While vessel tracking technology has been available for a long time, vessel tracking tools have become much easier and cheaper to use and have a demonstrated ability to provide critical data needed for more adaptive management. Lessons learned in other tracking programs can help California avoid pitfalls and make effective use of new systems. This report provides background information on available approaches and technologies, provides detailed considerations and recommendations regarding their use, and applies them to the Dungeness crab fishery which is beginning to use vessel tracking as a means of reducing whale entanglement.

Key recommendations in the report include:

- *Stakeholder engagement* - Given their knowledge of vessel configurations and fishing behavior, fishermen should be engaged in all aspects of tracking program design and implementation.

- *Technical scoping* - Technical scoping covers a range of device performance and data processing needs, including identifying the tools or approaches for differentiating fishing activity from transit. Technical scoping will force detailed discussions regarding program goals that will in turn inform data resolution and enforcement evidentiary needs.

- *Available tools* - There are different technologies available for vessel tracking including VMS, AIS, and GPS trackers. Given their lower cost and ease of use, GPS trackers will most often be the most appropriate tool for California.

- *Type-approval* – Type approval can represent an administrative burden and reduce program flexibility. However, in larger fisheries, where a tracking program is controversial, compliance is expected to be a challenge, and data is anticipated to be used in enforcement actions, type-approval may reduce data problems and legal challenges. Regardless of whether a type approval process is used, clarity regarding unit performance standards and expectations is key.

- *Use of an API* –Requiring any device used to submit via an established API can help improve data and reduce QA/QC and may be especially valuable in ensuring successful data delivery in programs without type-approval.

- *Gear sensors* - Whether the added complexity of sensors is worth it depends on program and enforcement goals and modeling approaches planned for identifying fishing activity.

- *Vendor competition* - The ease of using a sole-source provider needs to be weighed against the hazards of vendor lock-in and the benefits of fostering competition between vendors and flexibility for vessels to use tools best suited to their operation.

- *Regulation development* – Taking a high-level approach in the regulations can help preserve flexibility with more detailed guidance in a compliance manual. However, California's prohibition on underground regulations will shape this approach.

- *Data confidentiality* – Vendors can collect confidential vessel tracking on behalf of the Department as long as there are confidentiality provisions in their contracts.

- *Display of the data* – In some settings there may be a benefit to providing high resolution effort maps, for example enforcement needs may be quite different than what is needed for public consumption.

- *Data integration* - Integration with and validation of other data sets like logbooks and fish tickets can be one of the primary benefits of vessel tracking data.

- *Legal landscape* - Recent and current legal challenges to federal fisheries monitoring programs highlight the need for legal authority and clear articulation of a program's purpose and need.

- *Other monitoring options* - Vessel tracking is at one end of a continuum of at-sea monitoring tools with overlapping capabilities including E-logs, observers, and cameras. Which is appropriate depends on the fishery and its management needs.

In addition, the report includes a series of appendices that provide case studies, regulations from other states, an inventory of available tracking systems, and links to other reviews of monitoring tools and related resources.

Introduction

The impacts of climate change have already had a significant impact on California's marine ecosystem and fisheries. Warming ocean temperatures and changes in ocean chemistry are causing a cascade of negative effects on nearshore ecosystems. This includes impacts like sea star wasting disease, overpopulation of sea urchins, and the decimation of kelp forests. There have also been significant impacts to California's fisheries as species like squid, albacore, and sardine have shifted to the north in search of cooler waters, and harmful algal blooms have resulted in closures and delays for lobster and crab fisheries. Perhaps most significantly, warmer ocean conditions have also brought whales closer to shore in search of prey, leading to increased entanglement in Dungeness crab gear and resulting in fishery closures and serious impacts to fishing communities. In response, the Ocean Protection Council (OPC) and the California Department of Fish and Wildlife (Department) have worked closely with fishermen and other stakeholders to develop measures for assessing and addressing entanglement risk. These measures are discussed in detail below, but they include a new requirement for vessels to electronically track and periodically report their location. The goal is to better understand and manage the overlap between humpback and blue whale occurrence and fishing effort.[1] Identifying the best means of implementing this tracking requirement involves consideration of a range of issues such as the capabilities of available tracking systems, their costs, ease of use, and data formatting and management.

Providing recommendations across these categories for the Dungeness crab vessel tracking program was the original purpose of this report and remains a primary goal. However, after conversations with Department and OPC staff it became clear that the utility of vessel tracking in the state extends beyond reducing whale entanglements and can be a valuable tool for meeting fishery management goals more broadly. California's 2018 Master Plan for Fisheries calls for optimizing and modernizing the state's fishery data collection efforts to allow for more responsive and adaptive fishery management.[2] Strategic and combined use of tools like vessel tracking, electronic logbooks, onboard cameras, and electronic landing receipts can greatly increase and improve the data that is available to support decision making. Therefore, this report provides general recommendations related to the use of vessel tracking in California and then applies them to the pressing use-case of Dungeness crab.

It is also important to note that while this report is focused on the specific tool of vessel tracking, it is part of a broader set of analyses conducted over the last 15 years aimed at examining data collection needs and the technologies available to address them. Please see Appendix 1 for descriptions and links to these prior analyses. Where relevant, the report seeks to reference, draw from, and complement these other efforts.

Approaches to vessel tracking

Vessel tracking is a general term that includes a range of approaches and technologies aimed at providing vessel location data. It includes Vessel Monitoring Systems (VMS), Automatic Identification Systems (AIS), low-cost spatial data loggers, and electronic logbooks with automated spatial reporting. Some just collect position data while others can include information

[1] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=184177&inline
[2] https://mlmamasterplan.com/11-adapting-to-climate-change/

from integrated or connected sensors to help identify fishing activity. All can be effective tools, but each comes with limitations and considerations which are discussed below.

Vessel Monitoring Systems

VMS is a vessel position data collection system installed on commercial and recreational fishing vessels to ensure compliance with federal and regional fishery regulations.[3] It was first used by the National Marine Fisheries Service (NMFS) in 1994 to enforce spatial management measures in the Hawaiian pelagic longline fishery.[4] Since then its use has expanded and it is now used to monitor more than 4,000 vessels in the U.S.[5] In California, this primarily includes vessels operating in the Pacific groundfish fishery. Historically, VMS was defined in regulation as using satellite-based communication, however in 2020, NMFS amended the regulations to include cellular systems. VMS is now defined as, *a satellite and/or cellular based system designed to monitor the location and movement of vessels using onboard VMS units that send Global Positioning System position reports to an authorized entity*.[6] Federal regulations also set minimum standards for VMS equipment and data collection, while allowing for regional variations based on geography, fishery activities, and management goals. To approve specific VMS systems, NMFS administers a type-approval program which has approved 13 VMS units from eight vendors to date.

VMS data is sent in real time to the NMFS Office of Law Enforcement (OLE) 24 hours a day, whenever the system is required to be active. Most vessels send location data once per hour, but more frequently as a vessel nears a closed area. VMS units can also receive data and are used to send information to vessels. It is most often used to enforce time-area closures, and due to its real-time nature, can be used to direct enforcement intercepts. Since fishing activity can be interpolated from the data, it has also been used to predict fishing effort, including fishing gear deployment and retrieval.[7] The data are also used within NMFS to manage observer programs, validate data from other sources, and engage in marine spatial planning efforts like the siting of offshore wind installations.

VMS has proven itself to be an effective technology and an important management tool, but there are important challenges to highlight. First, system and subscription costs can be relatively high as compared to other vessel tracking options. While NMFS pays for VMS software, monitoring centers and staff, IT services, and data storage, fishermen are required to pay for the actual on-board VMS unit and transmission costs. A typical unit costs approximately $3,100 but cost can vary widely by vendor and subscription fees average about $600 per year/vessel.[8] These costs can be significant for many smaller operators and have shaped industry perceptions regarding the burden of VMS. VMS programs also create substantial agency costs, for example in 2018, the overall cost of the national VMS program was $6.9 million, out of an overall OLE budget of $69 million.[9]

---

[3] https://www.fisheries.noaa.gov/topic/enforcement
[4] Net Gains Alliance, VMS Discussion Document
[5] NOAA Fisheries: What is the vessel monitoring system?
[6] CFR § 600.1500
[7] Mendo T, Smout S, Photopoulou T, James M. 2019 Identifying fishing grounds from vessel tracks: model-based inference for small scale fisheries. R. Soc. Open sci. 6: 191161. http://dx.doi.org/10.1098/rsos.191161
[8] https://drive.google.com/file/d/1fLRRrmhs_LecLPnilT06oDyEbuJxnQJX/view
[9] NOAA Fisheries, "Office of Law Enforcement Annual Report for FY 2018."

As currently structured, data access can also be challenging for states, fishery commissions, fishermen, and even within NMFS, as the Magnuson-Stevens Act (MSA) generally prohibits disclosing VMS data unless data management and confidentiality agreements are in place.[10] Data requests are reviewed on a case-by-case basis by regional OLE staff. And while not specific to VMS data, the "rule of three" policy requires data to be aggregated from at least three points before it can be shared which can mean data gaps for analysts.[11] These factors have limited the utility of VMS data, especially for uses beyond enforcement. For example, the Department was interested in exploring the potential use of VMS data for vessel tracking in the Dungeness crab fishery but was unable to access it for this purpose. It is worth noting however, that there are ongoing discussions within NMFS regarding moving the management of the VMS program out of OLE and into the Office of Science and Technology which may eventually improve data access and facilitate broader use.[12]

VMS programs have long raised legal privacy concerns,[13] however its use has generally been upheld in case law.[14] A recent and notable exception, is a 2023 decision by the Fifth Circuit Court of Appeals in which the court invalidated NMFS's use of VMS in the Gulf of Mexico for-hire recreational charter boat fishery. The court reasoned that NMFS had not clearly articulated how VMS would advance the goals of MSA and that the benefits of the program did not outweigh the costs. The court also held that recreational fishing is not a "closely regulated" industry, meaning the recreational charter fleet has a greater constitutional expectation of privacy on their vessels than does the commercial fleet. While the case does not impact California or the West Coast directly, it will likely shape NMFS's initiation of new VMS programs going forward and raises privacy and administrative record issues that are worth considering when developing vessel tracking programs at the state level.

Finally, the type-approval process for VMS has come with an administrative burden to the agency as the implementing regulations have needed to be updated 7 times to keep pace with emerging technologies. It has also been relatively expensive for vendors to participate in, costing between $6,600 to $7,500 per application which has created a degree of vendor lock-in in the program.[15] For a more in-depth review of the evolution and application of VMS in the U.S., please see a 2021 review commissioned by the Net Gains Alliance here.

Automatic Identification Systems

In 2000, the International Maritime Organization (IMO) mandated the use of AIS as a safety feature to help vessels avoid collisions and enable authorities to monitor vessel traffic. While the rule originally applied to large oceangoing vessels, in 2015, the U.S. Coast Guard extended to the requirement to any commercial vessel over 65 feet operating within 12 nautical miles of the coast.[16] There are two types of AIS transponders, Class A transponders which have greater range and cost around $3,500, and Class B responders which have shorter range and cost around

[10] https://media.fisheries.noaa.gov/dam-migration/msa-amended-2007.pdf
[11] 16 USC 1881a.(b)
[12] Net Gains Alliance, VMS Discussion Document
[13] Crance, Jason R, and Mike Mastry. "Fourth Amendment Privacy Rights at Sea and Governmental Use of Vessel Monitoring Systems: There's Something Fishy About This." *J. Envtl. L & Litig.* 22 (2007): 36.
[14] Pers com. Robert Hogan (NOAA GC)
[15] NOAA Fisheries, "Vessel Monitoring Systems; Requirements for Type-Approval of Cellular Transceiver Units," Federal Register, January 24, 2020.
[16] https://www.ecfr.gov/current/title-33/chapter-I/subchapter-P/part-164/section-164.46

$700. Commercial and for-hire fishing vessels over 65 feet are required to at least install Class B units (§164.46(b)(2)). AIS data includes information on the vessel's identity, position, speed, and heading with a variable but significantly higher frequency than VMS. Since AIS was designed as a collision avoidance technology, the transmission rate depends on vessel speed, with lower transmission rates at slower speeds (every 3 mins) and higher transmission rates at higher speeds (every 2-30 seconds). AIS data is public and is compiled and made available by third party service providers such as Marine Traffic, and Vessel Finder.

While AIS is primarily for vessel traffic safety, the data has been used by groups such as Global Fishing Watch to provide insights into fishing effort both a regional and global scale.[17] When considering a new vessel tracking program, AIS has an advantage in that at least Class B devices are already installed on vessels over 65 feet. Additionally, the high ping rate can make it easier to develop models that can infer fishing activity and differentiate between gear types.[18,19] APIs for AIS data are also widely available and there is a growing number analytical tools and services available for analyzing AIS data such Up42. Finally, a program that expands the use of AIS to vessels under 65 feet, could have the additional benefit of improving safety at sea for those vessels. For these reasons, when the Atlantic States Marine Fisheries Commission (ASMFC) was considering options for tracking vessels in the American Lobster fishery in 2022, some in the NGO community proposed AIS as the preferred technology.[20]

However, using AIS for a dedicated fishing vessel tracking program poses some unique challenges. First, unlike VMS, AIS devices can easily be turned off. A 2022 analysis estimated that up to 6% of global activity from AIS broadcasting vessels in 2017–2019 was obscured by intentional disabling of AIS hardware.[21] This percentage may be significantly higher in certain regions or sectors. Any state program that relies on AIS data would therefore need to include a regulatory provision that makes turning off the unit a violation of state law. Second, the quality of reception coverage varies based on congestion of AIS signals, gaps in satellite coverage, and incomplete land-based receiver data.[22] These issues can be improved by requiring the use of the higher power and more expensive Class A devices, but at a significant cost to the vessels that do not already have one. Third, AIS data are inherently public and maintaining confidentiality of vessel location is not possible. For these reasons, ASMFC ultimately opted to use dedicated GPS trackers instead of AIS to track lobster vessels.

GPS trackers

GPS trackers have been most widely used in small-scale fisheries in developing countries given their lower costs and easier installation.[23] However, they are increasingly being used in developed countries for the same reasons and a growing number of devices are becoming available. They are generally cheap, easy to install, and some can transmit data via both satellite

[17] https://globalfishingwatch.org/publications/
[18] De Souza, E. N., Boerder, K., Matwin, S., and Worm, B. 2016. Improving fishing pattern detection from satellite ais using data mining and machine learning. PLoS One, 11: e0158248.
[19] Kroodsma, D. 2018. A Who's Who for the Oceans: Building a Global Database of Fishing Vessels.
[20] https://tnc.app.box.com/s/fm3sjqwsnr006sv427norw51n47cp3h6/file/1243276925820
[21] Welch, H., Clavelle, T., White, T.D., Cimino, M.A., Van Osdel, J., Hochberg, T., Kroodsma, D. et al.. 2022. Hotspots of unseen fishing vessels. Science Advances, 8: eabq2109.
[22] https://tnc.app.box.com/s/fm3sjqwsnr006sv427norw51n47cp3h6/file/1210837713815
[23] https://www.researchgate.net/publication/331874324_Application_of_Global_Positioning_System_Tracker_to_Detect_the_Fishing_Ground_Location_and_Effective_Effort_in_Artisanal_Fishery

and cell network. The information they provide depends on the design of the system. The simplest GPS trackers transmit vessel locations only, while others may also include speed, heading, vessel identity, or can be capable of communicating with onboard hydraulic or winch sensors to indicate fishing activity. For example, the Pelagic Data System (PDS) previously trialed in the California's Dungeness crab fishery, is a solar-powered vessel tracking device that records vessel positions every few seconds and uploads them via cellular network to a secure cloud server. PDS devices cost around $150 plus $20/month for data services.[24] Other asset tracking companies originally from beyond the marine space are also now engaging in fisheries tracking. For example, Particle Industries originally developed the Tracker One to track vehicle fleets, but in 2023 it was approved for use in the American Lobster vessel tracking program and won a contract from the state of Maine to provide trackers to the fleet.[25] Given that GPS trackers have a broader range of designs and potential specifications than VMS and AIS devices, selecting the most appropriate unit requires carefully aligning management needs with the planned approach for identifying fish activity, unit capabilities, data management strategies, and varying customer service levels. For details on available GPS trackers and potential selection considerations, please see Appendix 2. There is a growing number of programs using these trackers both within the U.S. and internationally, each yielding valuable lessons. Please see Appendix 3 for a detailed review of the development of the vessel tracking program in the American Lobster fishery, and Appendix 4 for a review of several international programs.

Electronic logbooks

Mobile devices equipped with GPS can also be used as a low-cost method for tracking fishing vessels. The GPS function on most current smartphones and tablets continues to work outside of cell range as these devices can still *receive* GPS radio signals directly from satellites. This means that electronic logbooks can record accurate fishing point locations without cell or dedicated satellite service and then report those locations when the vessel is back in port. If there are concerns regarding fishermen not reporting fishing completely or accurately, the electronic log can also be configured to provide a complete track of the vessel's trip. Fishing activity can then be inferred using similar methods applied to location information from AIS or VMS. [26,27] The use of an electronic logbook has the additional benefit of providing a platform for recording and reporting catch, effort, discard, and other trip data. However, if capturing additional information is not necessary, there are also simple low-cost, non-fishery apps that track and report in a variety of digital file formats.[28] The ubiquity of GPS-enabled smartphones can mean that no new hardware is required for most participants. Whether an electronic logbook or a simpler tracking app is used, the app-based approach requires reliable data transfer in the desired format and responsive customer service. It's worth noting that similar to AIS units, the device hosting the electronic log can be easily turned off which would need to be made a violation. For more information on electronic logbooks and considerations for their use in California, please see the 2017 review by Intertidal Agency.

---

[24] https://www.pelagicdata.com/howitworks

[25] https://www.maine.gov/dmr/fisheries/commercial/fisheries-by-species/lobsters/trackers

[26] Tassetti, A.N., Galdelli , A., Pulcinella, J., Mancini, A., and Bolognini, L. 2022. Addressing gaps in small-scale fisheries: a low-cost tracking system. Sensors, 22: 839

[27] M.M. Galotto-Tebar, A. Pomares-Padilla, I.A. Czerwinski, J.C. Gutiérrez-Estrada Using mobile device's sensors to identify fishing activity, Journal of Marine Science and Technology, 25 (2020), pp. 978-989. https://digital.csic.es/handle/10261/325620

[28] M.M. Galotto-Tébar, A. Pomares-Padilla, I.A. Czerwinski, J.C. Gutiérrez-Estrada, Is the vessel fishing? Discrimination of fishing activity with low-cost intelligent mobile devices through traditional and heuristic approaches, Expert Systems with Applications, Volume 200, 2022, https://doi.org/10.1016/j.eswa.2022.117091

Uses of vessel tracking data in California fisheries

Whatever technology is deployed, vessel tracking data can have a wide range of uses. This section draws on conversations had with Department staff regarding uses for vessel tracking data in California and identifies some of the primary potential applications.

Logbook and landing receipt validation

Accurate data on the level and distribution of fishing effort can be essential for both species management and ecological impact assessments. However, the spatial data from landing receipts is coarse (at the block level) and often considered by managers to be unreliable. Similarly, there is often low confidence in the accuracy of the spatial data from logbooks given the challenges fishermen face in accurately capturing locations during active fishing.[29] For the same reason, logbooks may also not always capture all sets or tows, skewing calculations of CPUE. Vessel tracking data can be integrated with landing receipt and logbook data to help validate spatial and effort data to provide more accurate and useable information for management. On the East Coast, the ASMFC is exploring how to efficiently integrate vessel tracking data with landing receipts/dealer reports.

MPAs and spatial management

California has an extensive network of Marine Protected Areas (MPAs) in which specific types of fishing may be prohibited. Effective enforcement of those MPAs is essential for achieving the goals of the network but monitoring and interdiction can be resource intensive. Depending upon the MPA's restrictions, vessel tracking can be an effective additional means of both promoting compliance and identifying and prosecuting violations. As discussed above, differentiating between transit and fishing activity is key, but the higher ping rates of modern GPS trackers can help identify behaviors consistent with fishing and can represent a meaningful piece of additional evidence. Beyond enforcement, MPA managers are also frequently interested in understanding any legal fishing effort within the MPA, as well as fishing effort just outside MPA boundaries, or "fishing the line". Beyond MPAs, vessel tracking data can be equally useful for enforcing and managing other closed areas, whether implemented for species management, bycatch reduction, or habitat impact reasons.

Dynamic management

Concerns regarding whale entanglements in California's Dungeness crab fishery led to legal action in 2017. The resulting settlement mandated (among other requirements) the implementation of a Risk Assessment and Management Program that was developed and piloted by the Dungeness Crab Fishing Gear Working Group. While discussed in more detail below, vessel tracking is playing an important role in RAMP implementation by providing near real-time understanding of where fishing effort is overlapping with whale occurrence. Vessel tracking will be a core tool for enforcing any closures imposed through the RAMP process. While the Dungeness crab fishery is currently the primary focus in terms of whale entanglement, vessel tracking may be an important tool for other trap fisheries in California that have the potential to entangle whales such those for spiny lobster, rock crab, spot prawn, and finfish.

[29] https://drive.google.com/file/d/1dWmqsvovr2qGZRdxq-ohYmex8Jegs92e/view

The California Department of Public Health (CDPH) coordinates monitoring of domoic acid toxins in commercially and recreationally important species such as Dungeness crab, rock crab, and spiny lobster. This monitoring can result in temporary fishery closures in areas where toxins are above acceptable limits. These closures are sporadic and would not justify a vessel tracking program on their own, however, for existing programs they can provide an additional management and enforcement tool and help demonstrate that fishermen are transiting closed areas and not fishing in them.

Marine spatial planning
Offshore wind installations can have significant impacts on fisheries which can be excluded from historical fishing grounds. During the siting process, inaccurate or low-resolution effort data can hamper the ability of decision makers to avoid or minimize socioeconomic impacts on fisheries.[30] Vessel tracking data can help substantiate the claims of fishermen regarding the areas that are most important to them and the communities they support.[31] This can in turn help ensure that installations are optimally sited and economic impact assessments are fully informed. While wind installations have been the recent focus, the ability to demonstrate effort patterns is also relevant to offshore aquaculture siting and Essential Fish Habitat designation processes and consultations.

Gear soak time
In fisheries such the gillnet fishery for California Halibut and White Seabass, stakeholder and Commission discussions have focused on reducing maximum soak times as a means of reducing bycatch and bycatch mortality. Vessel tracking systems with high ping rates can provide a means of enforcing soak times through model-based identification of fishing activity and duration. Incorporating reel sensors can help corroborate this information and provide a stronger basis for enforcement action.

Gear tracking
In addition to vessel tracking devices, gear tracking buoys are available from a variety of manufacturers such as blue ocean gear, nxtcatch and marine instruments with a wide range of capabilities and price points. Gear tracking buoys can be equipped with either AIS transponders or GPS trackers and can help better define where fishing is taking place, reduce impacts from lost traps, and help fishermen ensure that their gear does not drift into closed areas. For now, broad use of gear tracking buoys would be prohibitively expensive for most California fisheries given unit costs and the amount of gear deployed. However, for fisheries that use less gear like the deep-set buoy gear fishery for swordfish, tracking buoys may prove to be a valuable tool.

Legal basis and considerations
The MLMA broadly recognizes the need to "develop better information on which to base marine living resource management decisions".[32] Additionally, the authority for vessel tracking can be viewed as falling under the Commissions' general authority under Section 205 of the Fish and

[30] https://www.boem.gov/sites/default/files/documents/renewable-energy/state-activities/BOEM_OW1_FishGearVMS_V02-web_.pdf
[31] Maria S. Campbell, Kilian M. Stehfest, Stephen C. Votier, Jason M. Hall-Spencer, Mapping fisheries for marine spatial planning: Gear-specific vessel monitoring system (VMS), marine conservation and offshore renewable energy, Marine Policy, Volume 45, 2014, Pages 293-300, ISSN 0308-597X, https://doi.org/10.1016/j.marpol.2013.09.015
[32] FGC § 7050(6)

Game Code (FGC) which allows the Commission to "*prescribe the manner and the means of taking*" in fisheries. More specific authority is also provided by Section 8026(a) which states that "*The commission may require the owner and operator of a commercial fishing vessel, the holder of a commercial fishing license or permit, and the owner and license holder of a commercial passenger fishing boat to keep and submit a complete and accurate record of fishing activities in a form prescribed by the department."* Finally, fishery-specific provisions can provide authority to the Department instead of the Commission. For example, Section 8276.1(b) provides authority for the Department's regulations (including vessel tracking provisions) implementing the RAMP in the Dungeness crab fishery.

As vessel tracking systems become cheaper, easier to use, and more familiar to managers, they are being used more broadly, but linking their use to a clear and compelling management need is essential. As noted, in 2023 the Fifth Circuit held that NOAA had failed to articulate a sufficient rationale for a new VMS requirement in the recreational for-hire sector to overcome cost and privacy concerns. Given the broad utility of vessel tracking data, a multi-purpose rationale can be developed which can help a program survive legal challenge or a change in underlying conditions. On the East Coast for example, the rationale for the vessel tracking program for American Lobster included a range of other purposes beyond reducing North Atlantic right whale entanglements, such as improving stock assessments, enforcement, and engaging in marine spatial planning.[33] So when the D.C. Circuit invalidated NOAA's Biological Opinion for right whales in June of 2023, a legal basis for the vessel tracking program remained. Nevertheless, in early 2024, a group of lobster fishermen filed suit in the District of Maine seeking injunctive relief on privacy invasion grounds. Despite being in a different judicial venue, it will be worth tracking how the court balances management and privacy interests. Two other cases related to fisheries monitoring, Loper Bright and Relentless, are currently before the Supreme Court and may not only shape fisheries monitoring, but the exercise of agency discretion more broadly. Decisions could be foundational and are expected in the summer of 2024.

Recommendations

This section provides considerations and recommendations within each of the major areas associated with vessel tracking program development.

Stakeholder engagement

Any effort that involves installing, maintaining, and reporting with new hardware, requires engaging early with constructive fishermen representative of the varying operational characteristics of the fleet. Given their knowledge of vessel configurations and fishing behavior, their insights on the practicality and efficacy of potential approaches can shape all aspects of program design and implementation. The experience with onboard cameras in the Pacific groundfish fishery illustrates how engaging with the fleet on the technical details of installation, reporting, maintenance and catch handling can be instrumental to program success. While vessel tracking can be less complex than the use of onboard cameras, the formation of an ad-hoc technical advisory group similar to the Groundfish Electronic Monitoring Policy Advisory Committee (GEMPAC) can help increase transparency, further build the administrative record,

[33] https://asmfc.org/uploads/file/63d14df0AmLobsterAddendumXXIX_JonahCrabAddendumIV_March2022.pdf

interpret fishing effort data, and ensure that the Department and the program benefit from this expertise throughout the stages that follow. If an empaneled advisory group is viewed as too intensive, informally engaging existing advisory groups or fishing associations can help ensure a transparent and inclusive approach.

Program support
For many state-based vessel tracking, e-logbook, and onboard camera programs, the Pacific States Marine Fisheries Commission (PSFMC) or other groups can be a key implementation partner for the Department given their prior experience with vendors and data management. NOAA OLE manages the federal VMS program through a partnership with a company called Twoday that tests systems and manages vendor contracts. Managing a large or complex program without program support could be a significant burden for Department staff, especially until the Department gains more direct experience with vessel tracking. However, for less complex programs, it may be simpler or more cost effective for the Department to work directly with third party vendors. Factors to consider are the number of vessels/units, analytical needs/complexity, staff capacity, and any overlap and potential synergies with other programs.

Technical approach for meeting goals
It is important to consider at the outset how the data will be analyzed and visualized and the associated temporal and spatial resolutions required. Early identification of the planned approach for differentiating fishing activity from transit is a valuable exercise that will force the specific discussions needed regarding goals, resolution, the potential need for gear sensors, and evidentiary standards for enforcement. Please see the *Analysis* section below and Appendix 3 for potential analytical approaches to using tracking data to identify fishing activity. Early consideration of these details with fishermen will help guide subsequent program design elements like system selection and data management that follow.

System capabilities
Once the underlying program needs have been articulated, the tracking system capabilities that are needed can be identified. Even within the category of GPS trackers, there are significant differences across available systems including:

- *Cost* – Unit costs range from $300 to $3,000. Subscription costs can often be negotiated based on the number of subscribers, but generally range from $17 to $60 per month for currently available systems.
- *Connectivity* – Some trackers are cell-based only and report once the vessel is back in cell range. Others have both cell and satellite options and can be used for real-time enforcement purposes even when the vessel is offshore. Some units also have Wi-Fi and can report when back in port.
- *Ping rate* – Most modern units can record at 1-minute intervals. Ping rate significantly impacts transmission costs if the unit is using satellite connectivity.
- *Power source* – Solar powered trackers are easy for the fleet to install and are improving, but challenges with battery life and reliability have been reported. Units that require hardwiring are more reliable but can be logistically challenging for fishermen given existing hardware in use.

- *Geofencing* – Some units can automatically power down or stop reporting when in port to save on battery life and transmission costs, others can adjust their ping rate when close to closed areas.
- *Indicator lights* – Some units have indicator lights so a fisherman can easily see when the unit is functioning and reporting properly, others require logging into a vendor portal.
- *Compatibility with gear sensors* – Some systems include or have the option of integrated hydraulic sensors from the same vendor, others can be used with sensors from third-party sensors. A few either do not have or are in the process of developing this functionality.
- *Visualization options* – Some vendors provide proprietary visualization software that fishermen and managers can use to view and query the data.
- *API integration* – The ability to provide the data in the desired format through an API is essential. Some vendors have charged an additional fee for this.
- *Customer service* – Customer service availability and performance needs to match the obligations of fishermen for maintaining functioning units.
- *Performance in other programs* – The growing number of vessel tracking programs provides examples of where certain systems have performed well and others have not.

Appendix 2 applies some of these potential criteria to a range of available data loggers as a means of looking across current options.

Hydraulic sensors to help differentiate fishing from transit

Gear sensors have been used with mixed results to help differentiate fishing activity from transit. For example, in 2012 fishery managers in Ireland began using low-cost, solar powered trackers to track vessels in the Irish Sea.[34] Originally the effort combined trackers with the use of hydraulic sensors to identify fishing but the project leads found that with a sufficiently high ping rate (i.e. 1 min or less), modeling approaches are able to accurately predict fishing behavior without the added complexity of hydraulic sensors that can break or fail to communicate with the tracker. The project has developed an R Shiny app, called '*pings to pots'* to help others apply the same approach.

It is worth noting that there are differences between the use of hydraulic sensors in the Pacific groundfish onboard camera program and their potential use to indicate fishing in a vessel tracking program. In the groundfish EM program, cameras are the compliance mechanism and sensors just help focus video review.[35] Use of sensors as an enforcement tool increases the consequences associated with failures or false positives. A lack of hydraulic pressure could demonstrate that a vessel is not fishing, however depending on the vessel and its layout, spikes in pressure may or may not indicate fishing activity. For example, the system that provides power to a crab block often powers other components such as bait choppers, anchor winches, boom winches, and pumps are all tied into the hydraulic system and can spike PSI. There can also be significant variability in electric/hydraulic configurations across vessels, even within the same fleet. This can mean that generating reliable data from a hydraulic sensor can require some analysis of baseline/spike PSI on a range of vessels. Whether the added complexity of hydraulic sensors is ultimately worth the effort depends on program/enforcement goals and the modeling approaches planned for identifying fishing activity.

[34] https://emff.marine.ie/marine-biodiversity/automating-data-acquisition-vessels-under-12m-length-phase-2
[35] https://media.fisheries.noaa.gov/2021-05/2021_EM_ProgramManual_Final_1.0_0.pdf

Vendor participation
The Department will need to decide if it will approve certain systems or allow the use of any system that performs the functions and/or meets select criteria such as those identified above. The fundamental tradeoff is consistency and enforceability vs. ease and flexibility. In the Dungeness crab fishery, the Department has thus far adopted the regulatory strategy of allowing any system that meets the high-level specifications in the RAMP regulations below:

> (A) When operating under a depth constraint or when using Alternative Gear pursuant to subsection (e), all vessels must have an operational electronic monitoring system affixed to their vessel and must be recording location while engaged in any fishing activity for commercial Dungeness crab. Electronic monitoring systems must be capable of tracking and recording vessel location using GPS coordinates at a frequency of no less than once a minute during fishing operations. Electronic monitoring data shall be made available to the department or authorized agent upon request for the duration of the fishing period and 60 days thereafter.
>
> (B) By the 2023-24 Fishing Season, all vessels will be required to carry an electronic monitoring device that is capable of tracking and recording vessel location using GPS coordinates at a frequency of no less than once a minute during fishing operations when participating in the California commercial Dungeness crab fishery. Data shall be made available to the department within 72-hours of request.

The State of Washington similarly allows any vendor to participate in its Dungeness crab vessel tracking program, but it provides much more specificity in terms of system requirements. By contrast, in the American Lobster fishery, vendors must apply to participate and are approved by the ASMFC only if they and their systems meet the following requirements:

- The ability to collect data at a minimum rate of one ping per minute for at least 90% of the trip
- If the tracking device can determine when the vessel is in its berth, the device may automatically decrease the tracker ping rate. If the device is unable to automatically detect a berth location, the device must remain connected and pinging at one ping per minute at all times.
- 100 m accuracy and position fix precision to the decimal minute hundredths
- Meeting ruggedness specifications allowing function in the marine environment
- The ability to PUSH location data to the ASMFC trip locations API. Data transmission from the vendor to the ACCSP trip locations API should occur in near real time upon receipt.
- Device vendors are to serve as the primary contact for their systems. This includes technical support related to hardware and any device-specific software
- Vendors should provide diagnostic and troubleshooting support to permit holders and state agencies, which is available seven days per week and year-round. Response times for customer service shall not exceed 24 hours. In the event of tracker malfunction, vendors must be available to troubleshoot, repair, or replace the device.
- The vendor must maintain the confidentiality of personally identifying information

- Data transmission from the tracking device to the vendor should be initiated as soon as possible but no more than 60 minutes from the time the fishing trip is completed
- Devices can be powered by any combination of vessel power, internal battery, and/or solar

Another more detailed example is the set of requirements developed for the small vessel tracking program in the U.K. NOAA OLE uses a similar type-approval process to approve VMS units. Type-approval is a significant additional procedural step but can increase the likelihood that the agency receives the correct data in a timely way and that fishermen have greater certainty in terms of their compliance. As vendors apply for approval to participate, it can be important to verify their assertions regarding the capabilities of their systems. In some programs, systems that were type-approved were later found to not meet expectations.

Whether conducting a type-approval process is worthwhile depends on the size of the fishery and the risks that non-compliance represents. For example, in a small fishery where the data is largely used for non-enforcement purposes, well-crafted regulations that describe performance standards and responsibilities allow the use of any capable system makes sense. In larger fisheries with variable fishing operations, where compliance is expected to be a challenge, and the data is anticipated to be used in enforcement actions, a type-approval process may be worth the additional step by reducing future data problems and legal challenges.

Vendor contracts

Separate from which vendors can participate, which receive public funds raises other issues and requirements. In many fisheries, fishermen are required to purchase their own units and enroll in a subscription plan at their own expense. However, in some settings there may be public funds available to absorb unit costs and cover initial subscription fees to help launch the program. Depending upon the source of funds, the Department or PSMFC may contract directly with a preferred vendor. This is the case with PSMFC's current engagement of Archipelago Marine Research to provide tracking units and initial service to the Dungeness crab fleet. This is simple and can be based on past positive experience with the vendor. However, this approach can also reduce the benefit of competition between vendors and can create over-reliance on a sole-source provider that can shape program design and drive up costs. For this reason, or due to procurement rules, it may be advisable for the Department or PSMFC to issue an RFP to give other vendors an opportunity to compete. A vessel tracking-based example is the RFP issued by the Department of Maine Resources in 2023 through which ASMFC type-approved vendors competed for a state contract to provide vessel trackers to the lobster fleet. The contract was ultimately awarded to Particle, a company headquartered in San Francisco.

Regulation development

In regard to regulatory language, Appendix 6 contains recent approaches to vessel tracking from other states that are worth considering. The approach taken by Washington in the Dungeness crab fishery and by NOAA in the regulations for the EM program in Pacific groundfish has been to incorporate a compliance guide by reference in the regulations. Many of the finer scale instructions are included in the compliance guide (see *rollout* section below). In general, using performance standards wherever possible as opposed to rigid technical requirements, in either regulation or type approval criteria, will provide flexibility and allow for innovation while still

meeting program goals.[36] Additionally, a common perspective heard from fishermen participating in both tracking and EM programs is the importance of meaningful enforcement provisions in terms of the consequences of non-compliance and the consistency with which the regulations are applied. Similarly, when units are not working, clarity regarding the chain of communication and troubleshooting protocols is essential. Knowing that others are flaunting requirements creates resentment among the segment of the fleet that wants to comply, which can quickly undermine the success of the program.

Rollout

As noted at the outset, regular stakeholder engagement is an essential aspect of the development process above and will help ensure the eventual rollout of the requirement goes (relatively) smoothly. Nevertheless, sufficient (3+ months) advance notice and clear instructions to the entire fleet are important. The Department created a simple FAQ-based compliance guide for the new vessel tracking requirement in the Dungeness crab fishery. The state of Washington took a more detailed approach which was needed to ensure compliance with its more specific regulatory provisions. After the conclusion of the RFP process, the state of Maine published a compliance guide that is vendor-specific, providing details specifically on how to comply using the Particle One tracker. These compliance guides can significantly improve rollout, however, managers, fishermen and vendors should still expect initial challenges and plan on the need for additional time, staffing, and flexibility to address them.

Data confidentiality

Section 8022 of the FGC identifies what fisheries information is confidential and the conditions under which it can be shared. Vessel tracking data collected under the authority of §8026 (see above) would be confidential. Tracking data can only be shared with federal fishery management agencies, academic institutions with a confidentiality agreement in place, or under other conditions stipulated by the commission through regulation. Notably however, §8022 does not contemplate third-party vendors that may initially collect the data at the Department's direction. While on its face, §8022 only creates obligations for the Department to safeguard data it has received, a third-party vendor likely would be considered the Department's agent and held to the requirements and goals of the Section. Similarly, in the federal arena, Section §402(b) of the MSA requires the confidentiality of any observer information, defined under §1802(32), to include any information collected by an EM system. As a form of observer information, all EM data are considered confidential from the point of collection for MSA purposes, whether in the possession of NMFS or retained by a third party. In order to allow third parties to collect and possess confidential information, all federal vendor contracts include provisions requiring attestation to the ability to preserve data confidentiality as proscribed by §402(b).[37] In the same way, vendor contracts with the State (or with PSMFC) contracting on the State's behalf, should include similar provisions incorporating requirements associated with §8022.

PSMFC and the Department executed an MOU in 2022 that outlines the types of confidential information that can be shared with PSMFC and requirements for how the data is to be stored and used. It's notable that vessel tacking data is not explicitly called out as one of the types of

[36] Garren, Melissa & Lewis, Forrest & Sanchez, Laura & Spina, Daniella & Brett, Annie. (2021). How performance standards could support innovation and technology-compatible fisheries management frameworks in the U.S.. Marine Policy. 131. 104631. 10.1016/j.marpol.2021.104631.

[37] https://media.fisheries.noaa.gov/2022-05/04-115-04_0.pdf

shareable data under the MOU. Vessel tracking information could be viewed as included under a broad interpretation of "logbook data", however this may be something to address in a future MOU amendment.

With regards to public display, data would be subject to the "rule of three" reporting fishermen requirement currently applied by the Department to other confidential data as a means of complying with §8022. However, the spatial scale across which the rule of three is applied is a matter of some Department discretion. In some settings, providing stakeholders with the highest resolution maps possible can be essential. For example, the potential use of ropeless gear in the Dungeness Crab fishery presents a challenge to other gear types that will no longer be able to easily see and avoid crab traps. Making high resolution maps of trap locations available (derived from vessel tracking, logbooks, or a combination) can help avoid gear loss. In March 2024, NOAA released a proposed rule that outlines its planned approach to confidentiality. The rule currently contemplates developing guidance that will address data aggregation standards. This guidance may revisit "the rule of 3" and raise considerations regarding how the Department can strike its own balance between the need for confidentiality and allowing fishermen and others to make the best use of the data.

Analysis and data integration

Some third-party vendors have analytical and visualization software available either as part of the service provided or for an additional cost. PSMFC can also provide this function and is anticipated to act in this capacity for the Dungeness crab fishery. If the Department chooses to conduct its own analyses, Appendix 2 provides literature on available technical approaches and open source applications that can help streamline the process. As noted above, integration with and validation of other data sets like logbooks and fish tickets can be one of the primary benefits of vessel tracking data. While integrating these data sets can present technical challenges, lessons regarding efficient API-based integration of vessel tracking data have been learned elsewhere that are worth drawing upon.

Application of recommendations to the Dungeness crab fishery

While the Department has recently initiated a vessel tracking program in Dungeness crab fishery, the RAMP regulations are expected to be revised soon to add line marking requirements and update key provisions including those related to electronic tracking. There is therefore an important opportunity to adapt and update the vessel tracking program in light of experience to date and to consider some of the recommendations above. This section identifies issues that may arise as part of that update and provides considerations associated with each.

Articulating more specific goals

The RAMP regulations and vessel tracking efforts to-date have been developed under tight legal deadlines and shaped by specific funding opportunities. In future iterations of RAMP, there may be opportunity to articulate more detailed goals for the vessel tracking program. For example, clarity regarding the planned enforcement use of the data and the associated evidentiary standards could help inform clear vendor/unit performance needs, the need for hydraulic sensors, and modeling approaches. Similarly, addressing key management questions can also help shape design. These include, does the Department need to know where individual traps are being pulled, or does knowing the general area in which a vessel is fishing suffice? Does the

Department need to use vessel tracking data to better understand effort shift in the fishery and if so, at what scale? Raising and answering key enforcement and management questions can help ensure that the program has a purpose-driven design and is successful over the long term.

Stakeholder engagement
Engaging stakeholders in refining the goals and addressing the questions above can provide insights that help make the program more practical. Engagement in further field testing of other units, interpretation of data, and developing a more comprehensive compliance guide may also be helpful. Given the number of stakeholder bodies already engaged in the fishery, capitalizing on an existing structure makes sense. A sub-committee of the Fishing Gear Working Group may be the most appropriate venue to engage stakeholders given the focus and manageable size of the group. Additional industry and/or technical expertise can also be brought in to support specific discussions.

Unit performance standards
In many vessel tracking programs, fishermen are required to purchase their own equipment. The Department has been able to purchase units from Archipelago Marine Research for the entire fleet, which is a clear near-term benefit to the fishery. Over the longer-term however, fishermen may prefer to use other units based on subscription costs or functionality. If the Department wants to provide this flexibility but also avoid conducting a type-approval process, the regulations and especially the compliance guide will need to provide sufficient detail regarding unit features, performance, and data submission to ensure the Department consistently gets the data it needs, and fishermen can be confident of their compliance. The criteria established by the ASMFC as part of the vessel tracking program for American lobster provide a useful starting point to consider. Appendix 2 applies some these potential criteria to currently available units.

Data management and modeling
The data management and analytical experience currently being gained in the 23/24 fishing season can provide valuable lessons that should shape the next iteration of the vessel tracking component of the RAMP rule. In particular, the approach developed for differentiating fishing from transit can help shape future device requirements. Experience gained from data submission challenges can shape future versions of the compliance manual and any regulatory enforcement language. The Department may want to also test cross referencing vessel tracking data with other data sources to help improve enforcement and data quality. For example, any vessel with landings in eTix should have corresponding vessel tracking reports. The timeline for distilling these lessons may be short depending when the next RAMP package is developed, but the opportunity is an important one that PSMFC will be well positioned to assist with.

Regulations and compliance manual
For comparison, regulations for Washington and Maine's relatively similar vessel tracking programs are described in 1,400 and 900 words respectively. California's requirements are currently described in just 160. This higher-level approach can work well when regulations are paired with sufficient non-regulatory guidance to ensure that the agency still receives good data. For example, in the groundfish EM program, NOAA, PFMC, and stakeholders have recently made effective use of a compliance manual that contains all of the finer scale details associated with the program. The compliance manual is incorporated by reference in the regulations and

helps ensure data is properly collected and submitted and can be easily amended when needed. However, California's prohibition on underground regulations means that any compliance guide will need to tread carefully in terms of framing in order to avoid being viewed as containing requirements that were not properly promulgated under California's Administrative Procedure Act. The guide can still serve the valuable role of improving data submission performance and providing fishermen with clarity, but it should not describe agency's own procedures and guidance to fishermen should be provided as options/examples of how to comply, not descriptions of the only way in which to comply.

If the Department instead seeks to include some additional level of detail in regulation, it may want to consider articulating basic requirements regarding:

- *Data submission* – The Department may want to consider providing flexibility regarding the type of device that can be used but require that the device/platform be capable of submitting data via API to either the Department or PSMFC. This API approach has been successful in streamlining electronic vessel trip reports (eVTRs) on the East Coast. The compliance guide could then identify which units/providers are known to be able to submit via that API.
- *Unit performance standards* - If the Department does not establish the API submission requirement above, it runs the risk of receiving limited or improper data. For example, devices such as plotters or cell phones may currently fall under the RAMPs current definition but may not generate or be able to transmit appropriately formatted data. To mitigate this risk, the Department may want to first define more specifically what an "electronic monitoring system" is and what basic capabilities it should have.
- *Data recording* – Again, if the Department does not use an API requirement, it may want to also consider specifying the requisite data format in order to reduce processing and QA/QC time.
- Enforcement actions – The Department may want to expressly prohibit tampering with devices, stipulate penalty provisions, and create an affirmative duty on the part of fishermen to ensure data is being collected and submitted.

Enforcement and compliance

The fleet has raised concerns regarding the need for consistent enforcement of the vessel tracking requirement to ensure that it is not just "the good guys" who comply. In addition to regulatory provisions regarding enforcement, consistency in how non-compliance is actually addressed will be important in shaping fleet perspectives towards the program, compliance rates, and data quality.

Intersection with pop-up gear efforts

Current efforts to explore pop-up and other gear modifications include use of an electronic logbook that is capable of capturing the same location data. While there are no current plans to extend use of that logbook to the broader fleet, it nevertheless represents a valuable opportunity to test other methods of vessel tracking in the fishery.

Conclusion

Increased whale entanglement may be the most visible impact from climate change on California fisheries, but there are many. As species distributions continue to shift, ocean chemistry and

temperature change, and fisheries evolve, the need for good, timely data will become increasingly paramount. While vessel tracking has been a tool in the toolbox for a longtime, it's become much easier and cheaper to use and can provide critical data needed for more adaptive management. Drawing from lessons learned in tracking programs elsewhere and from pilot efforts here in California can help the Department and fishermen make the most of it.

Vessel tracking is at one end of an at-sea monitoring tool continuum which also includes electronic logbooks, observers, and onboard cameras. Other reviews have addressed the other parts of the continuum, but identifying which tool is most appropriate will always depend on the fishery. Future work may focus on integrating these reviews of specific tools into a single cohesive set of at-sea monitoring considerations for California.

APPENDICES

APPENDIX 1 - List of other related data collection review/efforts and links

APPENDIX 2 - Tracker capabilities and potential selection criteria

APPENDIX 3 - Lessons learned from vessel tracking in the American Lobster fishery

APPENDIX 4 - International GPS tracker programs

APPENDIX 5 - Literature on modeling approaches for differentiating fishing from transiting

APPENDIX 6 – Regulatory language from other states