TO: Maine Department of Environmental Protection
Bureau of Water Quality
17 State House Station
Augusta, ME 04333-0017

ATTN: Laura Crossley, Licensing Coordinator

RE: Public Comment in Opposition — Kingfish Maine, Inc., MEPDES Permit Renewal Application ME0037559 / Maine Waste Discharge License W009238-6F-A-N, Jonesport, Maine

July 8, 2026

Dear Members of the Department:

The Eastern Maine Conservation Initiative (EMCI) submits these comments, together with the attached technical report prepared by Remote Ecologist, *A Careful Path Forward for Aquaculture and Chandler Bay*, in opposition to the renewal of the above-referenced permit. We ask the Department to deny the application.

EMCI has worked in and around Chandler Bay for nearly thirty years, and our position has not changed across this proceeding's several stages. We opposed the original application on scientific grounds, questioning the modeling used to estimate nitrogen assimilation and the extremely limited baseline water quality data. We later petitioned the Department, and then the Board of Environmental Protection, to reclassify Chandler Bay from Class SB to Class SA — a request supported by four consecutive years of ambient monitoring showing the bay already attains SA conditions. Chandler Bay was excluded from the waters reclassified under L.D. 2187, adopted April 3, 2026, and remains Class SB. The existence of this unused discharge permit was among the implied reasons given. We have never opposed aquaculture in Maine, and we do not oppose it now. We oppose authorizing a discharge of this magnitude into waters whose demonstrated quality exceeds the classification the State has assigned them.

The permit now before the Department is the one in which DEP found that this discharge would lower water quality in Chandler Bay. The Department made a finding under the antidegradation provisions of 38 M.R.S. § 464(4)(F) for nitrogen as it pertains to eelgrass and authorized that lowering on the determination that it was necessary to achieve important economic or social benefits to the State. The Department's parallel Site Law and Natural Resources Protection Act order, issued on November 12, 2021, found Kingfish's financial capacity to be adequate, subject to preconstruction conditions. Before beginning construction beyond limited site preparation and stabilization work, the order required Kingfish to submit evidence of a line of credit, loan, or other acceptable financial assurance in the amount of $105.5 million for the Department's review and approval. Kingfish told this community the project meant a $110 million investment and seventy to one hundred jobs.

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Nearly five years on, no ground has been broken. In January 2026 the global company disclosed to investors that it expected to breach its EBITDA financial covenant at year-end 2025 and no longer expected to be cash-flow-positive from operations during 2026. It has since completed a financial restructuring bringing in a new largest shareholder and materially altering the capital structure the Department examined in 2021. It has separately sought thirty additional months from the Town of Jonesport to make a substantial start on the facility. Whatever the company's prospects now, the economic benefits that justified degrading this bay have not arrived, and the Department has never revisited the finding that made this discharge lawful. A renewal proceeding is the appropriate moment to do so.

Nor has the Department ever verified the assumptions on which the permit rests. The 2021 permit adopted dilution factors derived from modeling and required a dye study to confirm the outfall's actual mixing characteristics during the first summer of discharge at full buildout. There has been no buildout, no discharge, and no dye study. The Department is now asked to carry forward mixing assumptions that remain untested in Chandler Bay.

The technical record has not stood still either. The enclosed report sets out, in detail we will not duplicate here, why the modeling underlying this permit can no longer bear the weight the Department places on it: it was prepared in 2020, simulates roughly seven days of plume behavior, and cannot speak to cumulative nitrogen retention, return flow, or long-term loading over the seasons and years a discharge of this size would operate. The report further finds that the application contains no site-specific evaluation of outfall exit velocity, and that the report's statewide statistical analysis places Chandler Bay's median SA-likeness score above the median of Maine's historically designated Class SA waters. We ask that these findings be given full weight.

We commissioned this report because a decision of this consequence should rest on current science rather than assumptions carried forward from an earlier proceeding. The Department now has what it lacked in 2021: an actual record of what this bay is. We respectfully ask that the Department deny this permit renewal.

Respectfully submitted,

Anastasia Fischer

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Enclosure: A Careful Path Forward for Aquaculture and Chandler Bay (Remote Ecologist, Jason Krumholz, Ph.D. and Darby L. Pochtar, Ph.D.)

A Careful Path Forward for Aquaculture and Chandler Bay

A Respectful Request for Careful Review of Kingfish Maine Permit Renewal Application ME0037559

REMOTE ECOLOGIST
Type text here
A 501(c)(3) Non-Profit

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Project Team: Jason Krumholz, Ph.D. and Darby L. Pochtar, Ph.D.

The purpose of this report is to address our continued concerns with Kingfish Maine Permit Renewal Application, ME0037559. We had previously spoken in opposition to Kingfish's initial permit application, and while we respect DEP's decision on that matter, in the intervening years, substantial additional information has become available that raise additional concerns, and we do not think that Kingfish has adequately addressed these issues. This request is not about opposing aquaculture in Maine. We support responsible land-based aquaculture and recognize that it will be part of Maine's future coastal economy. However, aquaculture should be designed and operated in a way that protects existing water quality, fisheries, shellfish resources, eelgrass habitat, recreation, and the long-term ecological health of the receiving waterbody. The question before Maine DEP is not whether aquaculture belongs in Maine. The question is whether Kingfish Maine's proposed discharge can be authorized without risking Chandler Bay's clean waters, fisheries, shellfish beds, eelgrass habitat, and the community benefits the bay already provides.

Large-scale Nitrogen Discharge into a Sensitive, High Value Bay

Our first concern is the scale and nature of the proposed discharge. Kingfish Maine's renewal materials describe a land-based recirculating aquaculture facility that would grow approximately 6,000 to 8,000 tons of yellowtail kingfish annually and would use water from Chandler Bay in three ways: heat-recovery water, culture water that contacts fish, and processing water that contacts fish. The renewal materials state that the total maximum daily discharge would be 28.7 million gallons per day through one outfall at a time, with a 47.24-inch pipe extending 2,624 feet into Chandler Bay and a diffuser with six 8.3-inch ports. The current permit renewal materials also estimates the proposed effluent as containing 1,639 pounds of total nitrogen per day. Kingfish Maine identifies wastewater treatment measures, including solids filtration, nitrification and denitrification, and ozone or UV sterilization; however, the application has not shown that these measures are sufficient for a discharge of this size into a high-quality, nitrogen-sensitive bay that supports eelgrass, shellfish, fisheries, and other public resources.

The discharge volume alone is substantial. At the proposed maximum daily discharge rate of 28.7 million gallons per day (MGD), water would be released through six 8.3-inch diffuser ports. Based on those values, the estimated baseline exit velocity is approximately 13.4 miles per hour (11.5 knots) at each upward-facing port, assuming the flow is evenly distributed across all six ports, the discharge occurs continuously over 24 hours, and each port is fully open (Appendix 1: Equation 1). Actual velocities could be higher if the duckbill valves do not fully open, if fouling or debris reduces the effective opening area, if fewer than six ports are actively discharging, or if flow is not evenly distributed among the ports (Appendix 1: Tables 1–3). These conditions would either reduce the open area available for discharge or concentrate flow through fewer openings, which would increase the localized exit velocities.

These estimated flow velocities are high compared with documented Maine coastal currents, which typically do not exceed 2 knots[1], potentially expose organisms near the diffuser to localized flow conditions well above background current velocities typical for Maine waters. Therefore, part of our concern is not only what concentration the plume reaches after dilution, but what physical conditions are created at the point of release. Six upward-facing diffuser ports discharging at these velocities could create localized turbulence, sediment disturbance, and physical stress on organisms near the outfall, which should be evaluated directly before discharge is authorized. Given the size of the discharge, the nitrogen load, and the ecological value of Chandler Bay, DEP should require a site-specific review of outfall velocity, diffuser performance, sediment stability, and biological effects before authorizing discharge. This is also consistent with Maine's requirement to evaluate whether a discharge would cause adverse impacts to estuarine and marine life and habitat (38 M.R.S. § 465-B(2)(C)).

Further Evaluation is Needed to Understand Long-term Nitrogen Load

Our second concern is that the modeling submitted with the renewal application does not fully answer what happens to nitrogen over time. The near- and far-field modeling included in the permit renewal application was originally prepared in 2020, before several years of additional Chandler Bay water-quality monitoring and before newer documented changing circulation patterns in the Gulf of Maine. Recent research has found that surface flow in the Gulf of Maine Coastal Current has slowed over inter-decadal timescales[2], raising a reasonable concern that present-day water movement into and out of Chandler Bay may not be fully captured by the circulation assumptions used in the 2020 model. We recognize that modeling coastal systems is complex, and that Kingfish Maine's model does consider continuous discharge. However, the application relies on CORMIX to evaluate near-field dilution and TUFLOW FV to evaluate far-field plume movement over only approximately 175 hours, or about seven

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[1] Howard Lutnick, Neil Jacobs, and Nicole R. LeBoeuf, *United States Coast Pilot 1: Atlantic Coast: Eastport, Maine to Cape Cod, Massachusetts*, 56th edition (National Oceanic and Atmospheric Administration, 2026); NOAA, "Gulf of Maine OFS Currents Nowcast," NOAA: Tides & Currents.

[2] Kristin C. Burkholder, Jane HyoJin Lee, Meredith Kime, Cassandra Calabro, and James P. Manning, "Decadal-Scale Variability in the Surface Flow of the Gulf of Maine Coastal Current: The Impact of Changing Climate Conditions on Coastal Circulation," *Journal of Geophysical Research: Oceans* 129, no. 4 (2024): e2023JC020512.

days and 14 tidal cycles. That simulation period may help describe initial plume behavior, but it is too short to determine how repeated daily nitrogen discharge may accumulate, recirculate, or persist over months, seasons, or years.

As a result, the application does not clearly translate predicted nitrogen concentrations into cumulative nitrogen loading, retention, or long-term exposure in Chandler Bay. Dilution alone does not answer that question. Even where portions of the plume are predicted to become highly diluted, the application does not clearly show how much nitrogen remains in the bay, how much may return with tides and residual currents, or how repeated daily discharge could affect water quality over longer time scales. The permit materials also appear to emphasize a maximum dilution value, but the model results show that dilution within Chandler Bay varied across the seven-day simulation and did not uniformly reach that maximum throughout the plume. Before any discharge is authorized, DEP should require updated modeling that directly evaluates long-term nitrogen retention, return flow, cumulative loading, seasonal variability, and potential compounding at the intake, including consideration of Dr. Kincaid's CEM-ROMS modeling[3].

The Permit Renewal Should Reflect the Stronger Chandler Bay Water Quality Record

Our final concern is that the permit renewal should be evaluated in light of the much stronger water-quality record now available for Chandler Bay. When the Kingfish discharge was first considered, there was limited background water-quality information for the bay. Since then, several years of monitoring have been completed through Kingfish's own required monitoring program[4], along with additional review of outside data sources (Appendix 2: Enhancing the Use of Water Quality Data to Support Reclassification Decisions). That newer information strongly supports the conclusion that Chandler Bay has water-quality conditions consistent with Class SA waters (38 M.R.S. § 465-B). However, in DEP's November 2025 triennial review[5], Chandler Bay was not recommended for Class SA designation partly because of the status of the Kingfish wastewater discharge permit, even though no discharge has begun. Kingfish's current renewal materials also indicate that the application involves a new discharge of industrial process wastewater and a new or modified outfall structure. For that reason, we respectfully ask DEP not to treat Chandler Bay as already committed to this discharge. We suggest that the permit renewal be reviewed based on the fuller record now available, including the evidence that Chandler Bay currently supports water quality and ecosystem conditions worthy of the highest level of protection, and the virtual certainty that the issuance of this permit would reduce water quality below the SA thresholds.

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[3] Chris Kincaid, *Development of the CEM-ROMS Hydrodynamic-Transport Model for Circulation and Transport Processes in Chandler Bay (ME) and Surrounding Waters* (Kincaid Consulting, LLC, 2023), 37.

[4] The University of Maine, *2025 Ambient Water Quality Monitoring Report for Kingfish Maine, Land Based Aquaculture Project Jonesport, Washington County, Maine, USA* (Jonesport, Maine, 2025), 56.

[5] Maine Department of Environmental Protection, "2025 Triennial Review of Water Quality Standards," Final Recommendations, December 2025.

Conclusion

For these reasons, we respectfully asks DEP to deny the Kingfish Maine permit renewal in its current form, or to require additional review before any discharge is authorized. Additional review would help ensure that the decision is based on the best available science and that any permit conditions are strong enough to protect Chandler Bay over time. This should include updated multi-year hydrodynamic and nutrient modeling; clearer evaluation of nitrogen retention, return flow, cumulative loading, and intake compounding; renewed review of potential adverse impacts under 38 M.R.S. §465-B(2)(C); further consideration of practicable wastewater-treatment alternatives; expanded baseline monitoring; site-specific review of outfall velocity, sediment stability, and biological effects; and clear conditions requiring corrective action if water quality begins to decline. These requests are not meant to stand in the way of responsible aquaculture in Maine. They are intended to help ensure that aquaculture development proceeds carefully, transparently, and in a way that protects Chandler Bay's clean water, fisheries, shellfish resources, eelgrass habitat, working waterfront, and long-term public value. Kingfish has repeatedly stated that the challenges posed by this site make additional nutrient removal options at this site cost prohibitive, and if they were cost effective, they would employ them. And Kingfish has proven this to be true, with extremely low discharges from other facilities located elsewhere. However, our position is that if the profitability of operations at this site is dependent on water quality degradation in the receiving waters, then the "profitability" exists only because the costs are being passed on to others, and a more suitable site should be identified where profitability and sustainability can coexist.

Appendix 1: Estimated Outfall Port Exit Velocity Calculations

This appendix provides the equations used to estimate the baseline exit velocity from Kingfish Maine's outfall diffuser ports based on the discharge rate, number of active ports, and port diameter reported in Attachment 3 of the Permit Renewal Application, ME0037559. It also presents sensitivity calculations showing how exit velocity could increase if port openings are partially restricted (Table 1), fewer ports are active (Table 2), or flow is unevenly distributed across the diffuser system (Table 3).

Equation 1. The associated equations used to calculate the baseline velocity of Kingfish Maine's outfall port. The following information was provided as part of Attachment 3 to the Kingfish Maine Permit Renewal Application – ME0037559: Total discharge = 28.7 million gallons per day = 28.7 MGD; number of active diffuser ports = 6; diameter of each port = 8.3 inches.

Step 1: Convert daily discharge from gallons/day to cubic feet/second to calculate total discharge rate

Q_{total} = gallons/day ÷ 7.48052 gallons/ft^3 ÷ 86,400 seconds/day

Q_{total} = 28,700,00 gal/day ÷ 7.48052 gal/ft^3 ÷ 86,400 sec/day = 44.39 ft^3/sec

Step 2: Divide total flow across six ports

$Q_{port} = Q_{total}$ ÷ number of ports

Q_{port} = 44.39 ft^3/sec ÷ 6 = 7.40 ft^3/sec per port

Step 3: Convert port diameter from inches to feet

Diameter in feet = diameter in inches ÷ 12

D = 8.3 in ÷ 12 = 0.6917 ft

Step 4: Calculate area of each circular port

$Area = \pi \times (D \div 2)^2$

$A = \pi \times (0.6917\ ft \div 2)^2 = 0.376\ ft^2$

Step 5: Calculate velocity in feet per second

Velocity = flow rate ÷ area = $Q_{port} \div A$

V = 7.40 ft^3/sec ÷ 0.376 ft^2 = 19.69 ft/sec

Step 6: Convert feet per second to miles per hour

mph = ft/sec x 0.681818

mph = 19.69 ft/sec x 0.681818 = 13.4 mph = 11.6 knots

Table 1. Estimated exit velocity by effective duckbill valve opening or port fouling. Values were calculated using the baseline estimated exit velocity of 13.4 mph, which assumes the maximum daily discharge of 28.7 MGD is evenly distributed across six fully open 8.3-inch diffuser ports. Because velocity is inversely proportional to effective open area, adjusted velocity was calculated as: Adjusted velocity = baseline velocity ÷ effective opening fraction. These estimates may represent scenarios where duckbill valves do not fully open, as well as scenarios where the effective discharge area is reduced by port fouling, biofouling, sediment accumulation, debris, or partial obstruction.

Effective port opening	Formula	Estimated exit velocity
100% open	13.4 ÷ 1.00	13.4 mph = 11.6 knots
75% open	13.4 ÷ 0.75	17.9 mph = 15.6 knots
50% open	13.4 ÷ 0.50	26.8 mph = 23.3 knots
25% open	13.4 ÷ 0.25	53.6 mph = 46.6 knots

Table 2. Estimated exit velocity based on number of active discharge ports. Values were calculated using the baseline estimated exit velocity of 13.4 mph, which assumes the maximum daily discharge of 28.7 MGD is evenly distributed across six fully open 8.3-inch diffuser ports. This scenario estimates how exit velocity would change if fewer than six ports were actively discharging. Because the same total discharge would be forced through fewer openings, velocity increases in proportion to the reduction in active ports. Adjusted velocity was calculated as: Adjusted velocity = baseline velocity × (6 ÷ # of active ports).

Number of active ports	Formula	Estimated exit velocity
6 ports	13.4 x (6 ÷ 6)	13.4 mph = 11.6 knots
5 ports	13.4 x (6 ÷ 5)	16.1 mph = 14.0 knots
4 ports	13.4 x (6 ÷ 4)	20.1 mph = 17.5 knots
3 ports	13.4 x (6 ÷ 3)	26.8 mph = 23.3 knots
2 ports	13.4 x (6 ÷ 2)	40.2 mph = 34.9 knots
1 port	13.4 x (6 ÷ 1)	80.4 mph = 69.9 knots

Table 3. Estimated exit velocity by uneven flow distribution among ports. Values were calculated using the baseline estimated exit velocity of 13.4 mph, which assumes equal flow distribution across all six fully open diffuser ports. This scenario estimates how exit velocity at an individual port would change if flow was not evenly distributed and one port receives more than its average share of the total discharge. Because velocity of a discharge port is directly proportional to the amount of flow passing through that port, adjusted velocity was calculated as: Adjusted velocity = baseline velocity × flow distribution multiplier.

Flow distribution among ports	Formula	Estimated exit velocity
Equal flow across all six ports	13.4 x 1.0	13.4 mph = 11.6 knots
One port carries 20% more than average flow	13.4 x 1.2	16.1 mph = 14.0 knots
One port carries 50% more than average flow	13.4 x 1.5	20.1 mph = 17.5 knots
One port carries 2x average flow	13.4 x 2.0	26.8 mph = 23.3 knots

Appendix 2: Enhancing the Use of Water Quality Data to Support Reclassification Decisions

Case Study: A Statistical Defense in Favor of Reclassifying Chandler Bay, ME as Class SA

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Executive Summary

Maine's marine water classifications (SA, SB, SC) set the legal baseline for water-quality protection and determine how antidegradation requirements are implemented under both state and federal law. Most coastal waters are SB by default, which makes the ability to accurately identify waters that meet SA standards essential to protect "higher water quality" where it exists.

This report uses statewide water quality data to build a screening model that learns the multivariate environmental patterns historically associated with SA versus SB waters. The model is then applied—without refitting or threshold tuning—to an independent dataset from Chandler Bay collected under the Kingfish Company permit monitoring requirements. The purpose is not to replace Maine's statutory classification process, but to evaluate whether observed Chandler Bay conditions are consistent with historical SA waters or historical SB waters when placed in a statewide context.

Key findings are as followed:

1. A statewide random forest model can meaningfully distinguish historical SA from SB waters based on multivariate water quality patterns and monitoring structure.

2. Chandler Bay observations fall firmly in the SA-like region of the model's probability space. Chandler Bay's median predicted probability of SA-like conditions is higher than the median of historical SA waters statewide, and far above the historical SB distribution.

3. The model relies strongly on both (1) measured environmental conditions and (2) monitoring-regime structure (whether key parameters were measured). This reflects a real and policy-relevant feature of Maine's monitoring landscape: higher-quality or higher-priority waters tend to be monitored more intensively for regulatory-relevant variables.

4. A sensitivity analysis removing all monitoring-indicator variables shows that Chandler Bay remains strongly SA-like based on measured chemistry alone, though the strength of the signal decreases. This indicates that the sociopolitical factors impacting monitoring structure amplify, but do not create, the observed patterns.

5. These results underscore a critical implementation problem for 38 M.R.S. § 464(4)(F)(4): without consistent statewide measurement of classification-relevant parameters, Maine cannot reliably identify where actual water quality exceeds the minimum standards of the next highest class and therefore must be maintained and protected and recommended for reclassification.

Background

Marine Classification and Regulatory Significance

Maine's coastal waters are classified under state law (38 M.R.S. §§ 464, 465-B) in accordance with the federal Clean Water Act (33 U.S.C. § 1313). These classifications (SA, SB, and SC) establish the designated uses and water quality standards that apply to each waterbody. Under both federal and state law, discharge permits must include limitations stringent enough to meet water quality standards and protect designated uses (33 U.S.C. § 1311(b)(1)(C); 40 C.F.R. § 122.4(d); 38 M.R.S. § 414-A). Therefore, marine classification is not simply descriptive; it establishes the legal benchmark against which environmental protection and regulatory decisions are measured.

Under 38 M.R.S. § 465-B(1), Class SA is Maine's highest marine classification and applies to waters that are outstanding natural resources and should be preserved because of their ecological, social, scenic, economic, or recreational importance. Class SB is the second-highest classification and applies to waters that must support recreation, fishing, aquaculture, navigation, and unimpaired marine habitat (38 M.R.S. § 465-B(2)).

Antidegradation and the Protection of Higher Water Quality

Maine's antidegradation policy (38 M.R.S. § 464(4)(F)) requires protection of existing uses and the water quality needed to maintain them. Critically, § 464(4)(F)(4) provides that when the "actual quality of a classified water exceeds the minimum standards of the next highest classification, that higher water quality must be maintained and protected", and "the board shall recommend to the Legislature that the water be reclassified" accordingly. Given that most coastal waters are classified as SB by default under 38 M.R.S. § 469, the practical effectiveness of antidegradation depends on Maine's ability to (1) detect waters whose measured conditions exceed SB and align with SA standards, and (2) maintain and protect those conditions through classification accuracy and permitting decisions. However, achieving this requires consistent and comparable monitoring of the water quality parameters that differentiate marine classifications.

Purpose and Research Questions

Marine classification reflects both environmental conditions and regulatory considerations. Accordingly, the modeling framework developed in this report is intended to assess consistency between observed water quality conditions and historically classified waters, rather than to replace or supersede Maine's statutory classification process.

To evaluate how water quality conditions relate to marine classification at a statewide scale, we developed a data-driven modeling framework using a random forest approach. This framework was designed to learn how combinations of water quality measurements historically align with class SA and class SB designations across coastal Maine and to place individual waterbodies within that broader environmental context. By focusing on multivariate patterns rather than single parameters, the approach reflects the reality that marine classification is influenced by overall environmental conditions rather than any one measurement in isolation.

Within this framework, Chandler Bay is treated as a case study. Water quality observations collected throughout Chandler Bay under the Kingfish permit monitoring program (permit #ME0037559)[6] were evaluated as an independent dataset and compared against statewide patterns learned from historically designated SA and SB waters. The central research question addressed in this report is, "Given water quality conditions measured throughout Chandler Bay, Maine, are those conditions more consistent with historically designated SA waters than with historically designated SB waters?"

The objective of this analysis is not to assign or modify regulatory classifications, but to generate quantitative evidence regarding whether Chandler Bay's observed environmental conditions align more closely with the characteristics of SA waters than SB waters. In doing so, the analysis provides a scientifically grounded basis for evaluating whether Chandler Bay may warrant closer review under Maine's antidegradation framework, including the provisions of 38 M.R.S. § 464(4)(F)(4) concerning waters whose actual quality exceeds the minimum standards of their assigned classification.

Methods

All data curation and analyses were conducted in R Studio[7]. Reproducible code and outputs can be provided upon request.

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[6] The University of Maine, *2025 Ambient Water Quality Monitoring Report for Kingfish Maine, Land Based Aquaculture Project Jonesport, Washington County, Maine, USA* (Jonesport, Maine, 2025), 56.

[7] Posit team, *RStudio: Integrated Development Environment for R*, v. 2024.12.0.467, Posit Software, PBC, released 2024.

Statewide Historical Dataset

Water-quality observations were compiled from multiple monitoring programs and harmonized into a single analytical dataset. The two data sources that had the best coverage of regulatory-relevant water quality parameters were from the National Water Quality Monitoring Council (NWQMC)[8] and Maine Department of Environmental Resources Environmental and Geographic Analysis Database (EGAD)[9]. Each observation included location, sampling date, and available physical, chemical, and microbial measurements, including dissolved oxygen, salinity, temperature, pH, nitrogen concentrations (i.e., ammonia), and indicator bacteria (i.e., most probable number (MPN) of enterococci per 100mL). Observations that contained only temperature and salinity measurements and no additional water quality variables were excluded from the analysis to ensure that model inputs reflected parameters relevant to marine classification decisions. While temperature and salinity provide important environmental context, they are not used independently to determine marine classification and do not, on their own, distinguish among SA, SB, or SC waters. Requiring at least one additional water-quality parameter per observation ensured that model training was informed by variables directly tied to regulatory standards and water quality conditions. Variables that were infrequently measured or inconsistently defined across monitoring programs (e.g., chlorophyll, light availability, nitrate and nitrite, total nitrogen, and total phosphorus) were excluded to maintain interpretability across the combined dataset.

The response variable was marine classification, categorized as SA, SB, or SC. Marine classification was assigned by overlaying sampling observations on the official Maine DEP statutory water classification geographic information system (GIS) map[10]. Observations that did not fall within a classified marine area were excluded from analysis. Since the purpose of this report was to isolate and evaluate the environmental gradient separating SA and SB waters, SC observations were excluded from our analyses. Removing SC observations allowed the models to focus on the more subtle distinctions between adjacent regulatory classes most relevant to Chandler Bay's current designation. In addition, SC observations represented a very small proportion of the available dataset (3.6% of all observations) and following the removal of observations lacking all water-quality measurements except temperature and salinity, SC observations accounted for only 1.8% of the remaining data. Given their limited representation and distinct regulatory status, inclusion of SC observations would have added noise without improving the model's ability to resolve the SA–SB decision boundary. All included observations were then mapped to observe overall sampling coverage (Figure 1).

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[8] National Water Quality Monitoring Council, "Maine Biological Water Quality Metadata," Water Quality Portal.

[9] Maine Department of Environmental Protection, "Environmental and Geographic Analysis Database (EGAD) Maine SA Waters Water Quality," n.d., accessed February 4, 2026.

[10] Becky Schaffner, *Current Maine Statutory Water Classification*, Web GIS Map, Maine Department of Environmental Protection, April 28, 2025.

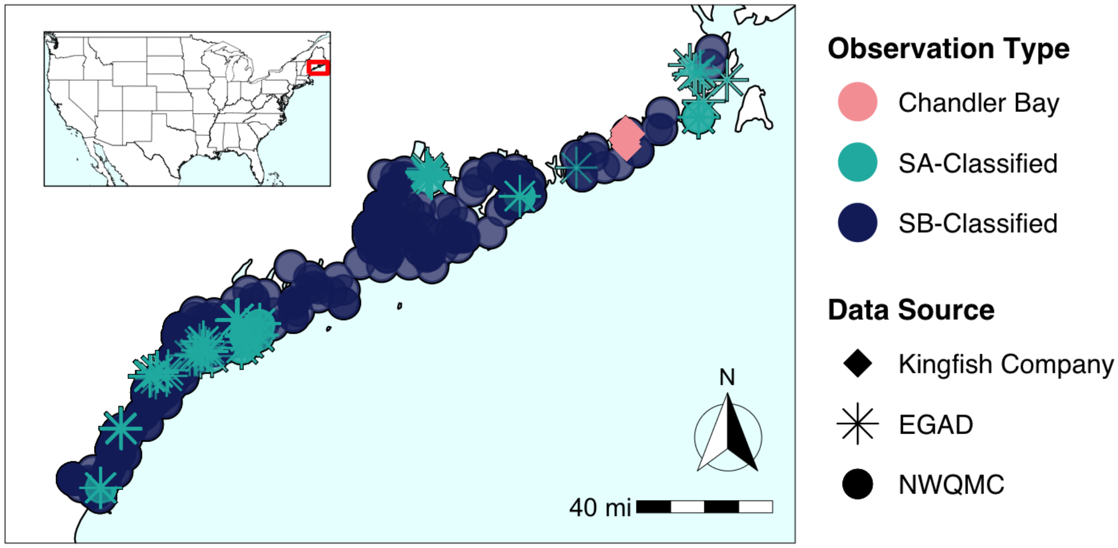

Figure 1. Map of the water quality monitoring locations across coastal Maine used in our analyses, categorized by marine classification and data source. Points represent individual sampling locations, with darker shading indicating a greater number of observations at a given location (i.e., higher sampling intensity).

Predictor Variables and Missing Data Handling

Predictor variables were selected to represent key aspects of coastal water quality, including physical conditions (temperature and salinity), dissolved oxygen, pH, microbial indicators, and nutrient-related parameters where available. Since data was compiled from multiple monitoring programs with differing objectives and sampling frequencies, many predictors were not measured for every observation. These missing values primarily reflect differences in monitoring design rather than data collection errors.

Instead of removing incomplete observations or replacing missing measurements with estimated values, missing data were left as collected and handled directly within the modeling framework. For each predictor, the model was given two types of information: (1) the measured value when available and (2) a simple indicator noting whether that variable was measured for a given observation (yes/no). This allowed the model to use both the environmental measurements and the monitoring patterns themselves, while retaining all available observations in the analysis and avoiding artificial value substitution.

Modeling Framework

Prior to model fitting, the dataset was partitioned into training and testing subsets using an 80/20 stratified split. Stratification was performed on the response variable (SA vs SB) to preserve class proportions in both subsets and ensure unbiased evaluation of predictive performance[11]. The resulting training set was used to fit the model, while the held-out test set was reserved for out-of-sample performance evaluation.

To evaluate how multivariate water quality conditions relate to marine classification, we implemented random forest models[12]. The random forest model works by building many simple decision trees and combining their results. Each tree examines the data in a slightly different way, and the final prediction reflects the overall agreement across all trees. By averaging across many trees, the model produces stable and reliable results rather than relying on a single decision rule. The model was configured to generate probabilities rather than only categorical classifications. For each observation, the model returned a value between 0 and 1 representing how strongly the measured water quality conditions resemble those historically associated with SA waters. Values closer to 1 indicate strong similarity to typical SA conditions, while values closer to 0 indicate stronger similarity to SB conditions. This probability-based approach allows assessment of degree of environmental similarity rather than forcing a strict binary classification.

Model performance was first evaluated on the held-out test data using a default probability threshold of 0.5 to establish baseline discrimination between SA and SB waters. To support screening use, model performance was then evaluated across a range of probability thresholds (a "threshold sweep") to quantify tradeoffs between (1) recall (sensitivity) for SA: how many true SA observations are flagged as SA; (2) precision for SA: how often SA predictions are correct; and (3) flagged rate: how aggressively the model label observations SA. As an initial benchmark, the threshold that maximized the F1 score (balanced recall and precision) was selected using historical statewide data only and fixed prior to application to Chandler Bay.

To identify which environmental factors most strongly distinguish class SA from class SB waters, permutation-based variable importance was used. This approach evaluates how prediction accuracy changes when individual variables are randomly shuffled, with larger reductions in accuracy indicating greater importance. This process provided an objective ranking of which parameters most strongly contribute to classification differences. Since multiple water quality parameters were evaluated together, the model captured how combinations of parameters jointly characterize regulatory classes, reflecting the multivariate nature of marine classification.

Finally, to ensure that results were not driven primarily by differences in monitoring practices across agencies, a sensitivity analysis was conducted in which all indicator variables reflecting whether a parameter was measured were removed. This chemistry-only model tested whether classification patterns persisted when predictions were based solely on measured environmental values. Comparison of results

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[11] Hannah Frick, Fanny Chow, Max Kuhn, Michael Mahoney, Julia Silge, and Hadley Wickham, *Rsample: General Resampling Infrastructure*, v. R package version 1.3.2, released 2026.

[12] Marvin N. Wright and Andreas Ziegler, "Ranger: A Fast Implementation of Random Forests for High Dimensional Data in C++ and R.," *Journal of Statistical Software* 77, no. 1 (2017): 1–17.

across model specifications allowed separation of environmental signals from potential effects of monitoring structure.

Intended Use and Limitations

This modeling framework is intended as a screening and decision-support tool to help identify locations where observed water quality conditions may warrant closer examination. Model results do not replace regulatory criteria or formal classification procedures and should be interpreted alongside site-specific context, monitoring history, and regulatory standards. Because marine classification reflects factors beyond measured water quality alone, including management considerations and historical designations, perfect replication of classifications using environmental variables alone is neither expected nor necessary for the intended application.

Chandler Bay Water Quality Data

Chandler Bay water quality data were collected from monitoring efforts conducted under the Kingfish Company discharge permit requirements (permit #ME0037559). These monitoring data were collected independently of this analysis and used as an external application dataset, not for training, variable selection, or threshold tuning. The Chandler Bay dataset includes sampling location and date information and the available water quality variables that correspond to those used in the statewide model. However, since the Kingfish company was not required to measure any microbial indicators, the Chandler Bay dataset was missing all enterococcus measurements.

Summary of Results

A total of 26,810 observations were initially assigned a marine classification based on spatial overlay with Maine DEP statutory GIS layers. Of these, 81.8% were classified as SB, 13.5% as SA, and 4.7% as SC. After removing observations that contained only temperature and salinity measurements (i.e., lacked any additional water quality parameter), 2,480 observations remained. Within this subset, SA comprised 48.1%, SB comprised 47.7%, and SC comprised 4.2%. Since the primary research question concerns the environmental gradient between SA and SB waters, the remaining 105 SC observations were excluded. The final SA-SB modeling dataset consisted of 2,375 observations (n = 1,193 SA; 1,182 SB). This near-balanced distribution reduced potential bias in model training and evaluation.

Model Results

Using the statewide reference dataset, the random forest model was able to tell apart water quality patterns typical of historically designated SA waters versus historically designated SB waters. In the held-out test set (i.e., data not used to train the model), the model correctly classified the majority of observations at the standard 0.5 threshold. When the model predicted that an observation was SA, it was correct about 85% of the time, meaning the model’s SA predictions were usually reliable. However, since the purpose of this work is to support regulatory screening, and not just to maximize overall accuracy, we then examined performance across many probability cutoffs to understand the tradeoff between (1) identifying more waters that may be SA-like and (2) maintaining confidence when the model flags a water as SA-like. The threshold that provided the best overall balance was 0.38, which maximized a combined performance measure that rewards both “finding SA-like waters” and “being correct when calling SA-like.” At this cutoff, the model identified about 82.8% of true SA observations while remaining correct about 77.6% of the time when it labeled an observation as SA-like (overall balance score = 0.80). Together, these results show the model learned meaningful, repeatable differences in environmental conditions, along with differences in monitoring patterns, that have historically aligned with SA versus SB classifications in the statewide data. Importantly, the 0.38 cutoff was selected using only historical statewide data and was fixed before applying the model to the independent Chandler Bay Kingfish dataset, so the Chandler Bay evaluation reflects a fair comparison rather than a threshold tuned to the case study.

To understand what the model relied on most when distinguishing historically designated SA waters from SB waters, we calculated “relative importance” for each input by measuring how much model predictions worsened when that input was randomly shuffled. For ease of comparison, we scaled these values so the most influential input equals 100, using the formula 100 × importance(variable) / max(importance) (Figure 2). The results show that water-quality measurements themselves did matter. However, the strongest drivers of the SA vs SB distinction were not the measured values alone, but whether certain parameters were measured at all (for example, whether dissolved oxygen or enterococcus were included in a given record). In the importance rankings, the “measured/not measured” indicators (especially DO measured and enterococcus measured) were more influential than any single water-quality value (Figure 2), meaning the model partly learned differences in monitoring patterns between the datasets historically associated with SA and SB. Because these measurement-pattern variables can reflect how monitoring is conducted, not just environmental conditions, we treated this as an important caution for interpretation and ran a separate “chemistry-only” sensitivity check to confirm that Chandler Bay’s conclusions were not dependent on monitoring-pattern signals.

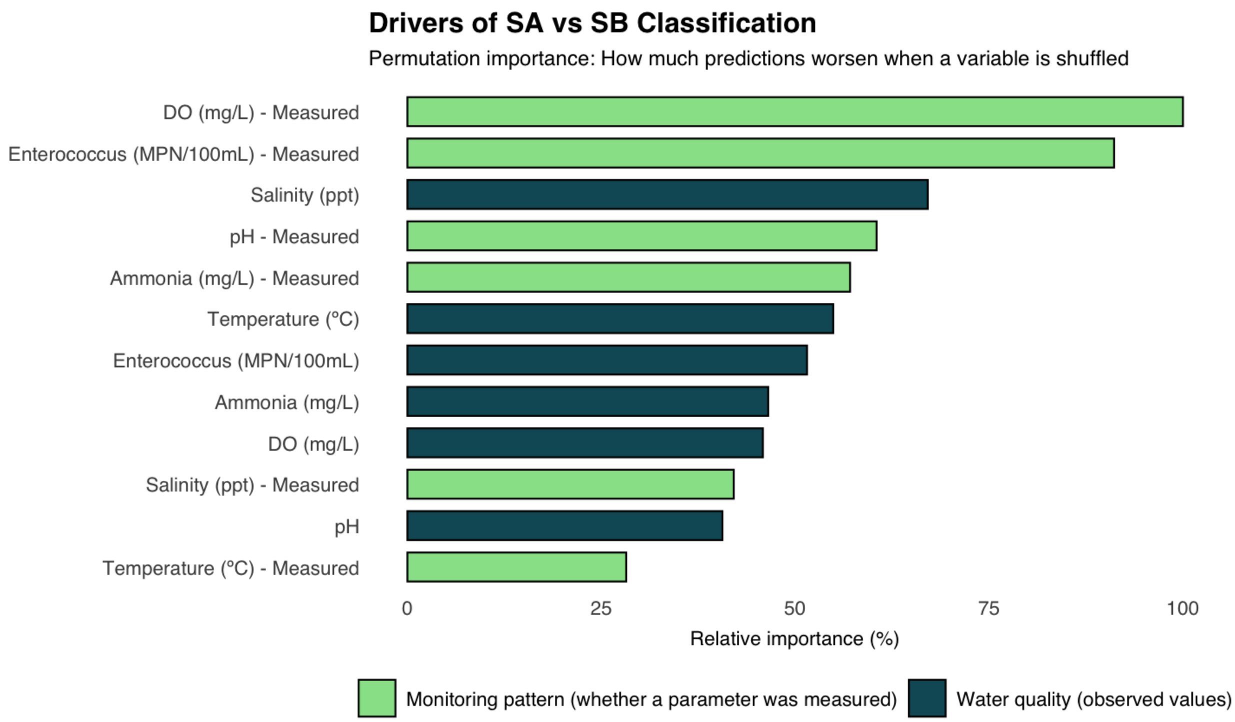

Figure 2. Relative importance of model inputs used to distinguish historically designated SA versus SB waters. Bays show permutation importance, defined as how much the model's predictions worsened when each input was randomly shuffled. Importance values are scaled so the most influential input equals 100% (relative importance = 100 × importance(variable) / max(importance)). Dark green bars represent measured water-quality values, while light green bars represent monitoring-pattern indicators (whether a parameter was measured or not).

To ensure that model results were not driven primarily by differences in monitoring practices across agencies, an additional random forest model was fit using only measured environmental values and excluding all indicator variables that reflected whether a parameter was recorded. This sensitivity analysis tested whether classification performance depended on patterns of data availability rather than underlying environmental conditions. Model performance under this restricted specification remained strong and yielded a similar separation between SA and SB waters. Variable importance rankings continued to emphasize dissolved oxygen, microbial indicators, salinity, pH, and nitrogen-related parameters.

Applying Models to Chandler Bay Data

When the trained model was applied to the Chandler Bay monitoring dataset, Chandler Bay observations consistently aligned more closely with the statewide pattern typical of historically designated SA waters than SB waters (Figure 3, Figure 4). Using the pre-selected cutoff of 0.38, 155 out of 156 Chandler Bay observations were classified as SA-like. The predicted SA-likeness scores for Chandler Bay were generally high (median 0.83; mean 0.80). In contrast, the model scores for statewide historical waters showed lower predicted SA-likeness values for SB and intermediate-to-high values for SA (historical SA test-set median 0.71; historical SB test-set median 0.28), with Chandler Bay's median score exceeding both and sitting well above the typical SA level. Consistent with this finding, about 80% of Chandler Bay observations had scores higher than the median score of historical SA observations, indicating that most Chandler Bay samples were not only SA-like, but often more SA-like than the “typical” SA observation in the statewide comparison set.

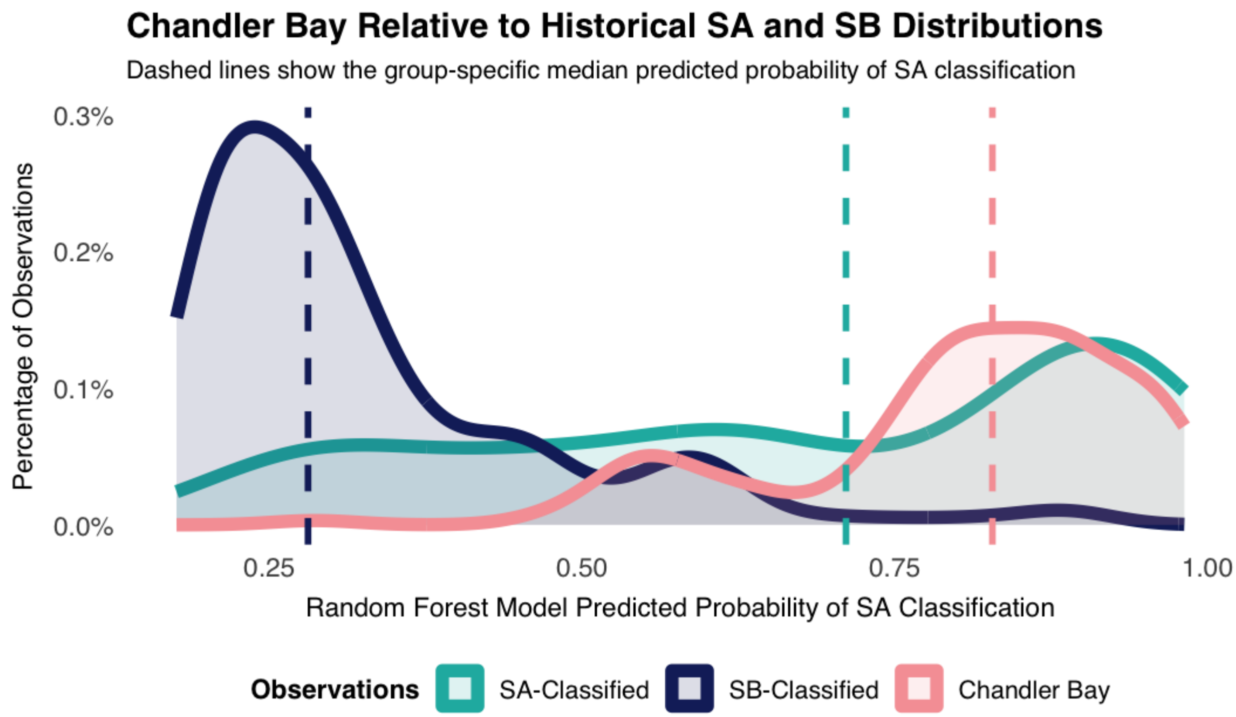

Figure 3. Frequency of model scores for waters designated SB, SA, and the observed data from Chandler Bay. Although there was a large range in model scores for waters classified SB, the median model score was 0.28. For waters designated SA, the median model score was 0.71, indicating that the model demonstrates skill in determining between SA and SB waters based on the provided parameters. The median model score for the Chandler Bay data is 0.83, which is above the SA average.

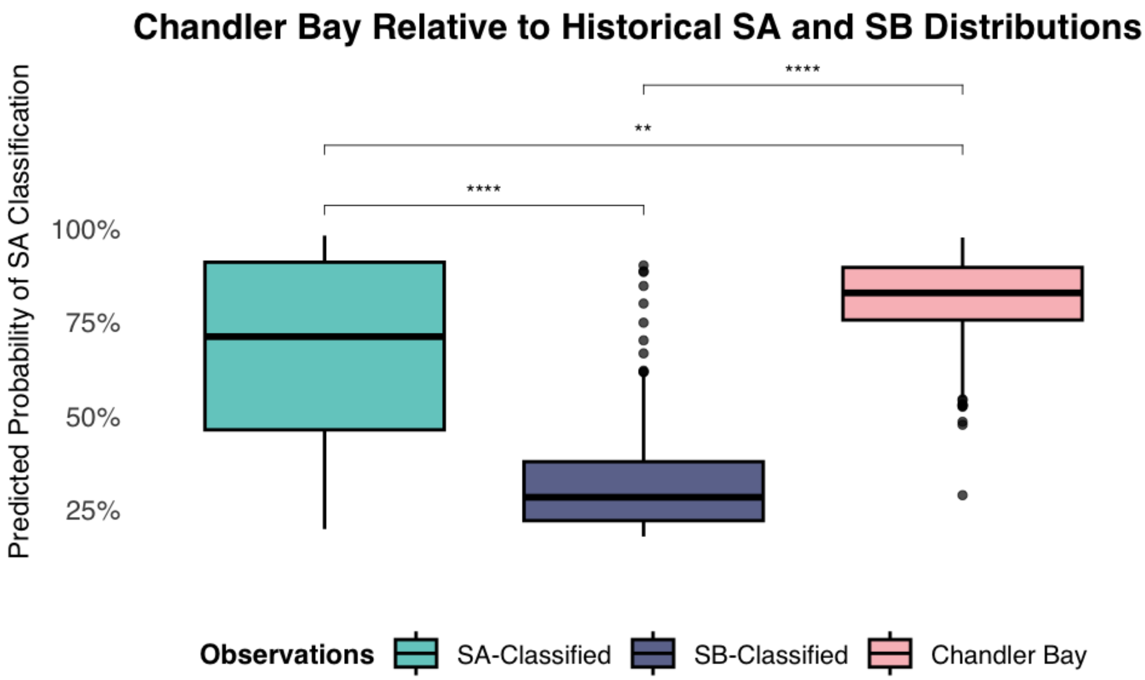

Figure 4. Distribution of the random forest's predicted probability that an observation is SA-like for three groups: historically SA-classified waters, historically SB-classified waters, and Chandler Bay. Higher values indicate conditions more similar to historically designated SA waters. The center of each box represents the group-specific median predicted probability of SA classification. Brackets indicate pairwise statistical comparisons of the three groups using a Dunn's test with Bonferroni adjustment for multiple comparisons. Asterisks represent the adjusted significance level.

Because statewide datasets can differ in how often parameters are measured, we also ran a sensitivity check that removed the "measured/not measured" indicator variables and relied only on the actual water-quality values (i.e., chemistry-only model; Figure 5). Under this chemistry-only approach, Chandler Bay still aligned more closely with historical SA conditions (median 0.80; mean 0.79). However, removing the monitoring indicators reduced the strength of the original signal: the proportion of Chandler Bay observations exceeding the historical SA median declined from roughly 80% to roughly 60%. This change does not mean Chandler Bay appears SB-like, and it does not mean the model result was artificial. Instead, it indicates that the original 80% finding reflected two components—measured environmental conditions and differences in monitoring structure—and that monitoring patterns modestly amplified the separation between SA and SB learned from the statewide data. Even after removing monitoring structure, the majority of Chandler Bay observations still fell above the typical historical SA level, indicating that Chandler Bay's SA-like result is primarily driven by measured environmental conditions, with monitoring patterns providing a secondary reinforcement rather than creating the conclusion.

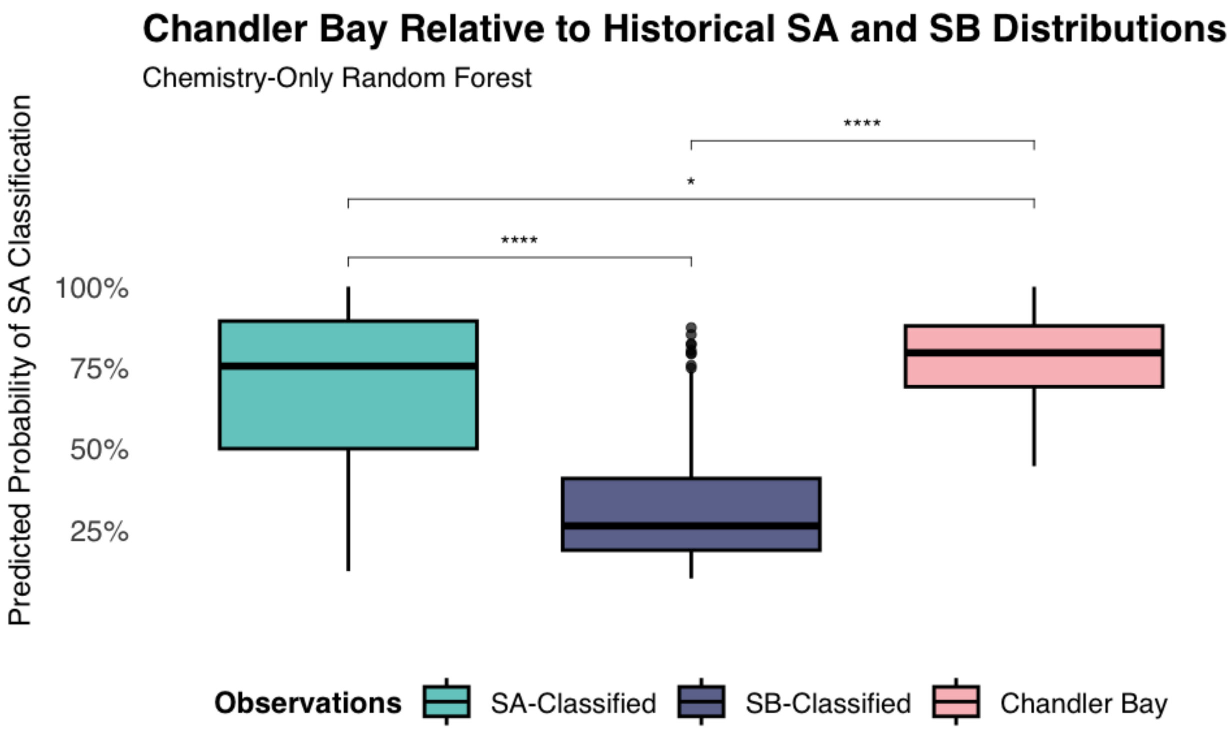

Figure 5. Boxplots show the chemistry-only random forest model's predicted probability that an observation is SA-like when the model is trained and applied using only measured water-quality values (i.e., excluding variables that indicate whether a parameter was measured). Higher values indicate conditions more similar to historically designated SA waters. The center of each box represents the group-specific median predicted probability of SA classification. Brackets indicate pairwise statistical comparisons of the three groups using a Dunn's test with Bonferroni adjustment for multiple comparisons. Asterisks represent the adjusted significance level.

Management Implications

The modeling framework presented in this report is designed to support, not replace, Maine's statutory marine classification process. Marine classifications are legal designations set by statute (38 M.R.S. §§ 464, 465-B), and they reflect a combination of environmental conditions, historical decisions, socioeconomic considerations, management priorities, and policy objectives. Because of this, it is neither expected nor appropriate for a statistical model based on water quality alone to exactly reproduce official classifications. What water quality data *can* do, however, is help answer a practical and policy-relevant question, "do conditions we are measuring in the water actually match what the given classification is meant to represent?" By being able to place individual waterbodies within a statewide environmental context, this analysis provides an objective way to evaluate whether observed conditions are more consistent with higher-quality (class SA) waters or with class SB waters.

Importantly, this analysis does *not* change or assign classifications. The random forest model does not "upgrade" or "downgrade" any waterbody and does not make regulatory decisions. Instead, it evaluates how similar a set of measured environmental conditions is to those typically found in SA waters versus

SB waters. When model results differ from official classifications, that difference reflects patterns in the data, not a change in legal status. From a management perspective, this distinction matters. Maine's antidegradation policy (38 M.R.S. § 464(4)(F)) requires the State to identify and protect waters whose actual quality exceeds the minimum standards of their assigned classification. That responsibility depends on being able to recognize when higher-quality conditions are present in the first place. This study shows that, when water quality data are evaluated in a statewide context, it is possible to identify consistent and repeatable environmental patterns that distinguish higher-quality waters from those under greater stress.

The analysis also identifies which water quality measurements are most useful for distinguishing higher-quality waters from those under greater stress. Dissolved oxygen and microbial indicators, parameters already central to regulatory decision-making, were among the strongest predictors in the model. In addition, pH and ammonia consistently emerged as important indicators of overall environmental condition. Although ammonia is not commonly highlighted in marine classification discussions, its influence in the model likely reflects its role as a signal of nutrient inputs, organic enrichment, and biological stress. Considered together, pH and ammonia capture broader water quality conditions that help differentiate higher-quality systems from those experiencing greater anthropogenic influence. While these variables are not currently emphasized to the same extent as dissolved oxygen or bacterial indicators in marine classification determinations (38 M.R.S. § 456-B), their strong and consistent statistical signal suggests that they should be considered important supporting variables when evaluating whether observed conditions align with assigned classifications.

A key finding of this study is that monitoring practices themselves influence how clearly higher-quality waters can be identified. The initial statewide dataset included more than 26,000 observations, but many of those records (90.7%) contained only temperature and salinity measurements. Because temperature and salinity alone do not determine marine classification, those observations could not meaningfully inform the SA–SB distinction and were excluded from the final analysis. As a result, fewer than 2,500 observations ultimately contained at least one additional classification-relevant water quality parameter. This highlights a practical limitation of current monitoring programs: when key parameters are not measured consistently, the ability to detect higher-quality conditions is reduced.

The chemistry-only analysis further showed that differences in monitoring intensity can amplify, but do not create, signals of higher water quality. Even when all monitoring-structure information was removed, Chandler Bay still aligned more closely with historically SA waters based on measured chemistry alone. This finding underscores that environmental signals are real, while also emphasizing that inconsistent monitoring makes those signals harder to detect.

From a management standpoint, these results point to a clear opportunity for improvement. More consistent documentation and standardized labeling of water quality measurements across agencies would greatly expand the usefulness of existing data. Improved consistency would facilitate the inclusion of additional water quality variables (such as chlorophyll, phosphorus, light availability, and total nitrogen) into future versions of the model. These variables are known to be ecologically important but are currently difficult to integrate due to inconsistencies in how agencies label, record, and document their water quality measurements. Standardizing how data are collected, labeled, and archived would also allow additional datasets and monitoring programs to be incorporated into the model. Expanding the range of comparable data sources would increase sample size, improve model accuracy, and strengthen the State's ability to detect and protect higher-quality waters. In this way, better data consistency directly translates into better management tools.

Overall, the modeling framework presented here is best viewed as a screening and prioritization tool. It can help identify locations where observed conditions appear inconsistent with assigned classifications and where additional monitoring, review, or regulatory attention may be warranted. Used alongside professional judgment and statutory procedures, this approach can strengthen the factual foundation of marine classification review and improve implementation of Maine's antidegradation policy as coastal uses and environmental pressures continue to evolve.

Data Limitations

The datasets used in this study did not include complete or consistent measurements across all coastal Maine waters. Monitoring coverage varied substantially across agencies, locations, and time periods. Salinity (missing from 2.7% of observations) and temperature (missing from 3.4%) were measured consistently across nearly all records, whereas dissolved oxygen was missing from about 96.5% of observations, enterococcus was missing from 94.2%, pH was missing from 97.8%, and ammonia was missing from 98.5%. In fact, no observation ever recorded all five of our core variables. After removing observations that only recorded salinity and/or temperature and all SC classified waters, approximately 61.8%, 37.4%, 75.7%, and 84.1% of observations were missing DO, enterococcus, pH, and ammonia readings, respectively. This uneven data availability is particularly important because dissolved oxygen and enterococcus are currently the top predictors associated with regulatory decisions.

Rather than filling missing values with artificial estimates, this analysis retained data gaps transparently and explicitly accounted for whether variables were measured. This approach avoids introducing assumptions into the dataset and ensures that model outputs reflect real-world monitoring constraints. However, it also means that uneven sampling directly influences model performance. As monitoring programs expand and more uniform measurements become available, our random forest model is expected to become increasingly effective tools for identifying trends, flagging potential inconsistencies, and evaluating longer-term dynamics relevant to marine classification review.

Future Considerations

Maine's statutory framework already provides mechanisms to maintain and protect high-quality waters. The effectiveness of that framework depends in part on whether marine classifications accurately reflect current environmental conditions. As coastal uses expand (e.g., expansion of the aquaculture industry in

Maine (e.g,[13]) and monitoring technologies improve, integrating modern analytical tools into classification review can help ensure that Maine's coastal waters receive the full level of protection provided under Maine's statutory framework.

We also want to emphasize that this report does not oppose aquaculture development or other coastal economic activity. Rather, it emphasizes that accurate, data-informed classification supports regulatory clarity, environmental stewardship, and long-term sustainability. By aligning marine classifications with observed environmental conditions, Maine can strengthen implementation of its existing statutory protections and preserve the ecological and economic value of its coastal waters for future generations.

[13] Frenchman Bay United, "DEP Triennial Review of Maine's Water Quality Standards- 2024 -2026 Written Testimony, Henry Sharpe, President, Frenchman Bay United," Maine DEP Triennial Review Proposal, 2024.