I See No Ships, Probably:

Chance of Contact in the Trafalgar Campaign of 1805

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Abstract

In summer 1805 Lord Nelson pursued the Combined Fleet of France and Spain under Villeneuve across the Atlantic and back. On the return passage he steered a southerly course for the Mediterranean rather than the northerly course taken by Villeneuve, and naval history has treated this as a near-miss recovered by the dispatch of a messenger ship to Plymouth. The campaign has been refought on paper for two centuries, with naval historians asking whether Nelson's judgement, the speed of his squadron, or the winds were what made the outcome. We decompose three potential drivers: the information available to Nelson, the quality of his fleet, and the weather he encountered. We estimate a speed function for British warships from logbook data and use it to simulate the return chase under varying weather. A 2×3 design varies Nelson's route choice against the quality of his squadron, spanning the rest of the British fleet, the chase squadron, and a fast counterfactual in which every chase ship performs like Belle Isle, the best-performing ship of the line in the squadron. Villeneuve's track is held fixed throughout. Weather in 1805 sat inside the climatological band along both routes and contributed little to the outcome. Fleet quality moves arrival times by a day or two and contact rates by five to seven percentage points. Route choice swings the probability of timely engagement with Villeneuve from 6 per cent on the southern route to 86 per cent on the northern route. The campaign therefore turned on the information Nelson lacked about Villeneuve's destination rather than on the weather or the quality of his ships.

Keywords: Naval history, cliometrics, counterfactual analysis, CLIWOC, age of sail, decision under uncertainty

JEL Codes: N43, N73, C15

1 Introduction

The Battle of Trafalgar on 21 October 1805 destroyed the Combined Fleet of France and Spain, secured British naval supremacy for a century, and is widely regarded as a hinge of European history. Less remembered is the four-month pursuit that preceded it. In May 1805 Lord Nelson chased the Combined Fleet of the French and Spanish, commanded by Vice-Admiral Pierre-Charles Villeneuve, from the Mediterranean to the Caribbean and back, twice nearly catching him at sea. On the return crossing in July, Nelson steered south for Gibraltar, expecting Villeneuve to make for the Mediterranean while Villeneuve was in fact steering north for Ferrol on the northwest coast of Spain. The two fleets crossed the Atlantic without sighting each other. Villeneuve was eventually intercepted off Cape Finisterre by Vice-Admiral Calder on 22 July in an indecisive action. The campaign culminated three months later off Cape Trafalgar.

The missed contact in the Atlantic and Calder's indecisive action are the two events most often singled out as having shaped what followed. Naval-historical accounts treat Nelson's southerly turn as a strategic error narrowly recovered by the dispatch of *Curieux*, a brig-sloop that carried word of Villeneuve's return to the Admiralty in time for Calder to be redirected [Corbett, 1910]. On this reading the campaign that culminated at Trafalgar was a near-miss saved by the speed of a single message. Whether a different choice, a faster fleet, or different weather would have produced a different outcome is the question the documentary record cannot answer.

We investigate three forces that could have shaped the outcome of the campaign: the information available to Nelson when he chose his route home, the quality of the fleet he commanded, and the weather he encountered along the way. The historical record fixes one realisation of each and cannot say which of them was binding. We decompose the contribution of each driver by combining a speed function for British warships, estimated from logbook data, with a Monte Carlo simulation of the return chase under varying weather. A 2×3 design varies Nelson's route choice against the quality of his squadron across three

levels: the rest of the British fleet, Nelson's chase squadron, and a fast counterfactual that applies the measured performance of HMS Belle Isle, the best-performing chase-squadron ship of the line, to every ship in the squadron. Weather is drawn from the historical climatology along each route. Villeneuve's track is held at his historical positions throughout. The design isolates the contributions of information, fleet quality, and weather. The headline result is that weather and fleet quality each move the outcome only at the margin, and that the route Nelson chose was the only axis along which a different decision would have produced a different outcome.

Three strands of prior work lead into this paper. The first is the Climatological Database for the World's Oceans (CLIWOC), which digitised 287,114 daily logbook observations from warships and merchantmen of eight national fleets between 1750 and 1855 [García-Herrera et al., 2005]. CLIWOC contains daily observations of position, course, wind force, and wind direction, and includes records from five ships of Nelson's chase squadron during the 1805 pursuit. The second is the cliometric literature on age-of-sail shipping productivity, which has used logbook and voyage-time data to estimate ship speed functions and document long-run productivity gains [Kelly and Ó Gráda, 2019].[1] Cliometric work in this tradition has focused on commercial shipping rather than our naval-pursuit problem. The third is the recent application of historical climate data to simulating sailing routes. Litvine et al. [2024] build a least-cost-path model of European coastal shipping using twentieth-century reanalysis data, validated against CLIWOC, and recover the dominant historical shipping corridors. Alberti [2017] and Perttola [2021] apply similar methods to ancient Mediterranean and East Asian routes. We share the methodological approach but apply it to a pursuit rather than a routing problem, and use CLIWOC observations directly as the climate input rather than modern reanalysis.

The naval-historical literature on the Trafalgar campaign is dominated by the early-

[1]Related contributions include Rönnbäck [2012] on transatlantic slave-ship speeds, Solar [2013] on East India Company voyage times, and Solar and Rönnbäck [2015] on the productivity gains from copper hull sheathing. Bogart et al. [2021] extend the analysis to coastal shipping.

twentieth-century reconstructions [Corbett, 1910, Fraser, 1906, Newbolt, 1905, Stevens and Westcott, 1920], with modern accounts in Schom [1990] and Adkins [2004]. These reconstructions agree on the broad outlines of the chase but differ on Nelson's reasoning and on whether the southerly turn was a strategic error or the best available decision. Resolving the question requires knowing what would have happened had Nelson chosen differently, which the documentary record cannot supply. The simulation framework we use here builds on the tradition of mathematical search theory developed by Koopman [1980] and Stone [1975] for naval applications, applied to a counterfactual that the documentary literature has been unable to settle.

This paper makes three contributions. First, we estimate a formal speed function for British ships of the line on CLIWOC observations from the Napoleonic period, with separate parameters for Nelson's chase squadron and the rest of the British fleet. The chase squadron is faster than the British average on running and broad-reach points of sail by around four to seven per cent, with no premium on close-hauled or head-wind passages. The pattern is more consistent with command quality than with hardware. Second, we use the speed function to decompose the 1805 outcome into the contributions of route, fleet quality, and weather. Route choice dominates. Under the historically realised chase-squadron fleet quality, taking the northern route would have produced contact with Villeneuve in around 80 per cent of simulations, while the southern route produces an actionable Gibraltar arrival in only 1.6 per cent. Fleet quality and weather each move outcomes only at the margin. Third, we revisit the standard naval-historical reading of the campaign. The simulation does not support the near-miss interpretation. The route Nelson took was meteorologically favourable and consistent with his standing orders to defend the Mediterranean, and the alternative route would have produced contact only with information he did not have when he left Antigua. The binding constraint was information rather than the speed of the messenger ship that later recovered the outcome. The decisive instrument of the chase was the dispatch system rather than the fleet it served.

The remainder of the paper is organised as follows. Section 2 introduces the navigational and meteorological concepts the analysis relies on. Section 3 narrates the 1805 chase and identifies the counterfactual questions we answer. Section 4 sets out the speed function, the Monte Carlo simulator, and the 2×3 counterfactual design. Section 5 reports the empirical results: the speed function and the chase-squadron premium, the wind field along each route, the southern-route arrival distribution, the northern-route contact rate, and the joint decomposition. Section 6 concludes.

2 Nautical Background

This section introduces the navigational and meteorological concepts the rest of the paper relies on. Readers familiar with age-of-sail naval practice may proceed to Section 3.

Positions at sea are reported in latitude and longitude. Latitude measures the north-south position relative to the equator and longitude the east-west position relative to Greenwich. Distances are reported in nautical miles (nm). One nm equals one minute of latitude, or 1.852 km. Daily distance covered by a sailing warship of this period is around 60 to 100 nm.

How far a ship travels in a day depends not only on wind strength but also on wind direction relative to the ship. The relationship matters so much to sailing that each direction is given a specific name, a point of sail, shown in Figure 1. The five categories used by CLIWOC and by this paper are head wind, close-hauled, beam reach, broad reach, and running. Square-rigged ships of the line in 1805 were best suited to sailing across the wind or with it from astern, so on a beam reach, broad reach, or running. They could make almost no progress directly into the wind.

In the North Atlantic at the time of the chase the wind pattern was strongly stratified by latitude. From the equator through the trade-wind belt to about 30°N, the wind blew reliably from east to west. Around 30 to 40°N, near the centre of the Azores high, winds were light and variable. Further north, in mid-latitudes above about 40°N, prevailing westerlies

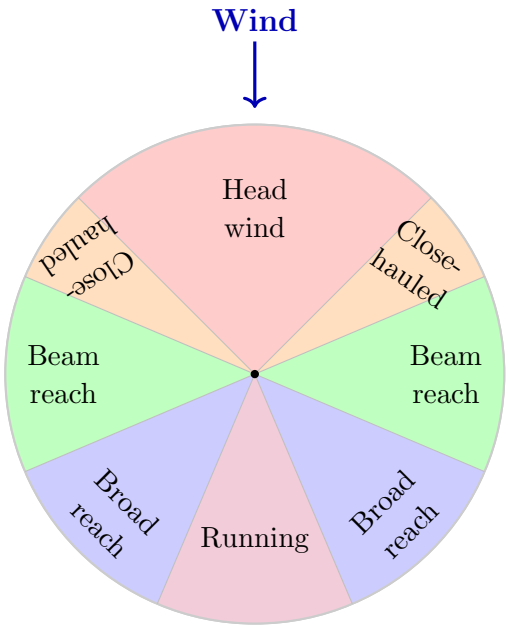

Figure 1: Points of Sail Relative to Wind Direction

Note: Categories follow CLIWOC convention. The wind blows from the top of the figure. Speeds rise from head wind, where a square-rigged ship makes no progress under sail, through close-hauled, beam reach and broad reach, peaking at running before steering control degrades. Section 4.2 estimates the speed-wind slope separately within each category.

blew from west to east. A westbound passage was therefore easiest at low latitudes and an eastbound passage easiest above the Azores high. Nelson's southerly return track ran through the trades. Villeneuve's more northerly track passed through the variable belt before reaching the westerlies.

Warships travelled together in squadrons. Each squadron was under the command of an admiral, and each ship within it under a captain. Ship classes had different roles. Ships of the line, two- or three-decked vessels of 64 to 120 guns, were reserved mainly for fighting in line of battle. Frigates and sloops, smaller single-decked vessels of 12 to 44 guns, carried out scouting, communications, supply and other auxiliary tasks. A squadron travels at the speed of its slowest ship in order to keep formation, so the speed function in this paper is estimated over ships of the line, the class that sets the pace of any squadron containing them. Two smaller ships nonetheless feature later as critical information vectors. The *Curieux*, a 16-gun brig-sloop, carried Captain Bettesworth's despatch from Antigua to the Admiralty.

The *Netley*, a schooner, carried Lieutenant Carr's report of the Antigua convoy capture back to Nelson.

3 The Chase

Britain entered the Napoleonic Wars with a strategy of naval containment. The Royal Navy maintained continuous blockades of the major French and Spanish ports, with the goal of keeping enemy fleets bottled up and preventing them combining for an invasion of Britain. By 1805 Lord Nelson commanded the Mediterranean blockade, watching the French Vice-Admiral Villeneuve at Toulon. In March of that year Villeneuve slipped out of port, joined Admiral Gravina's Spanish squadron at Cadiz, and disappeared into the Atlantic. Nelson searched the Mediterranean for weeks before concluding, on instinct as much as evidence, that the now Combined Fleet had crossed to the West Indies. The West Indies were the most valuable colonial possessions Britain held, since sugar revenues funded much of the war effort and a French descent on the islands was a standing nightmare of the Admiralty. Nelson sailed in pursuit on 11 May 1805 with eleven ships of the line.

What followed was one of the most remarkable pursuits in naval history. Two squadrons crossed the Atlantic, hunted each other through the Caribbean, and recrossed within four months, at times separated by only days. Villeneuve reached Martinique in mid-May and Nelson reached Barbados on 4 June. By the time Nelson worked north to Antigua, Villeneuve had already turned for Europe, sailing on 11 June, six days before Nelson followed on 17 June.

The two fleets remained relatively close in the early stages of the return crossing. Nelson took the southern trade-wind route home, fast and reliable in summer, while Villeneuve took the more northerly track to combine with another Spanish squadron at Ferrol on the northwest coast of Spain. Nelson made faster time and gradually narrowed the distance. But the fleets were closing geographically and diverging strategically. Nelson had become

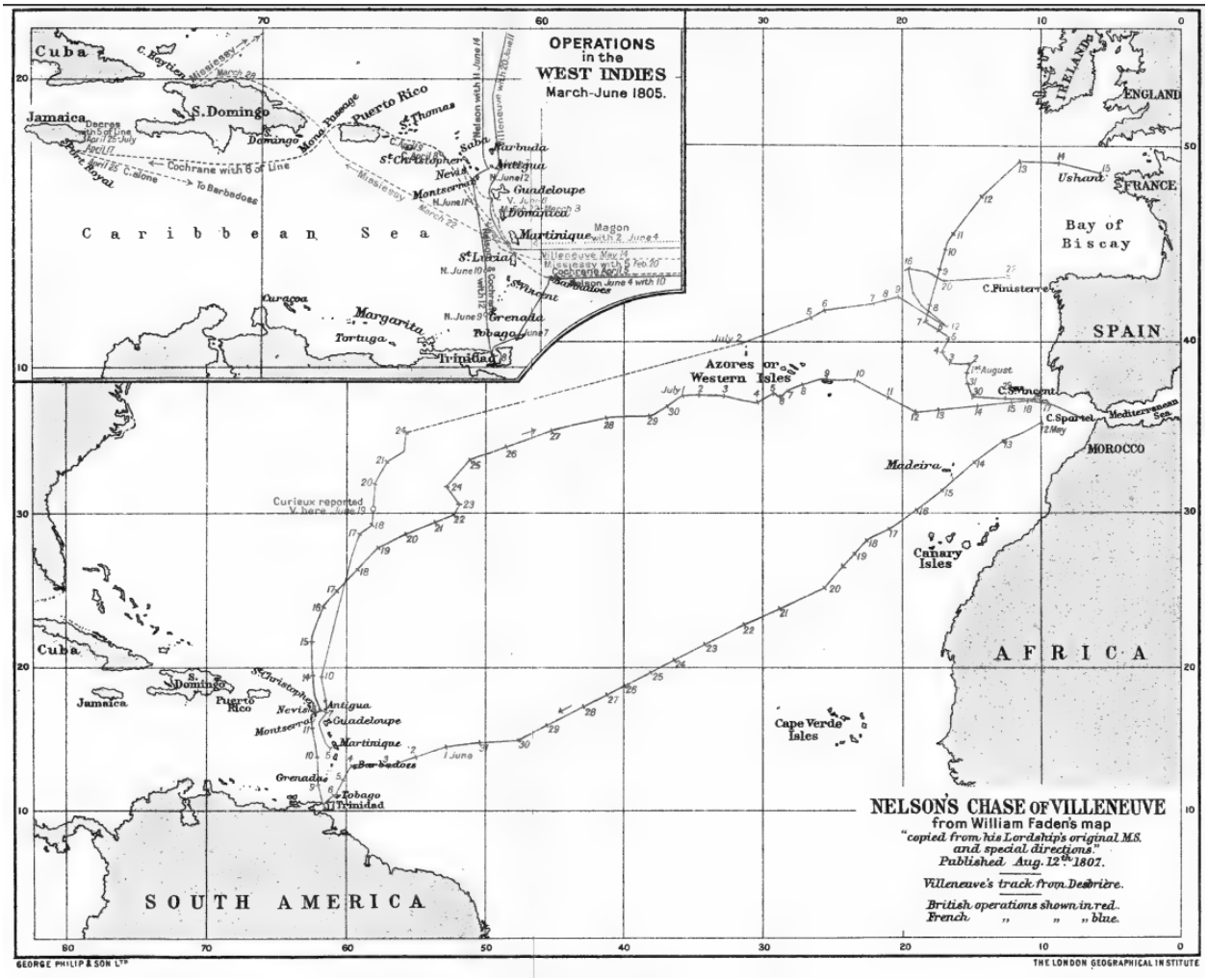

Figure 2: The 1805 Chase: Nelson and Villeneuve Across the Atlantic

Source: Corbett (1910).

convinced that Villeneuve was returning to the Mediterranean and was steering for Gibraltar, while Villeneuve was making for the northwest coast of Spain.

Nelson reached Gibraltar on 20 July, two days before Villeneuve was intercepted off Cape Finisterre by a smaller British squadron under Vice-Admiral Calder. Calder's action on 22 July was indecisive. Villeneuve sustained damage but escaped to Vigo, then to Cadiz, where he and Gravina were eventually brought to action by Nelson at Trafalgar on 21 October. Trafalgar destroyed the Combined Fleet, secured British naval supremacy for a century, and cost Nelson his life. It marked the strategic turning point of the naval war and is widely regarded as a hinge of European history.

The pursuit phase raises questions our model is built to answer. First, could Nelson have arrived in Europe earlier under more favourable weather and joined Calder for a decisive engagement in late July? Second, how much of his closing on Villeneuve in the Atlantic was due to the quality of the British squadron, and how much was simply the structural advantage of a faster route? Third, what if Nelson had received better intelligence in the West Indies and correctly anticipated that Villeneuve was bound for northern Spain rather than the Mediterranean: could he then have closed for an engagement in the open Atlantic, before Calder's indecisive action and the long road to Trafalgar? The remainder of the paper formalises these counterfactuals and answers them with a Monte Carlo simulation calibrated to the 1805 wind field.

4 Analytical Approach

This section sets out the analytical approach we use to answer the three questions raised at the end of Section 3. We estimate a speed function for sailing warships from logbook data, then drive a Monte Carlo simulation of the chase under varying weather realisations. A 2×3 grid of counterfactual scenarios decomposes the contributions of route choice, fleet quality, and weather to the realised 1805 outcomes.

4.1 Data Sources

Our primary data source is the Climatological Database for the World's Oceans (CLIWOC), a digitisation of 287,114 daily logbook observations from warships and merchantmen of eight national fleets between 1750 and 1855 [García-Herrera et al., 2005]. Each record contains a daily ship position in latitude and longitude, the ship's course, and observed wind force and direction, which allows us to reconstruct routes, speeds and weather along passages of interest. Wind force (referred to as W) is reported in tenths of a metre per second, scaled to the midpoints of Beaufort categories. The British, Dutch, French and Spanish fleets that fought the Napoleonic Wars are all represented, although coverage varies.

CLIWOC contains daily observations from five ships of Nelson's pursuit squadron during the chase: *Amazon*, *Belleisle*, *Conqueror*, *Decade*, and *Swiftsure*. This subset gives us roughly three hundred daily observations of the squadron's position, course and wind environment between March and August 1805, and forms the empirical basis for the chase-squadron speed function. The remainder of the British Mediterranean and Channel fleets are also represented in CLIWOC across the broader 1800–1810 window, which we use to estimate a baseline speed function for British ships of the line. The French fleet is largely absent because most French naval records of this period were destroyed in the nineteenth century.

For Villeneuve's track we rely on Sir Julian Corbett's *Campaign of Trafalgar* [Corbett, 1910], which reconstructed the chase from surviving French despatches, British logbooks, and Spanish records. We hand-digitised Corbett's published track maps in QGIS and validated the digitisation by comparing his daily positions for Nelson's fleet against the CLIWOC chase-squadron centroid. The two agree closely during the convoy phase of the chase from May to mid-June 1805, with a median daily disagreement of just 61 nm. Larger disagreements after 22 June reflect Nelson's documented dispersal of the squadron into a search formation, in which individual ships covered separate sectors of ocean and the centroid no longer corresponds to a single fleet position. Figure 10 reports the daily comparison and full source-reconciliation results are in Appendix B. With Corbett's British track positively vali-

dated against logbook evidence, we rely on his reconstruction for Villeneuve's daily position.

4.2 Speed Function

Our first analytical task is to estimate how fast a sailing warship covered ground under given conditions. We fit a speed function for British ships of the line on CLIWOC observations from 1800 to 1810, regressing daily distance covered (nm/day) on wind force interacted with point of sail, with ship fixed effects:

$$\text{daily_speed}_{it} = \alpha_i + \sum_p \left(\beta_p \cdot \mathbf{1}\{\text{pos}_{it} = p\} + \gamma_p \cdot W_{it} \cdot \mathbf{1}\{\text{pos}_{it} = p\}\right) + \varepsilon_{it} \tag{1}$$

where α_i are ship fixed effects, W_{it} is wind force, pos_{it} is point of sail in one of the five categories defined in Section 2, and the slope γ_p is allowed to vary by point of sail. The pooled sample has 12,819 daily observations across the British fleet. Ship fixed effects absorb time-invariant differences in design, condition, and crew quality. The residual variance enters the Monte Carlo as a Gaussian noise term, capturing the day-to-day variability that the deterministic part of the function does not explain.

We estimate the function separately for Nelson's chase squadron and the rest of the British fleet, allowing the possibility that Nelson's hand-picked vessels were systematically faster. Within the pooled 1800–1810 sample, 723 daily observations come from the five chase-squadron ships and 12,096 from the rest of the British fleet. Column 2 of Table 2 narrows the chase-squadron series to 1805 observations only, where, after voyage-prep filtering, 192 daily observations remain. As a robustness check, in the appendix we re-estimate the model with Dutch ships included, testing for cross-national differences once ship fixed effects are controlled. Coefficient estimates and goodness-of-fit are reported in Section 5.1.

We hold Villeneuve's track fixed at his historical positions throughout the simulation. The counterfactual question we ask is what different British choices would have produced against the actual French play, not what would have happened in a fully reactive game. This

is a partial-equilibrium framing where we vary Nelson's options and let nature draw weather, while Villeneuve's track is exogenous. Sensitivity to the related choice of contact threshold is reported in Appendix C.

4.3 Monte Carlo Analysis

With the speed function in hand, we simulate Nelson's daily progress under varying weather realisations using a Monte Carlo approach. For each simulated voyage we draw a sequence of daily wind force and direction observations from CLIWOC's historical record at the relevant location and time of year. The drawn weather is translated through the speed function into a daily distance covered, with a Gaussian noise term added at the residual standard deviation, and accumulated to give a daily position. The simulation continues until Nelson reaches Gibraltar on the southern route or until contact with Villeneuve is recorded on the northern route.

Weather draws are taken from CLIWOC observations in the same $5^\circ \times 5^\circ$ cell and same calendar month as each waypoint along the simulated track. Weather observations are pooled across all years and all national fleets to provide the largest possible source of information. This pool contains 8,647 observations across 80 route waypoints, giving a per-waypoint distribution of wind force and direction that is representative of seasonal patterns at the relevant location. Our approach of drawing from the historical record rather than imposing a parametric model preserves the joint distribution of force and direction at each waypoint, which is important in a wind system organised by latitude. Pooling across flags and years is a sample-size choice, and we test the validity of cross-flag pooling in Section 5.1.

Having a detailed weather grid also lets us vary the route by placing new waypoints within our weather observations. Each simulated voyage follows a sequence of waypoints, and switching from the southern route to a northern route simply changes which waypoints the fleet steers towards. Nelson's daily heading is set towards the next waypoint, and the speed function determines how far along the heading the fleet progresses given the day's

wind.

4.4 The 2×3 Counterfactual Design

To identify the relative roles of route choice and fleet quality we run the Monte Carlo simulation over a 2×3 design.

The first dimension is fleet quality which takes three levels. The basic approach here is to draw on different parameters from the speed function. The chase squadron and the rest of the British fleet are given their own intercepts and slopes within the speed function and so the resulting difference captures whatever made Nelson's hand-picked squadron faster than the British average, whether that is better ships, better officers, or better squadron-level coordination. We use "fleet quality" as a deliberately broad label because the empirical approach cannot distinguish them clearly. The third level is a fast counterfactual that asks what would have happened had every ship in the chase squadron performed like Belle Isle, the best-performing chase-squadron ship of the line, with all other chase-squadron speed premia preserved. Belle Isle is the only chase-squadron ship of the line whose measured performance advantage is observable over at least 50 daily observations across at least four points of sail and provides a 95 per cent confidence interval that excludes the British baseline. Selection details and the full performance distribution across the British fleet are reported in Appendix A.

The second dimension is route. We compare the southern route through the trade-wind belt to Gibraltar, which Nelson actually took, against a northern route. The northern route is constructed as a hybrid where we assume that Nelson follows his historical track until 17 June, then continue north along Villeneuve's actual track from that date forward. This represents the counterfactual in which Nelson, having received better intelligence, decided to abandon the run for Gibraltar. We adopt 17 June as the switch date because this is around when historical assessments consider that Nelson's strategic assessment crystallised. Until then he held a broadly northerly heading from Antigua. Corbett's reconstruction places

Nelson's commitment to the southern course around 17 to 20 June, when his belief that Villeneuve was bound for the Mediterranean became settled [Corbett, 1910]. The northern-route counterfactual asks what would have happened had this judgement gone the other way. Sensitivity to the switch date is reported in Appendix C.

A simulated voyage on the northern route counts as a successful contact if Nelson's position comes within 30 nm of Villeneuve's during a single day before 22 July, the date of Calder's historical action. The 30 nm threshold corresponds to a fleet sweeping with frigate scouts and sensitivity to the radius is reported in Appendix C. The 22 July deadline excludes catches that would simply replay Calder's action under a different admiral, and sensitivity to the deadline is also reported.

On the southern route Nelson is transiting rather than chasing and the relevant outcome is whether he can arrive at Gibraltar early enough to refit and redeploy north for Calder's action. We model this as a two-stage journey. After the simulated Atlantic crossing, each southern-route simulation is paired with a follow-on Gibraltar-to-Cape-Finisterre leg. The travel time for this leg is estimated using the same speed function and CLIWOC weather climatology. Two days at Gibraltar are allowed for water and supplies, and arrival at Cape Finisterre at least one day before 22 July is required for the redeployment to be useful. The median Gibraltar-to-Finisterre transit across simulations is six days, giving a deadline of arrival in Gibraltar of 13 July in order to achieve any actionably different outcome. This date is Calder's action minus one day on station, two days in port, and six days passage. Sensitivity to the port days and on-station buffer is reported in Appendix C.

Each cell of the design is run with $N = 1{,}000$ Monte Carlo draws over weather. Table 1 summarises the design.

Overall, the design isolates three sources of variation. Comparing across the two route rows captures the effect of information, since the only thing distinguishing the rows is whether Nelson know about Villeneuve's actual destination. Comparing across the columns captures the fleet-quality effect, since within a row only the speed function changes. The spread of

Table 1: The 2 × 3 Counterfactual Design

	Rest of UK fleet	Chase squadron (Nelson)	Belle Isle (fast)
Southern route (historical)	Pr(arrive by 13 Jul)	Pr(arrive by 13 Jul)	Pr(arrive by 13 Jul)
Northern route	Pr(contact at sea)	Pr(contact at sea)	Pr(contact at sea)

Note: The outcome variable differs by route because Nelson's posture differs by route. On the southern route the question is whether Nelson reaches Gibraltar in time to refit and redeploy north for Calder's action. On the northern route the question is whether he intercepts Villeneuve at sea before 22 July. The decomposition in Section 5.5 reports both metrics jointly.

outcomes within a single cell captures the weather effect. Together these three sources let us decompose the relative contributions of information, fleet quality and weather.

5 Findings

Section 5.1 estimates the speed function and reports the chase-squadron performance differential. Section 5.2 reports the wind field along the chase routes. Sections 5.3 and 5.4 deploy the model on the southern and northern routes respectively, each comparing chase-squadron performance against the rest-of-UK baseline. Section 5.5 reports the joint decomposition.

5.1 The Speed Function

We estimate three specifications of the speed function. These are reported in Table 2: the pooled UK fleet 1800–1810 in column 1, the chase squadron alone in 1805 in column 2, and the pooled fleet with a chase-squadron triple interaction in column 3. All include ship fixed effects. The pooled British specification has $R^2 = 0.30$ and a residual standard deviation of 44.3 nm/day. The chase-squadron-only model lifts to $R^2 = 0.41$ on a much smaller sample. Adding the chase interaction does not move the headline fit. The pooled UK specification is robust to the inclusion of Dutch ships of the line, with cross-flag triple interactions jointly insignificant which we report in Appendix A.

Figure 3 shows the model's predictions against the raw daily observations, with separate lines for the chase squadron and the rest of the British fleet. Three features deserve comment:

Table 2: Speed Function Estimates

	Dependent variable:		
	Daily run (nm/day)		
	UK pooled	Chase 1805	UK with chase int.
	(1)	(2)	(3)
Wind force (W, m/s)	0.185***	0.207	0.196***
	(0.027)	(0.313)	(0.028)
$W\times$ Close-hauled	0.170***	0.626	0.159***
	(0.034)	(0.368)	(0.035)
$W\times$ Beam reach	0.171***	0.519	0.157***
	(0.031)	(0.356)	(0.032)
$W\times$ Broad reach	0.208***	0.503	0.196***
	(0.031)	(0.349)	(0.032)
$W\times$ Running	0.298***	0.614	0.286***
	(0.032)	(0.352)	(0.033)
$W\times$ Close-hauled $\times$ Chase			0.199
			(0.156)
$W\times$ Beam reach $\times$ Chase			0.270
			(0.156)
$W\times$ Broad reach $\times$ Chase			0.242
			(0.142)
$W\times$ Running $\times$ Chase			0.275
			(0.161)
Ship FE	Yes	Yes	Yes
Sample window	1800–1810	1805	1800–1810
Observations	12,819	192	12,819
R^2	0.304	0.406	0.305
Adjusted R^2	0.297	0.362	0.297
Residual Std. Error	44.26	33.05	44.25

Note: Daily distance covered by British ships of the line in CLIWOC, regressed on wind force interacted with point of sail, with ship fixed effects. The reference category for point of sail is head wind. Column 2 estimates the model on Nelson's chase squadron alone in 1805. Column 3 adds a chase-squadron triple interaction to the pooled British specification. The cross-flag robustness check, adding Dutch ships of the line, is reported in Appendix A. Standard errors in parentheses. *p<0.05; **p<0.01; ***p<0.001.

why we expect linearity within each point-of-sail, the ordering of slopes, and the pattern of the premium seen between the chase squadron and the British baseline.

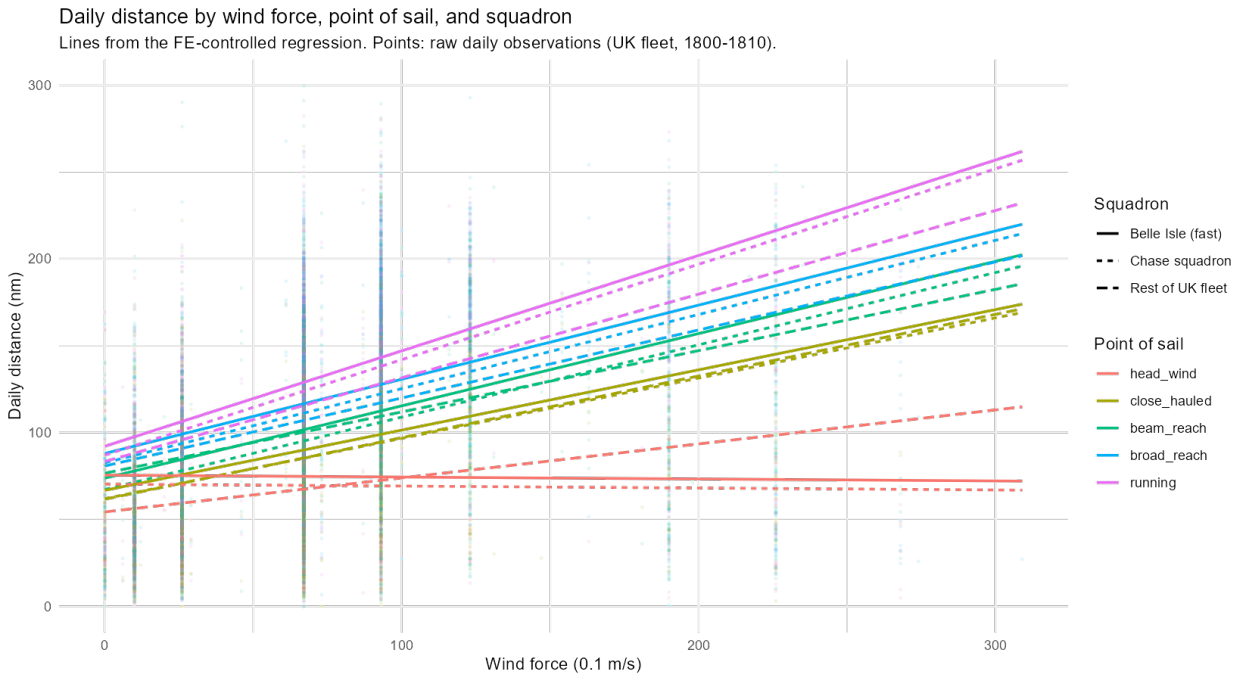

Figure 3: Estimated Speed Function: Daily Run by Wind Force and Point of Sail

Note: Daily runs (nm/day) for British warships in CLIWOC, 1800–1810. Lines drawn from the regression with ship fixed effects (column 3 of Table 2), with intercepts and slopes derived for each (point of sail, squadron) cell by averaging predictions across ships in that group. Points show raw daily observations.

The linearity expected within each point-of-sail is based on first-principles of physics applied to sailing. Aerodynamic force on a sail and hull wave-making resistance both scale roughly with the square of speed, so at equilibrium overall speed scales approximately linearly with wind speed.

The ordering across points of sail follows the expected performance of the square-rigged ships under investigation. Square-rigged ships of the line are most efficient with the wind behind them. In this direction, the square sails present maximum area, and they lose efficiency as the wind draws forward of the beam. The results show that response to wind speed is strongest on running and broad-reach points (where the wind is coming from behind the ship), less responsive on beam reach and close-hauled (where the wind is coming across or

towards the ship), and essentially flat on head winds.

To make the chase-squadron premium concrete in voyage-relevant units, Table 3 reports the model's predicted daily distance at $W = 70$, about 7 m/s which is the modal wind force along the chase routes. Distance is reported separately for the chase squadron and the rest of the British fleet.

Table 3: Predicted Daily Run by Squadron at Reference Wind ($W = 70$, ∼Beaufort 4)

Point of sail	Chase squadron (nm/day)	Rest of UK (nm/day)	Premium
Running	125.4	117.0	+7.2%
Broad reach	112.4	108.1	+4.0%
Beam reach	96.4	101.3	−4.8%
Close-hauled	86.2	86.4	−0.3%
Head wind	69.5	68.0	+2.2%

Note: Predicted daily runs at $W = 70$ from the regression with ship fixed effects in column 3 of Table 2, averaging across ships within each squadron. The chase squadron is Nelson's five hand-picked ships; the rest-of-UK series pools British warships in CLIWOC 1800–1810. The beam-reach row reflects a steeper slope but lower intercept for the chase squadron, with the lines crossing at high wind. The small chase sample ($n = 170$) limits what can be read into a single point.

The chase squadron is faster on the more wind-from-behind points of sail (running and broad reach), by 7 and 4 per cent respectively, and is essentially indistinguishable from the British baseline on close-hauled and head-wind passages.[2] The triple interactions $W \times \text{pos} \times$ chase in column 3 of Table 2 are individually marginal, with $p \approx 0.08$–0.09 on the three reaching cells and all positive. However, the pattern is informative even where the formal test sits at the margin.

Intuitively, if the results showed a uniform speed advantage this would suggest a hardware premium, with better hulls, cleaner copper, and superior provisioning paying off whenever

[2]The beam-reach cell shows a small negative differential at modal wind. This is an artefact of a steeper chase slope crossing a lower intercept, and with only 170 chase observations in that cell we read it as small-sample noise rather than a stable feature. The same caution applies to the head-wind cell, where the chase-squadron slope is slightly negative on $n = 69$ observations.

the ship is moving. The concentration of the premium on wind-aft points is harder to explain based on hardware alone but is more understandable when taking into account command quality. Running and broad reach are the points of sail with most discretion in sail trim, course holding, and squadron coordination. They are the points where a competent commander can drive his ships harder than an average one. Close-hauled and head-wind passages are constrained by the rig itself, and there is little a commander can do to make a ship of the line sail better than comparators. A potential read of the pattern is that it reflects the squadron's command quality rather than just its hardware. Statistically, we cannot separate these channels in the data and we report them together as fleet-quality.

The voyage-scale impact of this differential performance is limited. At the modal wind speed while on the running point of sail, the angle where the differential is largest, the chase squadron makes around 8 nm per day more than the British average. On broad reach the gap is around 4 nm and the other points of sail show essentially no premium. Over a forty-day Atlantic crossing, the cumulative running-point premium is on the order of 320 nm, which is meaningful but not transformative when the residual standard deviation of daily runs is 44 nm. Whether the differential survives or at the voyage scale is what Sections 5.3 and 5.4 test directly.

Beyond the chase-squadron average, the simulator also runs a fast counterfactual at the level of the best-performing chase-squadron ship of the line. Belle Isle's measured performance advantage in column 3 of Table 2 is +10.8 nm/day relative to the regression's reference ship, the highest among reliably-identified British ships of the line in CLIWOC. Of the five chase-squadron ships, three are well-identified at the (ship, point-of-sail) level: Belle Isle with a premium of 10.8 nm/day on $n = 165$, Decade with 8.4 on $n = 192$, and Swiftsure with 3.2 on $n = 166$. Conqueror has only two daily observations and Amazon serves as the reference ship for the chase squadron. Belle Isle was a captured French 74-gun ship, originally *Formidable*, taken at the Glorious First of June in 1794 and refitted into Royal Navy service. Her measured performance is consistent with the common perception at the

time of captured French ships of the line outperforming British-built equivalents, though we make no causal claim about which channel drives the premium. The fast counterfactual asks what would have happened had every ship in the chase squadron performed like Belle Isle, with all chase-squadron slope premia preserved. At modal wind on running the predicted daily run rises to 130.5 nm/day from the chase-squadron 125.4 nm/day, and at modal wind on broad reach it rises to 117.8 from 112.4. Whether even this extended premium changes the historical outcome is the question Sections 5.3 and 5.4 answer.

5.2 North Atlantic Wind Fields, Summer 1805

To know whether the realised outcomes of 1805 were driven by unusual weather, we compare the conditions actually observed in 1805 to long-run climatology along each track. Figure 4 plots wind force at each Corbett waypoint against the climatological 25–75th percentile band assembled from CLIWOC observations over 1750–1855 in the same $5^\circ \times 5^\circ$ cell and calendar month. Figure 5 reports the same data as a wind rose, separately for the two routes.

The wind in 1805 was unremarkable along both tracks. The median wind force across Nelson's southern waypoints was $W = 67$ in 1805, identical to the long-run climatological median. Along Villeneuve's northern track the 1805 observations sat slightly above the climatological median. Most 1805 points fall inside the climatological interquartile band on both routes. Whatever drove the outcomes of the chase, it was not anomalous weather.

Nelson's southern course was a structurally good choice on the meteorological merits, independent of any beliefs about Villeneuve's destination. The southern track sits in the trade-wind belt, where the wind comes mostly from the north and the east. For an east-bound ship that puts the wind on or forward of the beam, which Table 3 showed is workable but not ideal for a square-rigger. What the southern track offers instead is predictability. The wind sits in a narrow arc of directions at a narrow band of forces, and a captain can set sail trim once for the prevailing conditions and run for days without major adjustment. The northern track shows a different pattern. The dominant westerly component delivers

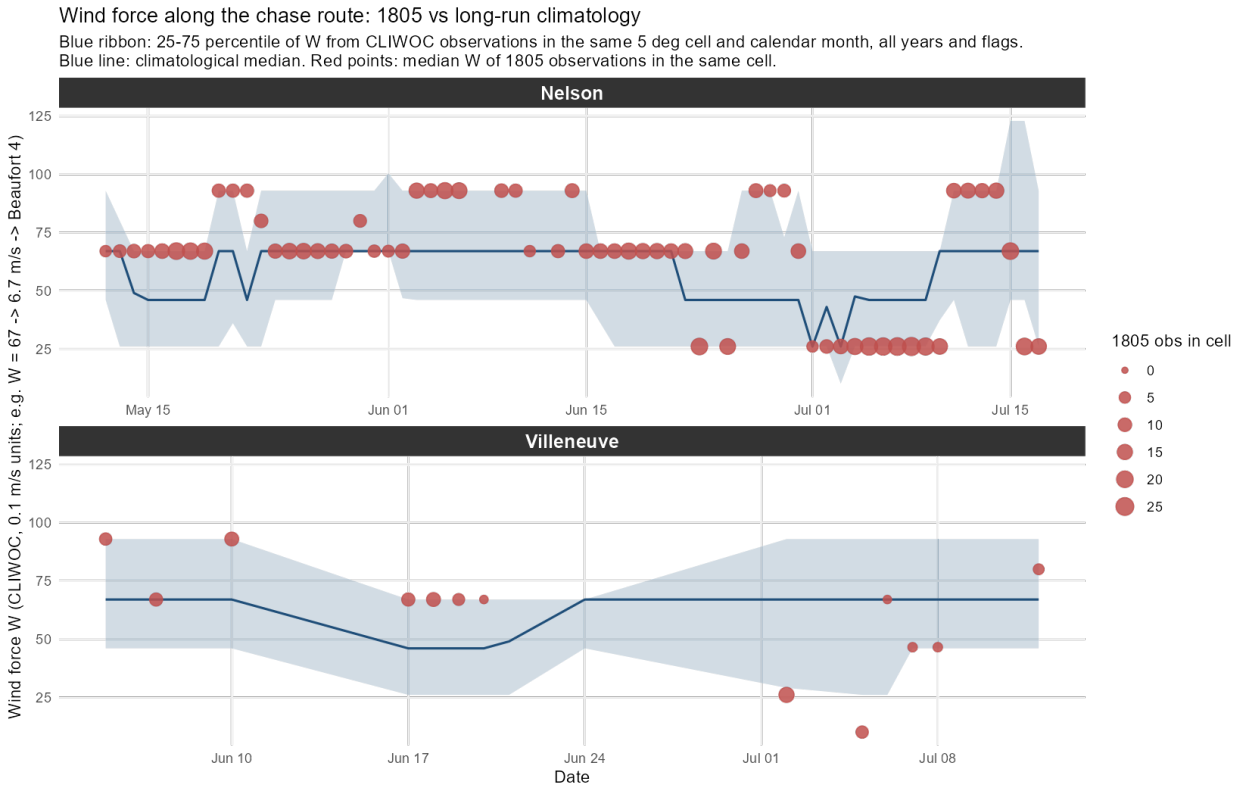

Figure 4: Wind Force along Nelson and Villeneuve Tracks: 1805 versus Climatology

Note: Red points show 1805 wind-force observations at each waypoint along Nelson's southern track and Villeneuve's northern track. Blue line shows the climatological median, blue ribbon the 25–75 percentile, both built from CLIWOC observations in the same $5° \times 5°$ cell and calendar month, all years and flags. Point size scales with the number of 1805 observations in the cell. CLIWOC wind force is in 0.1 m/s units, so W = 67 corresponds to 6.7 m/s, around Beaufort 4.

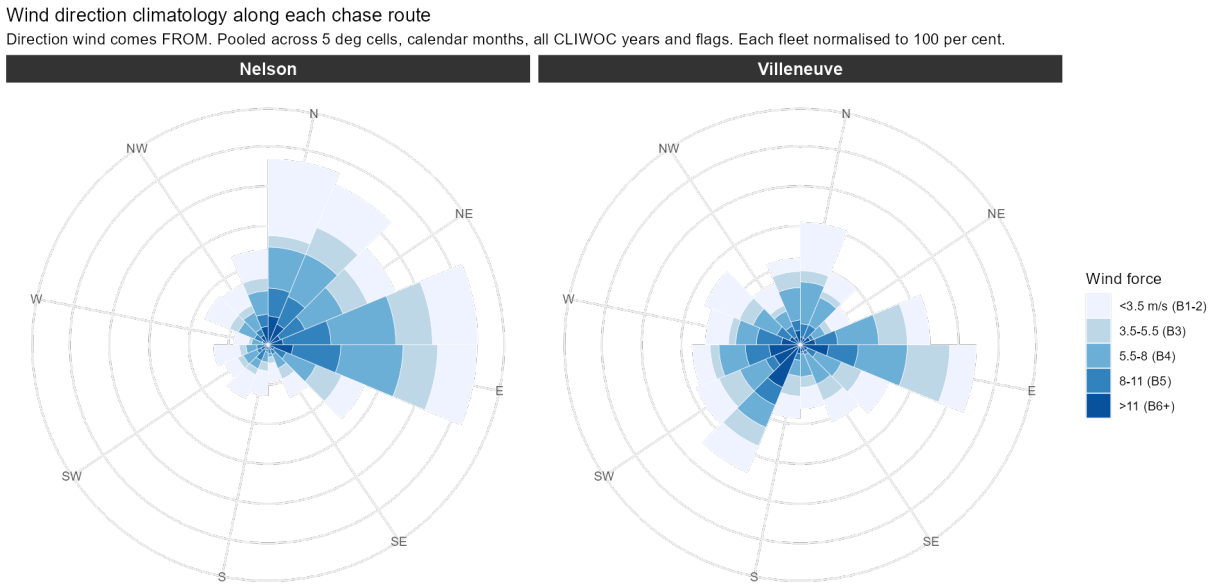

Figure 5: Wind Direction Climatology along Nelson and Villeneuve Tracks

Note: Direction the wind comes from at each waypoint, pooled across CLIWOC observations in the same $5° \times 5°$ cell and calendar month, all years and flags. Each panel normalised to 100 per cent. Colour shading bands wind force.

genuinely favourable broad-reach and running winds for an east-bound ship, but the wider directional spread also includes substantial easterly contributions that put the wind on the nose. Villeneuve gets better wind on his best days and worse wind on his worst, with more sail-handling work in between. A passage along the southern route is a steady push under reliable winds. A passage along the northern route mixes fast runs with stretches of awkward sailing. Holding aside questions of where Villeneuve actually was, the southern route was the better bet for predictable progress home.

This matters for the interpretation of the simulation results that follow. The route effects we report in Sections 5.3 and 5.4 are not artefacts of one summer's weather. They reflect persistent features of the North Atlantic wind system that any contemporary admiral would have known about, even without the precise information CLIWOC affords.

5.3 The Southern Route: Arrival Probabilities

The first experiment holds Nelson on his historical southern route to Gibraltar and varies the speed function and the weather draws around it. The relevant outcome is whether Nelson reaches Gibraltar early enough to refit and redeploy north for Calder's action on 22 July. Working backwards from that date, the actionable Gibraltar-arrival deadline is 13 July, allowing one day on station before the engagement, two days at Gibraltar for water and supplies, and a six-day median Gibraltar-to-Cape-Finisterre passage estimated using the same speed function and CLIWOC weather climatology. Sensitivity to each of the three buffer parameters is reported in Appendix C.

Figure 6 reports the simulated arrival distributions as kernel densities under each fleet-quality scenario, with the 13 July deadline marked alongside other reference dates. Table 4 reports cumulative arrival shares.

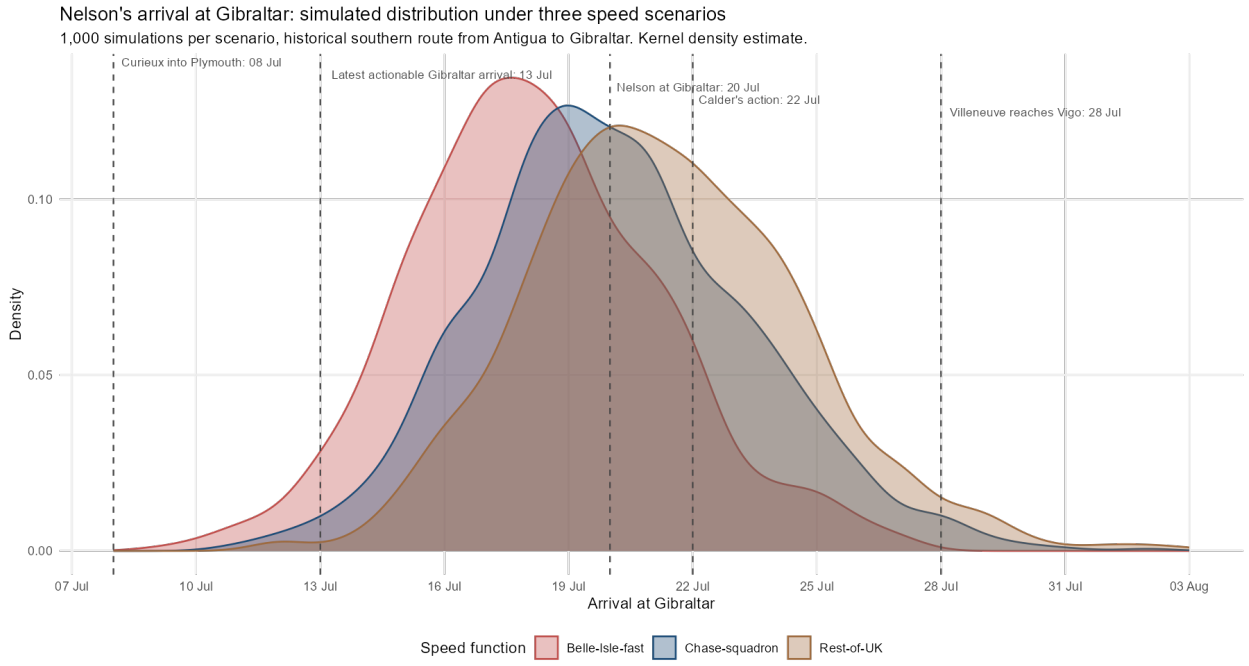

Figure 6: Simulated Arrival at Gibraltar under the Southern Route

Note: Kernel density estimates of simulated arrival dates at Gibraltar under three fleet-quality scenarios, all on the historical southern route. Vertical lines mark key campaign dates: *Curieux* into Plymouth (8 July), latest actionable Gibraltar arrival (13 July), Nelson's actual arrival (20 July), Calder's action off Cape Finisterre (22 July), Villeneuve into Vigo (28 July). $N = 1{,}000$ simulations per scenario.

Table 4: Cumulative Arrival Shares at Campaign Deadlines, Southern Route

Deadline	Rest of UK	Chase squadron	Belle Isle (fast)
By 8 July (*Curieux* into Plymouth)	0.0%	0.0%	0.0%
By 13 July (latest actionable Gibraltar arrival)	0.5%	1.6%	5.7%
By 17 July (week before Calder)	11.2%	20.4%	41.9%
By 20 July (Nelson's actual arrival)	42.8%	57.5%	78.2%
By 22 July (Calder's action)	65.8%	77.3%	89.7%
By 28 July (Villeneuve at Vigo)	97.7%	99.2%	99.8%

Note: Share of $N = 1{,}000$ simulated voyages reaching Gibraltar by each date, by fleet-quality scenario. Median arrivals are 21 July (rest of UK), 20 July (chase squadron), and 18 July (Belle Isle fast). The reference dates other than 13 July are reported for context. The actionable deadline of 13 July is the binding criterion for whether Nelson could have redeployed north in support of Calder.

The headline finding is that no fleet-quality scenario produces a meaningful share of actionable arrivals at the 13 July deadline. Even the most favourable Belle-Isle-fast counterfactual, which applies the fastest measured chase-squadron ship to the entire squadron, returns just 5.7 per cent of simulations meeting the deadline. Under the historically realised chase-squadron the figure is 1.6 per cent. Under the rest-of-UK baseline it is 0.5 per cent. The southern route does not produce a fleet of the line at Cape Finisterre in time to support Calder under any plausible specification of British fleet quality.

The fleet-quality contribution is real but limited at voyage scale. Using Belle Isle speed shifts the median Gibraltar arrival to 18 July from 20 July under the actual squadron, a two-day improvement consistent with the 5 nm/day intercept differential at modal wind speeds. The actual squadron versus rest-of-UK comparison is a single day at the median. Further, the full distribution sits in a window of about three weeks centred on Nelson's actual arrival, and the daily standard deviation of arrival dates within each scenario, 3.2 to 3.3 days, exceeds the gap between any two scenario medians.

The southern route therefore never produces actionable arrivals in a meaningful volume a fleet of the line simply cannot cover the distance in time.

These results also confirm that it is not possible for the squadron to arrive before *Curieux* arrived in Plymouth. No simulation under any fleet-quality scenario achieves the dispatch

ship's transit time. We return to the significance of this asymmetry in Section 6.

5.4 The Northern Route: Contact Probabilities

The second experiment puts Nelson on the northern hybrid route described in Section 4.4. He holds his historical track until 17 June, then turns north onto Villeneuve's track. The outcome of interest is whether Nelson's position comes within 30 nm of Villeneuve's during a single day before 22 July, the date of Calder's historical action.

Table 5 reports the headline contact rates. Under the chase-squadron scenario Nelson catches Villeneuve in 78.5 per cent of simulations. Under the rest-of-UK baseline the rate is 79.0 per cent, and under the Belle-Isle-fast counterfactual 86.3 per cent. That is, the northern route delivers contact in roughly four out of five simulations under any fleet-quality scenario we consider.

Table 5: Northern Route: Contact Rates by Fleet-Quality Scenario

Scenario	Simulations	Contact rate
Rest of UK fleet	1,000	79.0%
Chase squadron	1,000	78.5%
Belle Isle (fast)	1,000	86.3%

Note: Share of simulations in which Nelson came within 30 nm of Villeneuve on a single day before 22 July, the date of Calder's historical action. Sensitivity to the contact threshold and deadline reported in Appendix C.

Where the catches occur is just as interesting as how often they occur. Figure 7 maps the spatial distribution of contacts, with one panel per scenario. Two similar clusters dominate every panel, separated by an essentially empty mid-Atlantic. About 59 per cent of catches happen in the western cluster, west of 40°W, with a median timing of around 23 June. About 39 per cent happen in the eastern cluster, east of 25°W, with a median timing around 16 July. Only 2 per cent fall in the middle Atlantic. The pattern is qualitatively identical across scenarios, with the eastern cluster slightly denser under Belle Isle, where the additional speed

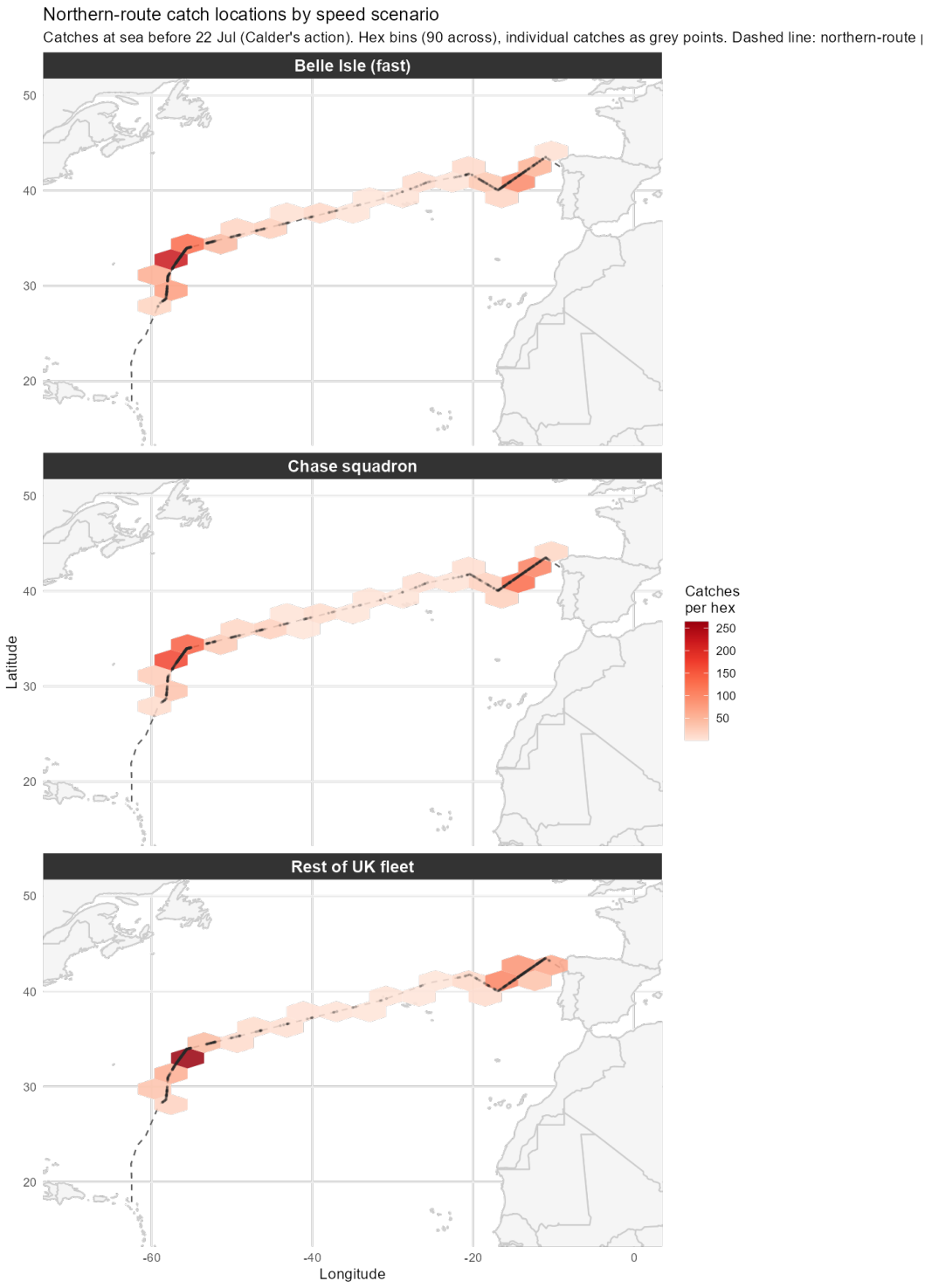

Figure 7: Spatial Distribution of Contacts on the Northern Route

Note: Density of contact locations from $N = 1{,}000$ Monte Carlo simulations per scenario, in three vertical panels. Dashed line shows nominal northern route. The bimodal western and eastern clusters reflect early-convergence and late-stern-chase geometries respectively, and the middle Atlantic is essentially empty under any scenario.

lets a stern chase close in more cases.

Intuition suggests that this bimodality is a result of the geometric properties of the chase. The western cluster reflects an early intercept where Nelson is steering directly towards Villeneuve, and the two fleets converge over the next ten days while still relatively close after both have left the Caribbean. The eastern cluster reflects a late stern chase. By mid-July Villeneuve is approaching Calder's patrol zone, slowing as he runs into the variable winds north of the Azores, and a Nelson on the same track has the ability to close from astern. The middle Atlantic gap reflects the dynamics in between, where the two fleets settle into roughly parallel pursuit and the day-to-day variability of the wind is too small to close the remaining gap.

The bimodality has implications for how the headline contact rate is read. The eastern catches are partly attributable to Villeneuve being held to his historical track in our simulation. In a fully reactive model where Villeneuve adjusts to British movements, the eastern cluster would shrink. The western catches are more likely to be robust to this concern because they happen early, before the British counterfactual has had time to influence Villeneuve's behaviour. Tightening the deadline to dates before the eastern cluster occurs, reported in the decomposition in Section 5.5, lets us isolate the early-intercept case from the late-stern-chase case. The headline result is that, even on the conservative deadlines, the northern route delivers contact in roughly half of simulations, against essentially zero useful contact on the southern route.

5.5 Decomposing Route and Fleet-Quality Effects

Table 6 brings the six cells of the design together. Panel A reports the percentage of southern-route voyages that arrive by 13 July, the last actionable arrival date. Panel B reports the northern-route contact rate by 22 July. Panel C reports the northern-route contact rate at tighter deadlines, which have been selected to fall before the eastern cluster of catches on the northern route. Panel C therefore allows us to test the sensitivity of the headline result

to these late catches.

Table 6: Decomposition of Route and Fleet-Quality Effects

	Rest of UK	Chase squadron	Belle Isle (fast)
Panel A: Pr(*actionable Gibraltar arrival by 13 July*)			
Southern route (historical)	0.5%	1.6%	5.7%
Panel B: Pr(*contact Villeneuve at sea before 22 July*)			
Northern route	79.0%	78.5%	86.3%
Panel C: Northern route, tighter deadlines (deterministic-Villeneuve robustness)			
Contact before 17 July	65.3%	67.6%	81.6%
Contact before 8 July	47.8%	48.5%	64.2%

Note: Each cell reports the share of $N = 1{,}000$ Monte Carlo simulations meeting the relevant outcome criterion. The southern-route panel uses the actionable Gibraltar-arrival deadline of 13 July, derived from Calder's action on 22 July less one day on station, two days at Gibraltar for water and supplies, and a six-day median Gibraltar-to-Cape-Finisterre passage. Panel C uses tighter contact deadlines, chosen to fall before the eastern stern-chase cluster identified in Section 5.4 so that contact occurs while Villeneuve's historical track is closest to what he would have done under any plausible reaction to British counterfactual moves. Sensitivity to all parameters in Appendix C.

There are three main results to take from this table.

First, the route effect dwarfs the fleet-quality effect. Going from the southern route in Panel A to the northern route in Panel B takes the probability of timely engagement with Villeneuve from between 0.5 and 5.7 per cent to between 79 and 86 per cent. Going across the fleet-quality columns within either route, the gap between the rest of the British fleet and the Belle-Isle-fast counterfactual is 5.2 percentage points on the southern route and 7.3 percentage points on the northern route. The route dimension moves outcomes by an order of magnitude more than the fleet-quality dimension at any specification we consider.

Second, the fleet-quality dimension is present but limited. The Belle-Isle-fast counterfactual sits roughly 7 percentage points above the chase squadron on both routes, while the chase-squadron-versus-rest-of-UK gap is small and not meaningfully different at the 22 July deadline. The day-level speed advantage we documented in Section 5.1 is real, but at voyage scale the cumulative gain is reduced by the variability of weather. Even applying the highest

measured chase-squadron premium to every ship in the squadron, the southern route does not produce actionable arrivals in volume.

Third, the route effect survives every tightening of the contact deadline. Reducing the late eastern catches by restricting the latest date for a catch to 17 July keeps the main conclusion intact, with the chase-squadron northern-route rate still around forty times the chase-squadron southern-route rate. At 8 July, the most conservative deadline that excludes essentially all of the late eastern catches, the chase-squadron northern rate is 48.5 per cent against an essentially zero southern rate.

The decomposition speaks directly to the question that motivated the paper. Three forces could in principle have determined the outcome of the 1805 chase: information about Villeneuve's destination, the quality of Nelson's fleet, and the weather. Within our simulation each is a separate axis of variation. Information varies across the rows, fleet quality across the columns, and weather across the draws within each cell. The finding is that information dominates, with route choice moving the outcome from low single digits of success to over eighty per cent. The fleet-quality dimension is present but small, with a Belle-Isle-fast premium of 5 to 7 percentage points above the historically realised chase squadron. The weather dimension, captured by the spread within each cell, places Nelson's actual arrival inside the central band of the simulated distribution.

Overall, the historical outcome of the 1805 chase was driven by Nelson's choice of route, which was a direct consequence of his lack of information on Villeneuve's route and the necessity to act on inferences about Villeneuve's destination. The seamanship and ship quality of his squadron as well as the weather he encountered each played, at most, a marginal role.

6 Conclusions

The standard naval-historical reading of the 1805 chase treats Nelson's southerly turn as a strategic error narrowly recovered by the dispatch of a messenger ship to Plymouth. The implicit claim is that a different choice would have produced a different outcome. Our simulation lets us test that claim by running alternatives.

On the southern route, the question is not whether Nelson could have caught Villeneuve, since the southern route was never a pursuit, but whether he could have arrived in Europe early enough to make a historical difference. We model this as a two-stage journey with an Atlantic crossing to Gibraltar, two days in port, and a follow-on passage to Cape Finisterre to support Calder's action on 22 July. Across three thousand draws spanning all three fleet-quality scenarios and the full range of plausible weather, only 1.6 per cent of simulations under the historically realised chase squadron produce an actionable Gibraltar arrival, rising to 5.7 per cent under the Belle-Isle-fast counterfactual. The weather Nelson actually encountered in 1805 sat squarely inside the climatological range for his route. Better ships, better weather, or both, would not have produced a meaningfully different historical outcome on the southern route.

On the northern route, the answer is unambiguous in the other direction. Had Nelson turned north, he would have caught Villeneuve in roughly four out of five simulations under the historically realised chase squadron, rising to 86 per cent under the Belle-Isle-fast counterfactual. Holding fleet quality at its most favourable level, route choice swings the probability of timely engagement with Villeneuve to 86 per cent. Choosing the northern route would have required better information about Villeneuve's destination rather than better fortune at sea.

Weather, fleet quality, and information each contribute to the 1805 outcome, but they are not of the same order. Weather and fleet quality each move arrivals around by a few days or contact rates by a few percentage points. Switching to the northern route, an information-driven choice, raises the contact probability to about eighty per cent. Within

Nelson's information set, both routes were defensible. The southern course delivered him to Gibraltar in good time on reliable winds and was consistent with his standing orders to defend the Mediterranean and his prior that Villeneuve was likely bound there. The northern course offered the chance of contact at sea against an imagined Villeneuve who might have been bound for the Channel. Without intelligence to break the tie, Nelson took the route that was meteorologically favourable and consistent with what he had been ordered to defend. Our reading is that this was a reasonable decision on his information set. The campaign turned on the information he did not have, more than on the choice he made with the information available to him.

This reframes the role of *Curieux* in the standard account. The brig-sloop is usually cast as a lucky thread that pulled the campaign together, an act of fast frigate work that recovered a fleet-level miss. Our model suggests the more accurate framing is structural. No simulation under any fleet-quality scenario we consider produces a fleet of the line at Plymouth in time to beat the brig-sloop on the same passage, so information of this kind, fast and accurate, was the only mechanism available. The decisive instrument of the chase was therefore the dispatch system rather than the fleet the dispatches concerned. *Curieux* carried to the Admiralty the information that Nelson did not have when he left Antigua, and the campaign that culminated at Trafalgar followed from that.

This paper has limitations. The speed function is estimated from a sample of warships of the period rather than from Nelson's individual captains, so the chase-squadron premium captures the squadron's measured performance rather than the residual genius that contemporaries attributed to its commander. Villeneuve's track is held at its historical positions, which means the late-stern-chase catches we report are exposed to the simplification that he does not react to British counterfactual moves. The contact threshold of 30 nm is conservative, and the actionable Gibraltar-arrival deadline of 13 July rests on choices about port time, on-station buffer, and median Iberian-coast transit. We report sensitivity to all of these in the appendices, and none changes the main findings.

The framework we have used here, a CLIWOC-derived speed function feeding a Monte Carlo simulation over a small grid of counterfactual scenarios, has applications beyond Trafalgar. Other age-of-sail pursuits and blockades follow the same basic structure. A fleet under one commander pursues or contains a fleet under another in a known wind field over a known geography, and the question is whether the realised outcome was the one the dynamics made likely or whether luck or genius pulled it in some other direction. The Brest blockade, the East Indies station, and the Java campaign are all candidate applications. Cliometric naval history has tools available now that were not available to Corbett or Mahan. Using them to revisit familiar campaigns is likely to produce more findings of the kind reported here, where the historical outcome turns out to have been a great deal closer to the dynamic equilibrium than the prevailing narrative allowed.

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A Speed Function: Robustness

This appendix reports two robustness checks. First, we look at the ship-level performance distribution across the British fleet that motivates the Belle-Isle-fast counterfactual. Second, we re-estimate the speed function pooling Dutch ships of the line with the British sample to test for cross-flag differences.

Ship performance distribution and the Belle Isle selection

Figure 8 plots the ship-level fixed effects from the pooled premium regression in column 3 of Table 2 against rank. The chase squadron sits in the upper portion of the distribution but is not concentrated at the top. Of the five chase-squadron ships, Belle Isle is in the top decile, Decade and Swiftsure rank in the upper quartile, Conqueror is poorly identified on $n = 2$, and Amazon is the regression's reference ship.

We define the Belle-Isle-fast counterfactual using a reliability filter that requires at least 50 daily observations, coverage across at least four of the five points of sail, and a 95 per cent confidence interval on the performance estimate that excludes zero. Of the British fleet, three ships pass this filter: *Dedaigneuse*, a frigate, with a premium of 19.7 nm/day on $n = 91$; *Nisus*, a frigate, with 17.1 nm/day on $n = 70$; and Belle Isle, a ship of the line, with 10.8 nm/day on $n = 165$.

We adopt Belle Isle as the fast counterfactual for two reasons. First, Belle Isle is in the chase squadron, so the counterfactual is internally consistent. Second, the two other reliable ships are frigates which carried out scouting and communication roles in the chase squadron, while ships of the line set the pace. Selecting the fastest reliable ship of the line is therefore the cleaner counterfactual at the level of the squadron's binding constraint. For reference, the mean performance premium of the chase squadron is 1.3 nm/day relative to the regression reference. This sits in the upper third of the British distribution but well below the reliable top tail. Belle Isle's premium of 10.8 sits at the 95th percentile.

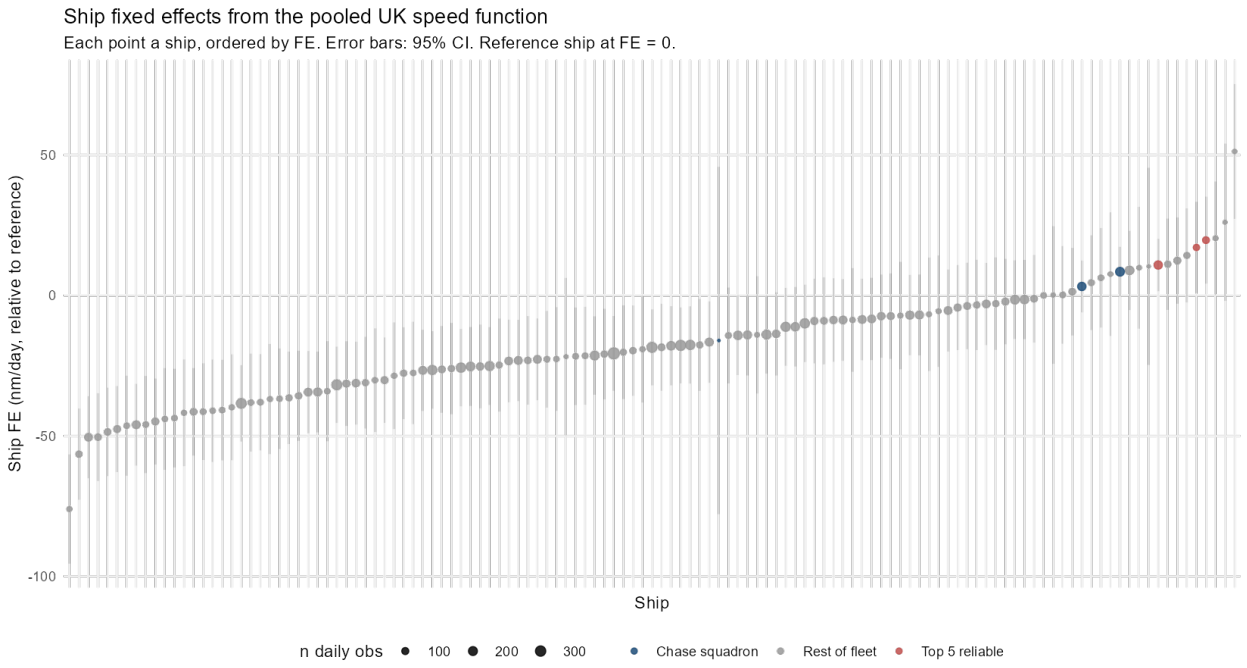

Figure 8: Ship-Level Performance Estimates from the Pooled UK Speed Function

Note: Each point is a ship, with height showing the ship's fixed-effect estimate in Table 2 column 3, point size scaled by sample size, and error bars at 95 per cent confidence. Chase-squadron ships highlighted, with the top five reliably-identified ships overall highlighted separately. Reliability filter requires $n \geq 50$, point-of-sail coverage ≥ 4, and a 95 per cent CI excluding zero.

Cross-flag robustness

Table 7 re-estimates the speed function with Dutch ships of the line added to the pooled sample and a Dutch-flag triple interaction. The cross-flag triple interactions are individually small and statistically indistinguishable from zero, with $p > 0.5$ on each. This is consistent with Kelly and Ó Gráda [2019] who find a convergence of Anglo-Dutch sailing productivity by the early nineteenth century. The pooled UK slope estimates in column 1 are essentially unchanged when Dutch observations are added in column 2.

Table 8 reports simple slope estimates by national fleet for descriptive comparison. Dutch slopes are nominally steeper than UK slopes on running, with 0.72 against 0.48, and on close-hauled, with 0.59 against 0.35. However, the Dutch sample is roughly an order of magnitude smaller than the UK sample at every point of sail. The cross-flag tests in Table 7 cannot reject equality once ship fixed effects are controlled.

Table 7: Speed Function: Cross-Flag Robustness

	Dependent variable:	
	Daily run (nm/day)	
	UK pooled	UK + NL
	(1)	(2)
Wind force (W, m/s)	0.185***	0.185***
	(0.027)	(0.027)
$W\times$ Close-hauled	0.170***	0.170***
	(0.034)	(0.034)
$W\times$ Beam reach	0.171***	0.171***
	(0.031)	(0.031)
$W\times$ Broad reach	0.208***	0.208***
	(0.031)	(0.031)
$W\times$ Running	0.298***	0.298***
	(0.032)	(0.032)
$W\times$ Close-hauled $\times$ NL		0.093
		(0.281)
$W\times$ Beam reach $\times$ NL		0.073
		(0.256)
$W\times$ Broad reach $\times$ NL		0.063
		(0.260)
$W\times$ Running $\times$ NL		0.094
		(0.262)
Ship FE	Yes	Yes
Sample window	1800–1810	1800–1810
Observations	12,819	13,359
R^2	0.304	0.302
Adjusted R^2	0.297	0.294
Residual Std. Error	44.26	44.21

Note: Daily distance for British and, in column 2, Dutch ships of the line. The reference category for point of sail is head wind. Standard errors in parentheses. *p<0.05; **p<0.01; ***p<0.001.

Table 8: Speed-Wind Slopes by National Fleet

Fleet	Point of sail	Slope	Intercept	n
UK	Running	0.478	84.06	3,110
UK	Broad reach	0.388	81.23	2,746
UK	Beam reach	0.357	75.98	3,327
UK	Close-hauled	0.350	61.88	2,385
UK	Head wind	0.175	55.61	1,251
NL	Running	0.717	78.48	172
NL	Close-hauled	0.585	60.29	71
NL	Broad reach	0.526	78.67	153
NL	Beam reach	0.474	77.63	110
NL	Head wind	0.157	58.91	34

Note: CLIWOC observations 1772–1830, simple slopes by point of sail without ship fixed effects. The Dutch sample is roughly an order of magnitude smaller than the UK sample.

B Source Reconciliation

This appendix validates the chase track by comparing four prior reconstructions against CLIWOC daily positions. The four sources are Corbett (1910), the primary reference for our Villeneuve track, Fraser (1906), Stevens & Westcott (1920), and Newbolt (1905).

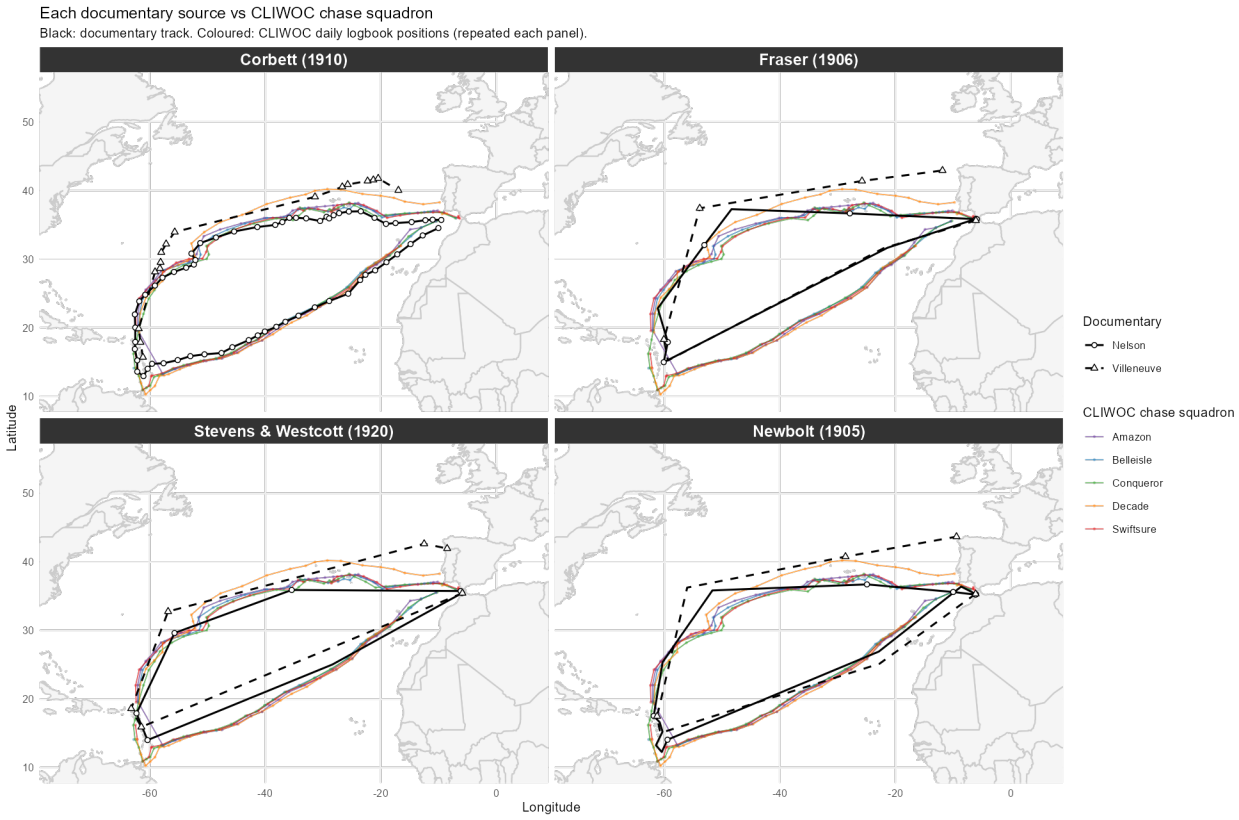

Figure 9: Prior Chase Reconstructions Compared with CLIWOC

Note: Each panel shows one prior account's reconstruction overlaid with daily CLIWOC positions for the chase squadron. Sources: Corbett (1910), Fraser (1906), Stevens & Westcott (1920), Newbolt (1905).

The four sources broadly agree on the geographic outlines of the chase. Corbett's daily positions for Nelson agree with the CLIWOC chase-squadron centroid to within a median of 60.8 nm during the convoy phase from May to mid-June 1805. This is well below the 30 nm contact threshold once squadron formation is taken into account. Larger disagreements after 22 June reflect Nelson's documented dispersal of the squadron into a search formation, where

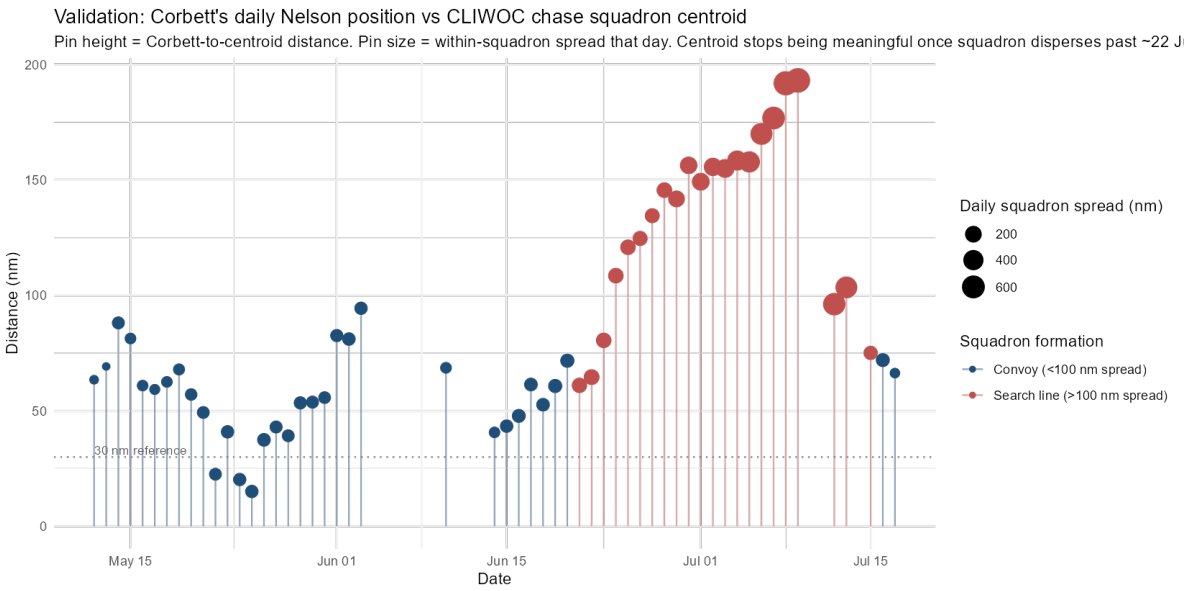

Figure 10: Daily Disagreement: Corbett (1910) versus CLIWOC

Note: Daily distance (nm) between Corbett's reported position and the CLIWOC mean position for the same date. Pin size scales with within-squadron spread on the day. Reference line at 30 nm corresponds to the contact threshold used in the simulation.

individual ships covered separate sectors of ocean and the centroid no longer corresponds to a single fleet position. We use Corbett for Villeneuve's track since CLIWOC is silent on French ships, with the convoy-phase agreement on the British track validating this choice.

C Sensitivity Analyses

This appendix reports four sensitivity exercises addressing the most likely reader objections to the headline 2×3 design. We look at the choice of contact threshold, the choice of contact deadline, the parameters of the Gibraltar-to-Cape-Finisterre redeployment leg, and the choice of switch date for the northern hybrid route. Each test reports the headline route-versus-fleet-quality decomposition under varied parameters.

A. Contact threshold radius

Table 9 reports northern-route contact rates at four contact radii spanning a tight 15 nm bound to a permissive 100 nm definition appropriate for a fleet sweeping wide with frigate scouts.

Table 9: Sensitivity: Contact Threshold Radius

Radius (nm)	Rest of UK	Chase squadron	Belle Isle (fast)
15	54.9%	60.9%	65.7%
30	78.1%	80.3%	84.7%
60	91.7%	95.7%	97.8%
100	95.7%	97.1%	99.6%

Note: Contact rate as a share of $N = 1{,}000$ northern-route Monte Carlo simulations at each contact radius. Headline radius in the body is 30 nm.

Contact rates rise monotonically with the radius. The ranking across scenarios is preserved at every radius, with Belle-Isle-fast above the chase squadron and the chase squadron nominally above the rest of the UK fleet. The 30 nm headline is at the conservative end of plausible interpretations. Even at the strictest 15 nm threshold the chase-squadron rate is still 60.9 per cent, and at the permissive 100 nm threshold it reaches 97.1 per cent. The route-versus-fleet-quality decomposition is stable across the range.

B. Contact deadline

Figure 11 and Table 10 report the cumulative contact rate against the deadline date at five-day intervals from 1 July to 31 July.

The contact rate rises through July and plateaus in the final week. By 1 July the chase-squadron contact rate is already 47.3 per cent and the Belle-Isle-fast rate is 62.3 per cent. These early contact rates are dominated by the early western cluster identified in Section 5.4 and are robust to the deterministic-Villeneuve simplification because they occur before any British counterfactual move could have influenced Villeneuve's track. Contact rates plateau

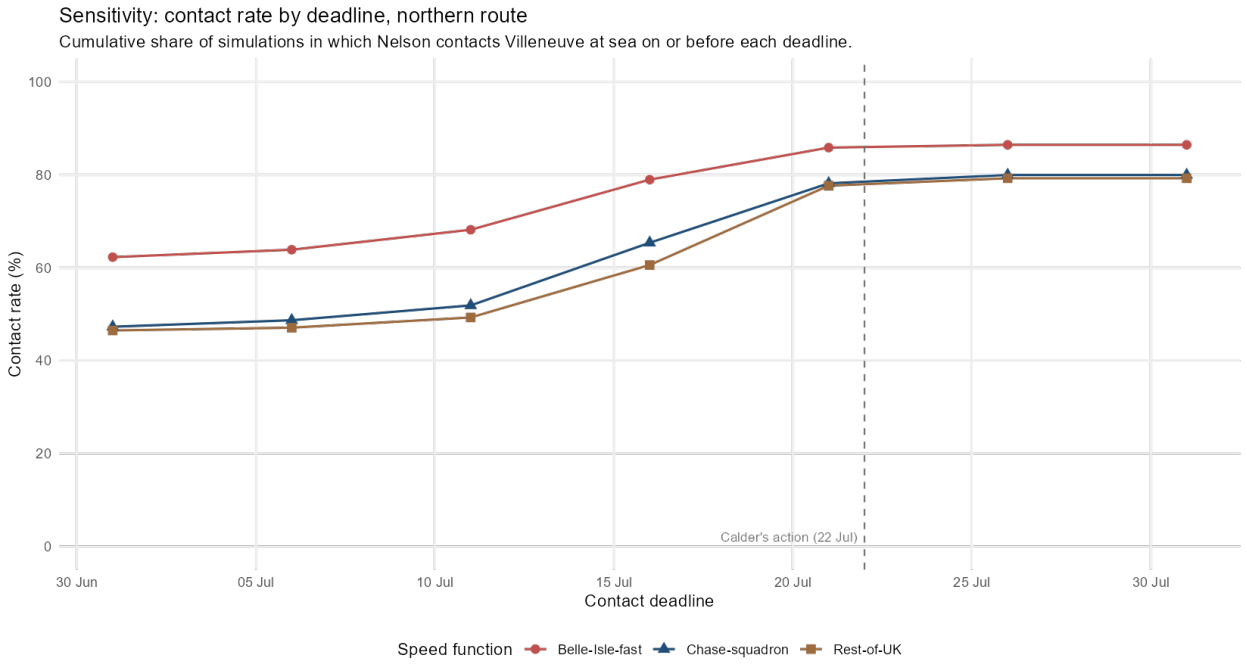

Figure 11: Sensitivity: Northern-Route Contact Rate by Deadline

Note: Cumulative share of $N = 1{,}000$ simulations with contact at sea on or before each deadline, by scenario. Dashed line marks Calder's action on 22 July, the deadline used in the body.

Table 10: Sensitivity: Contact Rate by Deadline

Deadline	Rest of UK	Chase squadron	Belle Isle (fast)
1 July	46.5%	47.3%	62.3%
6 July	47.1%	48.7%	63.9%
11 July	49.3%	51.9%	68.2%
16 July	60.6%	65.4%	79.0%
21 July	77.7%	78.2%	85.9%
26 July	79.3%	80.0%	86.5%
31 July	79.3%	80.0%	86.5%

Note: Cumulative share of $N = 1{,}000$ simulations with contact at sea on or before each deadline. Headline deadline in the body is 22 July.

after 22 July, so any deadline from 21 July onward yields essentially the same contact rate. The choice of 22 July as the headline deadline is therefore not pivotal.

C. Redeployment-leg parameters

The actionable Gibraltar-arrival deadline of 13 July depends on three buffer parameters: the median Gibraltar-to-Cape-Finisterre transit time of six days, the time spent at Gibraltar for water and supplies of two days, and the on-station buffer required before Calder's action of one day. The transit time is itself a simulation output and is reported in Section 5.3. This exercise varies the other two. Tables 11 through 13 report actionable arrival rates as a 3×3 grid in port-days and on-station buffer, separately by scenario.

Table 11: Sensitivity: Redeployment Parameters, Chase-Squadron

Port days at Gibraltar	On-station 0 days	On-station 1 day	On-station 2 days
0 days	14.1%	9.0%	4.1%
2 days	5.4%	2.2%	1.1%
4 days	0.9%	0.3%	0.0%

Note: Actionable arrival rate (% of N = 1,000 simulations) for the chase squadron under each combination of port days and on-station buffer. Headline cell in the body is 2 port days, 1 on-station day, giving 2.2 per cent.

Table 12: Sensitivity: Redeployment Parameters, Rest of UK

Port days at Gibraltar	On-station 0 days	On-station 1 day	On-station 2 days
0 days	9.1%	5.0%	2.9%
2 days	1.8%	0.9%	0.4%
4 days	0.2%	0.0%	0.0%

Note: Actionable arrival rate (% of $N = 1{,}000$ simulations) for the rest-of-UK baseline under each combination of port days and on-station buffer.

The grids show the southern-route conclusion is robust across the realistic range of buffer assumptions. Under the most generous reading, with zero port days and zero buffer, the chase-squadron rate is 14.1 per cent and the Belle-Isle-fast rate is 35.5 per cent. Under stricter readings the rates fall sharply. With two days in port and a one-day buffer the

Table 13: Sensitivity: Redeployment Parameters, Belle-Isle-Fast

Port days at Gibraltar	On-station 0 days	On-station 1 day	On-station 2 days
0 days	35.5%	24.9%	15.4%
2 days	14.2%	8.6%	4.4%
4 days	4.2%	2.2%	1.0%

Note: Actionable arrival rate (% of $N = 1{,}000$ simulations) for the Belle-Isle-fast counterfactual under each combination of port days and on-station buffer.

chase-squadron rate is 2.2 per cent and the Belle-Isle-fast rate is 8.6 per cent. The route-versus-fleet-quality decomposition holds across every cell of the grid. The northern-route contact rate at the chase squadron of 78.5 per cent exceeds the southern-route actionable rate by an order of magnitude under any reasonable assumption.

D. Switch date for the northern hybrid route

The northern hybrid route holds Nelson on his historical track until a switch date, then turns north onto Villeneuve's track. The headline switch date is 17 June. Table 14 reports contact rates at five switch dates spanning Nelson's options from immediate turn at Antigua on 11 June to Corbett's documented commitment date on 22 June.

Table 14: Sensitivity: Switch Date for the Northern Hybrid Route

Switch date	Rest of UK	Chase squadron	Belle Isle (fast)
11 June	82.0%	81.7%	86.3%
14 June	81.1%	83.3%	88.6%
17 June	78.3%	78.8%	84.7%
20 June	63.8%	63.4%	73.4%
22 June	42.1%	49.6%	60.8%

Note: Contact rate as a share of $N = 1{,}000$ simulations at each switch date, by scenario. Headline switch date in the body is 17 June.

The contact rate is high at switch dates of 11 to 14 June, between 82 and 89 per cent across scenarios. Here, Nelson's turn comes early enough to deliver him onto Villeneuve's track while the two fleets are still close. Contact rates fall as the switch is delayed, although

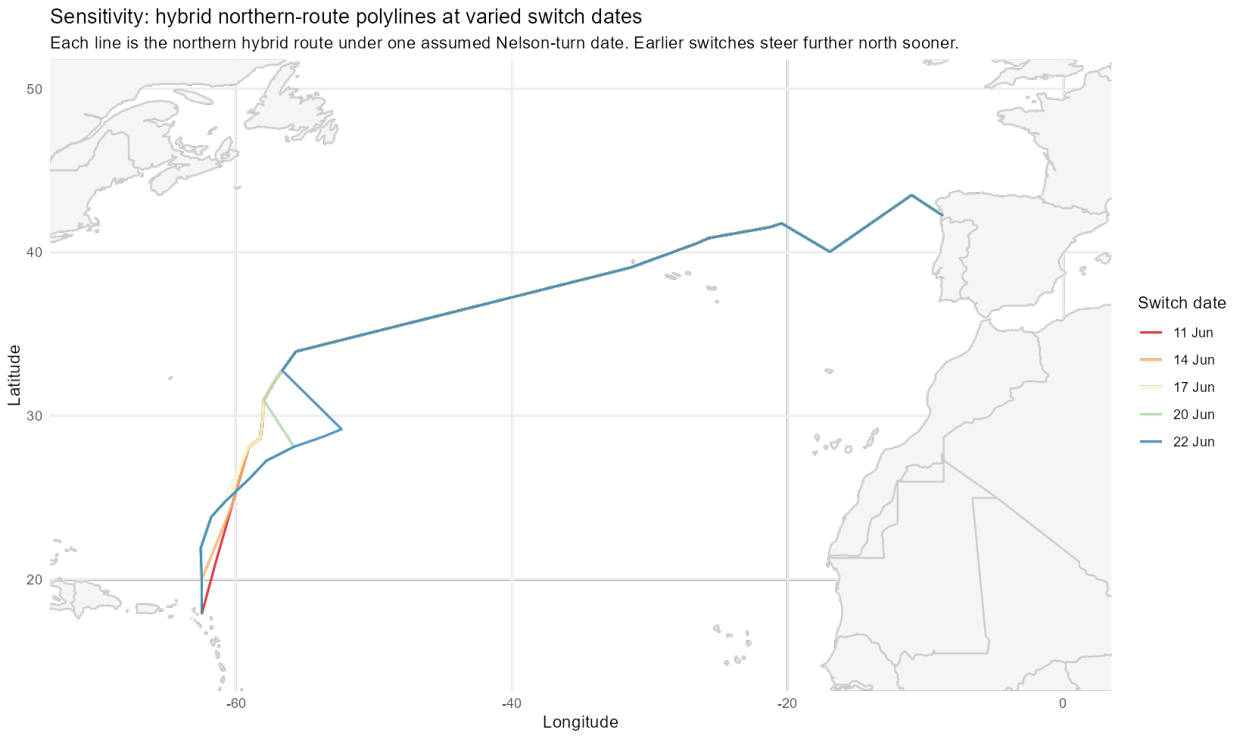

Figure 12: Northern Hybrid Route Polylines at Varied Switch Dates

Note: Each line is the northern hybrid route under one assumed Nelson-turn date. Earlier switches steer further north sooner.

the Belle Isle counterfactual holds above 60 per cent even at the latest 22 June commitment date. The Belle-Isle premium also widens at later switch dates, from 4.6 percentage points at 11 June to 11.2 percentage points at 22 June. When the geometry is unfavourable, ship quality matters more for closing the remaining gap. When the geometry is favourable, almost any decent fleet contacts Villeneuve. Even under the most generous reading of Nelson's commitment date and the most pessimistic reading of the chase squadron's quality, the northern route delivers contact in roughly half of simulations.