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ORIGINAL PAPER

Completing the journey in the global north: the Manila clam (*Ruditapes philippinarum*) (Bivalvia: Veneridae) arrives in the Northwest Atlantic Ocean

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Abstract The Manila clam, *Ruditapes philippinarum*, is one of the world's most widely introduced marine bivalves, but its establishment has not yet been documented in the Northwest Atlantic Ocean. Here we report the first records of reproducing populations of *R. philippinarum* from Massachusetts, U.S.A. Observations were collected through opportunistic field surveys, community science platforms (i.e., iNaturalist), and correspondence and discussions with commercial and recreational shellfish harvesters. These observations revealed the presence of *R. philippinarum* at multiple locations in Cape Cod and Boston Harbor between 2023 and 2025, with northernmost occurrences now reaching Salem Sound, north of Boston. Live individuals from Cape Cod ranged from 31 to 71 mm in shell length (SL). Similar size ranges were documented in Boston Harbor, with additional targeted sediment sampling documenting early settlers (500 µm SL) and young juveniles (1–7 mm SL), confirming this species to be established and reproducing. Community science contributions and

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engagement with shellfishers expanded the known distribution of *R. philippinarum* and prompted additional search efforts in 2025, highlighting the importance of broad community engagement in early detection. Further work is needed to determine the potential source population, understand the species' role in Northwest Atlantic ecosystems, and track its potential spread.

Keywords Community science · Shellfish · Vectors · New England · Massachusetts

Introduction

The Manila clam, *Ruditapes philippinarum* (Adams and Reeve, 1850) (=*Tapes japonica* Deshayes, 1853 and *Venerupis semidecussata* Reeve, 1864, among other synonyms), native to the Northwest Pacific Ocean, is one of the world's most widely introduced marine bivalves, with established populations in Europe (Humphreys et al. 2015; Amor et al., 2016; Reise et al. 2024; Greeve et al. 2025) and the Pacific coast of North America (Cordero et al., 2017). This extensive global distribution is due, in part, to its status as one of the most widely cultivated and intensively farmed clams in the world (Humphreys et al. 2025). Across its global range, *R. philippinarum* is known by several common names including the Manila clam, the Japanese littleneck clam, and the Japanese carpet shell (World Register of Marine Species). Hereafter we refer to this species as the Manila clam and *Ruditapes*.

Ruditapes is a burrowing venerid bivalve typically found in lower intertidal habitats, residing within the top 15 cm of sediment and occupying sand, mud, gravel, and mixed substrates (Humphreys et al. 2007). *Ruditapes* has an oval, strongly reticulated shell, with a distinct heart-shaped lunule, orange foot, and short, partially fused siphons (Habtemariam et al. 2015). In regions such as the Mediterranean and Northeast Atlantic, it is sometimes confused with a native congener, *Ruditapes decussatus* (Linnaeus,1758), which differs in having a less pronounced lunule, longer separated siphons, and a white foot, among other differences (Alonso Suárez & Raven 2020). Notably, *Ruditapes* is not visually similar to any native bivalve in the New England region of the United States and thus it is easily recognized.

Across its invaded ranges, *Ruditapes* exerts a variety of ecological impacts. It can outcompete and replace native bivalves (Bidegain et al. 2015), be a vector for parasite transfer (Bathige et al. 2025), and shift biodiversity and alter ecosystem function (Pranovi et al. 2006). It is also capable of hybridizing with *R. decussatus*, with uncertain consequences (Hurtado et al. 2011). At the same time, *Ruditapes* serves as an important food source for a variety of predators, including moonsnails (Naticidae), crabs, fish, shorebirds, and raccoons (Carlton & Hodder 2003; Caldow et al. 2007; Beninger & Boldina 2014; Boschiero et al. 2025).

Although *Ruditapes* has never been formally documented as established in the Northwest Atlantic, it has appeared on various alien species watch lists in New England for the last decade (Pederson et al. 2017). A small number of isolated observations have been reported since the 1980s in Massachusetts (Carlton 1984). Additionally, occasional living specimens and dead shells, assumed to be food discards or bait, have been recorded in the New England-New York region on community science platforms such as iNaturalist (ID # 253568665; 278107522l; 306657664). In 2023, experienced shellfish harvesters began noting living *Ruditapes* on Cape Cod in Chatham,

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Massachusetts, while researchers in the Boston region reported empty shells found in the Squantum neighborhood of Quincy beginning in 2024. Despite these intermittent reports, no confirmed records or evidence of establishment (i.e., capable of sustaining populations through local reproduction) were documented.

We here report on the invasion—the arrival and establishment of a species where it was historically absent—of *Ruditapes,* and provide evidence that it is now established in Massachusetts, U.S.A., in the Northwest Atlantic, representing the completion of its journey across the Global North.

Materials and methods

Field observations

Cape Cod region

Observations and specimens of suspected *Ruditapes* were gathered opportunistically from 2023 to 2025 by shellfish harvesters and local shellfish management agencies, including the Chatham Shellfish Department (CSD) and Cape Cod Cooperative Extension (CCCE). Harvesting activities included manual digging and raking within the intertidal using clam (including quahog) rakes, along with some dredge-based collections in subtidal habitats. Reports were collected across multiple towns on Cape Cod (e.g., Chatham, Wellfleet, Supplementary Table S1). Observers provided photographs and, when possible, live specimens. Species identification was confirmed by an expert intimately familiar with this species in California since the 1960s (J. T. Carlton). When live individuals were provided, specimens were measured (shell length, SL), preserved, and dissected to record internal anatomy and reproductive condition.

Boston Harbor region

The *Ruditapes* population in Boston Harbor was first noticed in the summers of 2024 and 2025 during opportunistic shoreline surveys by the authors at Squantum (June 2024; July 2025); Calf Pasture Park (June 2025) and Spectacle Island (July 2025). Subsequently, additional observations (Supplementary Table S1) were made in 2025 opportunistically at these and other numerous sites including Webb Memorial State Park (Weymouth). After the detection of live juveniles in sediments at Squantum (September 2025), we further evaluated whether this population could be considered established and reproducing by conducting targeted sediment sampling at Calf Pasture Park. Sediment was collected on 8 September 2025, from intertidal mixed coarse sediment locations haphazardly and passed through a series of sieves (10 mm, 1 mm, 300 µm). Material retained on the finer sieves was inspected under a dissecting microscope to detect any early-stage (nepionic) juveniles or young clams.

Additional opportunistic surveys

Additional opportunistic and targeted surveys were completed at sites along the North Shore of Massachusetts, in Rhode Island, and in Connecticut. Along the North Shore, Salem Sound Coastwatch (SSCW) and the Massachusetts Office of Coastal Zone Management (MA CZM) completed opportunistic and targeted surveys between August and November 2025, ranging from Salem to Gloucester. Here we completed 30–60-min-long visual surveys along the shoreline. In most instances, the top ~ 5 cm of sediment was periodically passed through a 2 mm sieve at haphazard locations along the lower intertidal. In addition to monitoring along the North Shore, the authors completed opportunistic surveys in conjunction with existing sampling efforts in Rhode Island (RI) (July–September 2025) and Connecticut (CT) (July 2025). See supplementary material table S1 for GIS coordinates for all MA, RI, and CT sampling locations.

iNaturalist search and data collection

iNaturalist (iNat) observations of *Ruditapes* on the Atlantic coast of North America were obtained (13 August 2025) by searching "Bivalves" and specifying the state (U.S.A.) or province (Canada). This search was conducted for the state in which *Ruditapes* were first discovered (i.e., Massachusetts) and expanded to include states south of Massachusetts (south to North Carolina) and northward through eastern Canadian provinces (Nova Scotia through Quebec, excluding Newfoundland and Labrador). Additional searches were conducted repeatedly, with a final search on 2 December 2025 and again on 12 May 2026 (at which

time there were no records of live *Ruditapes* outside of Massachusetts in the U.S.A.). All candidate observations were visually verified to confirm species identification. We extracted iNat metadata (date, location, coordinates), grouped the observations into regions by state, and supplemented each observation with biological details (e.g., live vs. dead) obtained through image review. When necessary, we conducted direct follow-up communication with observers to clarify uncertain observations such as whether a clam photographed in an image was alive or dead. For dead, empty shells, the shell condition was qualitatively categorized according to articulation and weathering. Articulation was categorized as articulate (paired valves remaining connected) or inarticulate (valves separated and/or shell broken). Weathering was classified as fresh, semi-fresh, or weathered based on coloration and evidence of dissolution or bleaching. Observations lacking confirmation for metrics required for data visualization were excluded.

Data visualization

All graphs were generated using the ggplot2 package (Wickham, 2016) in R Studio (Posit Team, 2025), equipped with R version 4.5.1 (R Core Team, 2025). All maps were generated using ArcGIS (Esri, 2025), equipped with ArcGIS Pro 3.5.0. Data for the occurrence map were retrieved from iNaturalist in December 2025. Any data points that did not contain a date or were entered as obscured (i.e., precise location hidden) were not included in the analysis.

Results

Confirmed occurrences of multiple sizes spanning different life stages of living *Ruditapes* have now been documented in Massachusetts, representing the first verified records of this species in the Northwest Atlantic Ocean (Fig. 1).

Field observations

Cape Cod region

Live *Ruditapes* were documented across four locations around Cape Cod between 2023 and 2025, including locations within Cape Cod Bay and along the Atlantic-facing coast. The earliest observations were recorded by experienced shellfish harvesters in Chatham in 2023 and 2024, who reported multiple live individuals to the CSD. Although photographed, these individuals were not identified to species until 2025 through expert review. Subsequently, shellfish harvesters reported the species from multiple Chatham locations from June to September 2025. Additionally, in 2025, a commercial shellfish harvester fishing in Wellfleet Harbor began regularly reporting live specimens and dead shells among native quahog (*Mercenaria mercenaria* (Linnaeus, 1758)) catches. Live individual *Ruditapes* were also found in Provincetown in November 2025, and a commercial harvester in Yarmouth provided two live specimens that same month, all of which were confirmed to be *Ruditapes.*

In total, more than 50 specimens were reported or collected by shellfish harvesters in areas of abundant quahogs (*M. mercenaria*) or native soft-shell clams (*Mya arenaria* Linnaeus, 1758), with habitat generally characterized by coarse sand, sometimes fringed by pebble/cobble edges. Although accurate density estimates are not available, a harvester in Wellfleet estimated a relative abundance of one *Ruditapes* per 100–200 quahogs captured via dredge (subtidal) throughout the summer of 2025.

Live specimens were measured (31–71 mm SL), frozen or preserved in ethanol (95%) (n = 38), and dissected (n = 10) to record reproductive conditions. The dissection of a female clam from Chatham revealed the presence of oocytes in the follicles (Fig. 2), suggesting that the Cape Cod population is also reproductively active.

Boston Harbor region

Opportunistic observations by the authors uncovered 138 live *Ruditapes* in the Boston area between August and November 2025. Before this, numerous articulated and inarticulated empty shells between 30 and 53 mm SL were observed in Squantum (October 2024; July 2025), Spectacle Island (July 2025), and Webb Memorial State Park (August 2025). These observations prompted additional opportunistic searches for live individuals in different locations. At Squantum (1 September 2025), a 2-h digging effort yielded 27 live specimens (20–49 mm SL), and a similar effort at Calf Pasture Park (8 September 2025)

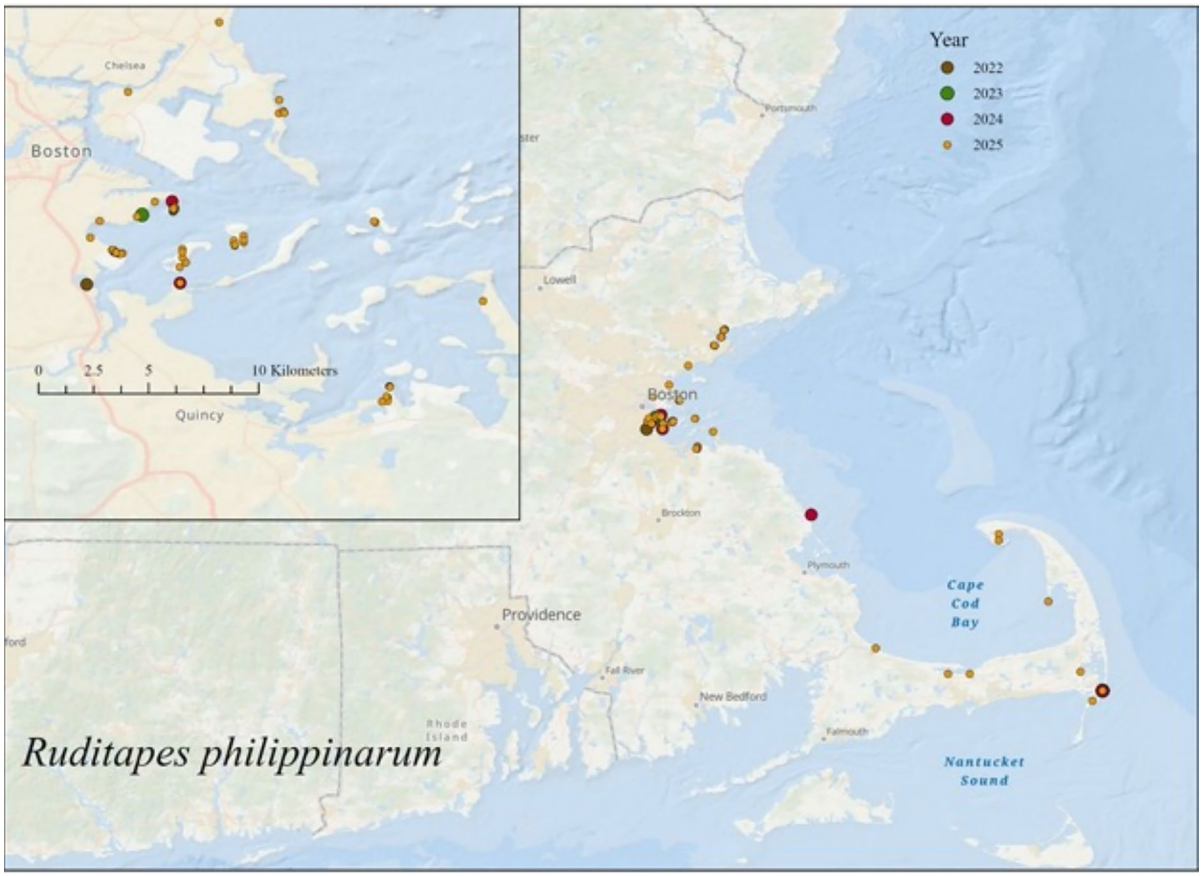

Fig. 1 Documented occurrences of *Ruditapes philippinarum* along the northeastern United States coast from 2022–2025. Colors indicate year of observation. Variable point sizes are used solely to improve visualization in areas of dense clustering (notably in 2025) and do not reflect abundance or sampling intensity

resulted in 25 live individuals (3–37 mm SL, Fig. 3a). Sieve-based sampling at Calf Pasture rendered 25 live juveniles (2–6 mm SL) using a 1 mm sieve size and 30 live individuals (500 µm–3 mm SL) using a 300 µm sieve size (Fig. 3b and c), confirming recent reproduction and recruitment. Clams across all sites were found in the first several centimeters of sediment in mixed coarse substrate (Bell et al., 2002, 2005) consisting of varying amounts of rocks, boulders, cobbles, gravel, shell, and sand.

Additional opportunistic surveys

The first observation of *Ruditapes* north of Boston Harbor was recorded by SSCW in August 2025 during routine Marine Invader Monitoring and Information Collaborative monitoring. The individual was found at Lynch Park in Beverly, MA, in the rocky intertidal portion of the shoreline, dominated by boulders and gravel. Two additional live individuals, as well as dead shells, were found in October in the same habitat at Lynch Park. These observations represent the northernmost records of live *Ruditapes* in the Northwest Atlantic, to date. The additional targeted monitoring at sites along the North Shore did not uncover live clams. Only dead shells were found at Winter Island in Salem, MA. No live *Ruditapes* or dead shells were found at the Connecticut and Rhode Island sites.

iNaturalist (iNat)

The first iNat observation of *Ruditapes* along the east coast of North America was a dead, inarticulated,

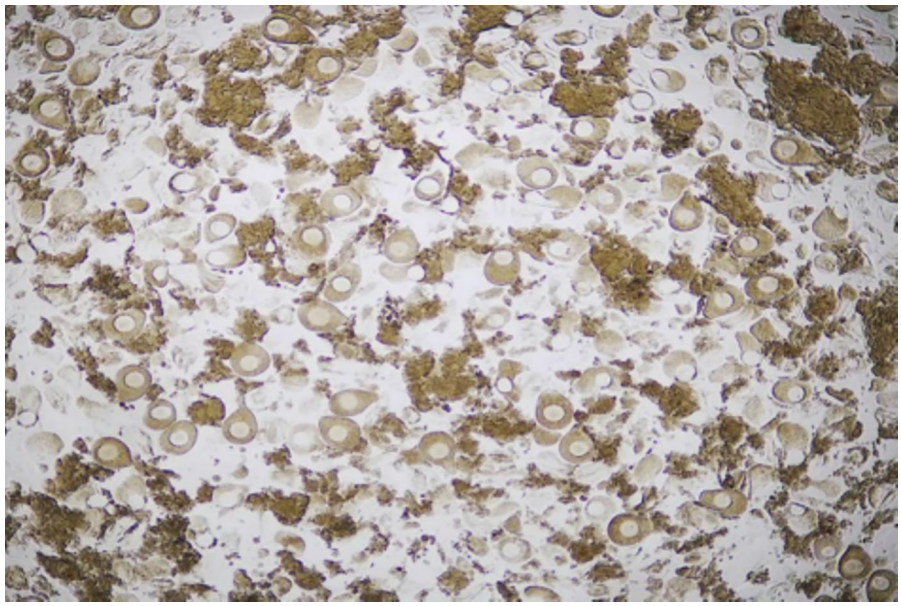

Fig. 2 Photomicrograph (100 × magnification) of female *Ruditapes philippinarum* (48.75 mm SL) collected on 29 July 2025 from Chatham, MA, showing spawning condition with ripe oocytes, alongside empty, post-spawning oocytes. Photograph by Joshua Reitsma

heavily weathered shell from Plumb Beach on Long Island, New York (NY), on 8 November 2020 (ID # 64517493). Additional observations from Long Island, NY followed, including ≥ 17 live (confirmed by observer) adult *Ruditapes*, seemingly discarded on the shore of a beach near Cold Spring Harbor in May and August of 2021 (ID # 79976331) (Fig. 4a). The first iNat record of *Ruditapes* in Massachusetts was a dead, inarticulated and heavily-weathered adult shell, observed in Dorchester Bay Basin (Boston area) on 10 August 2022 (ID # 130292949). Since then, 192 additional *Ruditapes* observations (222 individuals) have been added to iNat (as of 2 December 2025), spanning the coast of Massachusetts from Cape Cod to Salem/Beverly, with the majority of observations occurring in 2025 (Fig. 4b; note that a small portion of the iNat observations overlap with the survey dataset, 6%). Other isolated records were associated with the species being available in restaurants and markets in both Connecticut and Pennsylvania (ID # 253568665; 278107522 l; 306657664). The majority of iNat observations of *Ruditapes* were of dead shells with varied shell condition (87%) compared to living observations (13%) of both adults (10%) and juveniles (3%) (Fig. 4 c & d). No observations of *Ruditapes* were recorded from other U.S. states or eastern Canadian provinces during the study period, and a subsequent verification search on 12 May 2026 identified no live observations outside of Massachusetts.

Discussion

In this study, we used both structured and opportunistic surveys and observations from community scientists and science practitioners (e.g., shellfishers, resource managers, collaborators, and iNaturalist), to document a contemporary invasion of Manila clams, *Ruditapes philippinarum*, in eastern North America. These multiple data sources point to the conclusion that *Ruditapes* has recently become established on the Atlantic coast of North America, with Massachusetts (the Boston and Cape Cod areas) representing the epicenter of discovery for this species.

Evidence of establishment, timing of reproduction, and dispersal potential

The size distributions observed across both the Boston and Cape Cod areas, coupled with the observation of reproductively-active female clams and early settlers, indicate that *Ruditapes* is established and reproducing in Massachusetts. In Boston Harbor, individuals ranged from juveniles to adults, and targeted sediment sampling recovered newly-settled recruits (500 µm SL). On Cape Cod, more than 50 live clams have been documented across multiple towns and the dissection of a female revealed oocytes within the follicular tissue, consistent with an individual in a reproductive phase. Although growth and spawning

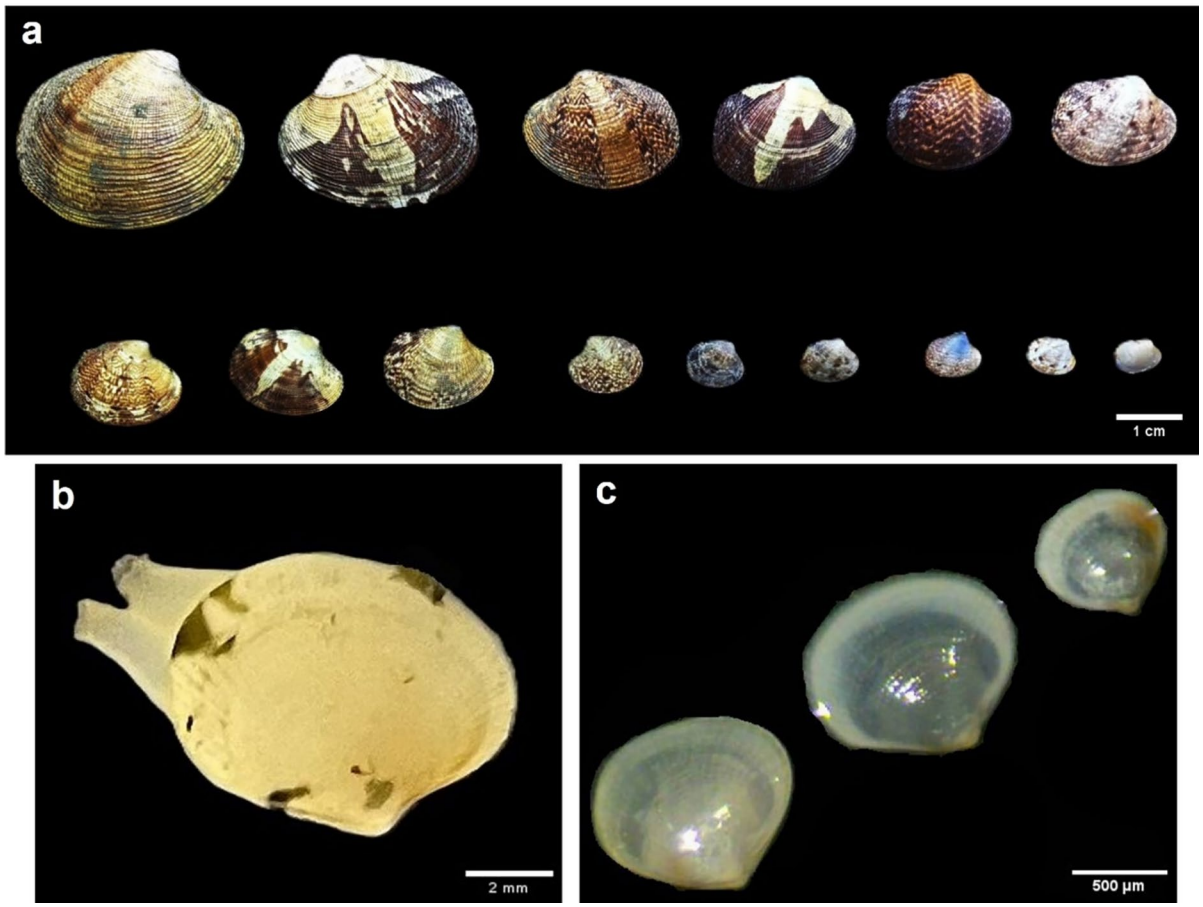

Fig. 3 Size series and early life stages of *Ruditapes philippinarum* collected from Calf Pasture Park, Boston, Massachusetts 8 September 2025. **a** size series illustrating the range of shell sizes from juveniles to the largest adults. Early life stages collected during sediment sieving including a **b** juvenile clam; **c** nepionic clams. Photographs by Carolina Bastidas

age vary across global populations (Drummond et al., 2006; Reise et al. 2024), the presence of adult *Ruditapes* across a range of sizes (up to 71 mm SL) and newly settled juveniles in 2025 point to multiple spawning events.

This evidence of recent recruitment provides important context for evaluating the timing of the species' arrival in the region. A 2023 survey of environmental DNA (eDNA) at multiple Boston Harbor sites, including areas near where *Ruditapes* is now established, detected several native bivalve species (e.g., *Mercenaria mercenaria*, *Mytilus edulis* Linnaeus, 1758) but not *Ruditapes* (Garner et al. 2025). While the eDNA data apply only to Boston Harbor, when combined with the evidence of reproduction and recruitment documented at both Cape Cod and Boston Harbor, they collectively support a recent establishment, likely within the last few years, rather than a longstanding undetected presence. In addition, opportunistic (but limited) searches in Rhode Island, Connecticut, and the North Shore of Massachusetts did not detect *Ruditapes*. Manila clams exhibit broad thermal tolerance (0–37 °C; Kamenev & Nerkrasov, 2012; Shin et al. 2000) and a wide spawning thermal range (14–26 °C; Reise et al. 2024) that much of New England now experiences throughout the summer. Given the species' rapid larval development (~ 2–3 weeks), there is ample opportunity for dispersal and spread to coastal areas both north and south of Massachusetts. In addition, we would predict that vessels moving ballast water along the

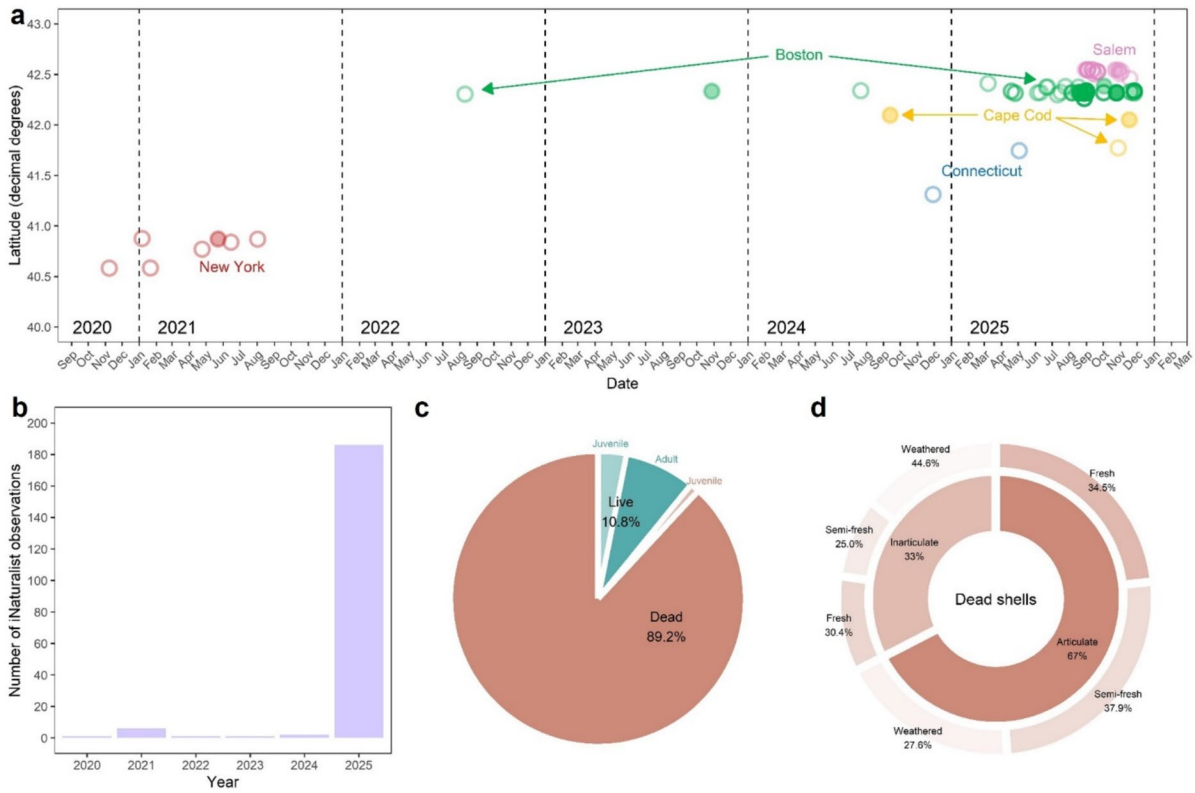

Fig. 4 iNaturalist data for eastern North America *Ruditapes philippinarum*. **a** Latitude of iNaturalist observations plotted by observation date. Points represent individual observations coloured by region. Open points indicate dead clams and closed points live clams; circles denote observations in or near marine habitat and squares denote observations away from natural habitat (e.g., along inland wooded trails, at markets or restaurants, in a parking lot, or at the observer's home). **b** Annual number of iNat observations for years in which *Ruditapes* was observed in eastern North America. **c** Proportion of observations containing live (teal) and dead (brown) clams across juvenile (light) and adult (dark) life stages. **d** Proportion of dead-shell observations by articulation (inner ring) and weathering categories (outer ring)

Atlantic seaboard may facilitate rapid jump dispersal (i.e., long distance dispersal leading to initially disjunct populations).

Potential ecological interactions

Wherever *Ruditapes* eventually spreads in the Northwest Atlantic, it will enter novel biological communities and potentially influence local ecological dynamics. In other regions, *Ruditapes* is known to outcompete native bivalve species, altering benthic community composition (Kim et al. 2020). In British Columbia, European green crab (*Carcinus maenas* (Linnaeus, 1758)), which are highly abundant in the Northwest Atlantic, prey upon *Ruditapes* (Curtis et al. 2012). As such, a similar interaction could occur here, potentially redirecting green crab predation away from native clams. Alternatively, if green crabs continue exerting predatory pressure on native clams rather than on *Ruditapes*, this could facilitate *Ruditapes'* establishment, similar to how predation on native clams aided the establishment of the eastern gem clam (*Gemma gemma* (Totten, 1834)) in California (Grosholz 2005). Consistent with *Ruditapes* as prey in other regions, several individuals from Massachusetts that we examined showed evidence of predation (Supplementary material, Fig. S1), including moonsnail (Naticidae) drill holes and chipped margins, possibly resulting from crab predation.

Vectors of introduction

There appear to be two primary vectors by which *Ruditapes* may have been introduced to the New

England coast: ballast water and the live shellfish trade. We set aside a third vector—intentional plantings of *Ruditapes* by government agencies—which led to the Manila clam's introduction to Europe in the 1980s (Humphreys et al. 2015) and, after its accidental introduction to the North American Pacific coast in the 1930s, to plantings in the Pacific Northwest (Chew 1984). We know of no such intentional agency plantings in New England.

Ballast water originating from European ports with established *Ruditapes* populations may have been discharged into Boston Harbor, a port with extensive traffic from the Eastern Atlantic (Bowen et al. 2019). Despite the implementation by the United Nations, and specifically by the United States, of ballast water management guidelines and regulations, partially treated or untreated ballast water with living plankton may still arrive in New England (Bailey et al. 2022).

A second potential means for the introduction of *Ruditapes* is the live shellfish trade (Chapman et al. 2003; Weigle et al. 2005). Chapman et al. (2003), who included *Ruditapes* among many other shellfish species, were especially prescient in their title (i.e., "Live seafood species as recipes for invasion"). Currently, mariculture-grown *Ruditapes* are readily available online, both for human consumption and for fishing bait, and are produced in substantial quantities from shellfish farms in the U.S. Pacific Northwest (U.S. Department of Agriculture, 2023). Regionally, *Ruditapes* may also be purchased in grocery stores and in bait supply shops throughout New England and New York. Once in the hands of the public, live clams may then be either accidentally lost or discarded (as bait) or intentionally but illegally planted—the latter with the idea of establishing local harvestable populations (Padilla et al. 2011). Prayer animal release (Magellan 2019; Du et al. 2024) may also be occurring, although we have no direct evidence for this in the present case.

iNaturalist observations and forensic evidence of discarded shells lend some evidence for its release, one way or another, through the live shellfish trade. Multiple iNat observations report live *Ruditapes* in markets, restaurants, and at dinner tables. Coupled with the observation of seemingly cast-off live *Ruditapes* on a beach in New York, these observations suggest that consumers in New England may be discarding live clams near habitat where the clams can establish themselves. Further, we recovered several articulated *Ruditapes* shells with distinctive marginal chip holes typically made for placing a fishhook in a clam to be used as bait. Still-living clams may then be lost during the fishing process.

The roles of community science and collaborative science

Our study highlights the importance of community science, cross-sector collaboration, and effective communication in detecting and responding to emerging marine invasions (O'Neill et al. 2025). Contributions from community members and shellfishers, together with targeted outreach and "be on the lookout" (BOLO) notifications by multiple organizations (Boston Harbor Ecosystem Network, Massachusetts Shellfish Officers Association, Northeast Regional Invasive Species and Climate Change Network, Center for Coastal Studies, and MA CZM's Marine Invader Monitoring and Information Collaborative), were essential in identifying further occurrences and prompting additional targeted search efforts across Massachusetts. These collaborative efforts have also revealed that *Ruditapes* extends beyond Boston Harbor and Cape Cod, with verified live and dead observations, as noted above, as far north as Salem Sound. Observations shared with us directly, via social media groups, and through iNaturalist also emphasize the value of community-engaged monitoring for early detection and rapid response. Our findings also demonstrate the utility of iNaturalist for invasion detection when paired with expert identification, consistent with studies from other regions showing its effectiveness in detecting novel species invasions (Hiller & Haelewaters 2019; Morrison 2024; Mason et al. 2025).

Conclusion and future research

This study provides compelling evidence that the Manila clam, *Ruditapes philippinarum*, has recently established populations in Massachusetts, completing its circumglobal distribution in the Global North. The observations presented here represent an initial detection and verification effort that combined opportunistic observations, community science records, targeted field searches, and sediment examination for early-settlers and juveniles, and provides multiple lines of evidence suggesting local reproduction and

establishment. As such, future work should involve structured sampling and seasonal monitoring to better understand the phenology and life histories of *Ruditapes* in the Massachusetts population. Ongoing long-term monitoring efforts are currently underway to quantify patterns of abundance, recruitment, and seasonal dynamics within Massachusetts populations, and to track the expansion of the Manila clam in New England. Given its reputation as one of the most successful marine invaders around the world, *Ruditapes* is likely to spread to other areas of the Northwest Atlantic. Monitoring in adjacent states and Canadian provinces will thus be integral in tracking geographic spread in the Northwest Atlantic. In addition, genetic analyses should be conducted to determine source populations and spread, and whether the clams in Massachusetts represent a single introduction and subsequent spread or multiple separate invasions.

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Author Contributions JTC, OCN, and ABP conceptualized the manuscript. JTC confirmed species identifications. OCN, JR, RH, RG, TT, and VRL contributed to data collection of Cape Cod clams. ABP, CB, IY, EFH, and DWC contributed to data collection of Boston Harbor clams. AN and AF contributed to data collection of North Shore clams. All authors contributed to iNaturalist data entry. JCC conducted curation, analysis, and visualization of iNaturalist data. MLG developed the spatial distribution map. ABP wrote the initial manuscript. All authors read, edited, and approved previous and final versions of the manuscript.

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Data availability All raw data, including URLs to iNaturalist records, data files for analysis, and annotated R code are all openly available via Zenodo at 10.5281/zenodo.18663942.

Declarations

Conflict of interest The authors declare that we have no conflict of interest to disclose.

Permits Field sampling was conducted under Massachusetts Division of Marine Fisheries Scientific Collection Permits by Salem Sound Coastwatch (Permit No. 173091 issued to AF), the Massachusetts Office of Coastal Zone Management (Permit No. 185408 issued to AN), and the Center for Coastal Studies (169784 issued to OCN).

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