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Fostering public health and academic partnerships during and beyond a public health emergency: lessons learned from COVID19

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Introduction

The COVID-19 pandemic severely strained local,state,and federal health agencies across the United States. Rapid and sometimes unexpected rises in disease transmission led to increased morbidity and mortality and associated shortages in health care staffing, testing capacity, and personal protective equipment. Modeling and advanced analytics that provided predictive information on the timing and magnitude of surges under various scenarios were urgently needed to inform public health response. However, in order to provide such insights, there were several challenges to overcome. First, prior to the COVID-19 pandemic, minimal infecti us di eas delin a existed at state, tribal, local, and territorial hea Bf) twaepartments. At a e eral level, the Centers for Disease Control and Prevention (CDC) also had limited capacity until the formation of the Center for Forecasting and Outbreak Analytics (CFA) in late 2021; even then, its capacity for locally focused modeling outputs remained restricted. Second, early in the COVID-19 pandemic, govemment systems struggled to ingest, manage, and report the tremendous volume of COVID-19 data, while data access for infectious disease modelers remained a barrier. Despite significant funding efforts by CDC and other agencies in support of data modernization and forecasting, challenges persisted for many public health agencies, including the California Department of Public Health (CDPH).

The CDPH addressed the need for infectious disease modeling expertise in Analytics Team that both leveraged existing CDPH staff and onboarded infectious disease modelers. The team was dedicated to synthesizing externally developed nowcasts, forecasts, and scenarios and producing internal modeling and analytical tools, with a major focus on the launch and development of the California COVID Assessment Tool (CalCAT, https://calcat. cdph.ca.gov/).The CalCAT compiles available nowcasts,forecasts, and scenario models for both internal situational awareness and to share with other public health agencies, health care systems, and the public. These modeling resources—especially those at the county scale—were extremely helpful for understandingnearfuture health care impacts and informing policy decisions in the face of substantial uncertainty about COVID-19 biology, epidemiology, and control measure by Virginia Polytechnic Institute and Sté

However, the CDPH Modeling and Advanced Analytics Team sometimes had insufficient staffor specific expertise to answer pressing policy questions in a short timeframe, especially when evidence in the literature was lacking. Specifically, there was a need for rapid, ad hoc modeling and expert assessment on fast-breaking topics such as the potential impact of emerging viral variants and waning immunity on transmission. Acquiring these resources within CDPH and other health jurisdictions would have required significant time and effort amidst many competing priorities during an ongoing public health emergency. In contrast, manyacademicswerealreadywellpositionedtodigcsttherapidly

multiple ways. First, CDPH engaged external public and privatesector stakeholders and citizen scientistsearly on during the COVID-19 response to iteratively develop and synthesize

Received: September I l, 2024. Accepted: January 13, 2025 modeling results and build internal capacity to interact with modeling outputs. This effort resulted in the formation of a Modeling and Advanced

The University of California Health-CDPH COVID Modeling

evolving literature on variant properties and immunity and synthesize the implications for modeling transmission and hospital burden. Therefore, CDPH recognized that its response would benefit from closer academic collaborations, including with the I()campus University of California (UC) system, a large state-based institution.

Consortium (https://modelingconsortium.ucsf.edu/), hereafter referred as the "Modeling Consortium", vvas launched in early 2021 with the backing of top leadership of both institutions to facilitate collaboration between CDPH and UC scientists on COVID-19 through 4 major areas. First, the Modeling Consortium awarded several rapid grants and contracts to UCbased investigators, enabled by state and federal funding for the pandemic response. The CDPH leadership and staff scientists provided frequent input on project progress, resulting in deliverables that were directly relevant to CDPH for pressing policy questions, including tailored nowcasts, forecasts, and scenarios that were displayed on CalCAT, as well as more traditional academic publications. [1-4] Second, the Modeling Consortium provided UC investigators access to more granular data than publicly available for rapid analysis of research questions specifically relevant to California's COVID19 situation. Although data sharing challenges persisted, this finer scale data access and ongoing alignment with CDPH and its counties may have benefited model performance. In a retrospective analysis of forecasting performance, two Califomia-specific forecasting models run by UC partners (ie, COVID NearTerm and LEMMA) outperformed the CalCAT ensemble when forecasting COVID-19 hospital census at the county level.[5-7] Third, through mutual training opportunities, UC graduate students and postdoctoral researchers interacted more directly with public health practice, and CDPH employees gained access to academic courses and cutting-edge research to further their professional development. Finally, the Modeling Consortium hosted virtual seminars and targeted small-group meetings I to 2 times each month. Each seminar combined shortformat presentations on a topic of urgent concem (eg, COVID-19 transmission in schools, masking effectiveness) followed by open discussion. These fora included dozens of scientists from across the UC system and a range of CDPH staff including the State Health Officer and State Epidemiologist who indicated that these meetings provided them with critical information to make urgent policy-related decisions and recommendations to state government leadership. The targeted small-group meetings included the CDPH Modeling Team and a core group of UC scientists who discussed the most urgent scientific questions that the CDPH Modeling Team was addressing. Three key examples that demonstrated the benefit of the Modeling Consortium were the prediction of hospital burden during emergence of the Delta and Omicron variants, discussion and synthesis of evidence around nonpharmaceutical interventions, and collaborative work on understanding COVID-19 transmission in K-12 schools.[3,6]

Several challenges to this collaboration were mitigated but not eliminated during the pandemic, and many lessons were leamedfromthisjointeffort(Table 1).ItwaschallengingforCDPH to establish data use agreements (DUAs) quickly and to subsequently

make that data one ',vay to continue to increase collaborations and improve coordination across levels and sectors. However, the feasibility and sustainability of such an approach is not certain, as the COVID19 pandemic response facilitated funding this type of collaboration in an unprecedented way. State, territorial, local, and tribal (STLT) governments are generally not in a position to provide such funding, but funding bodies should consider alternative mechanisms wherein STLTs can help shape grant priorities and deliverables rather than being more passive partners. Building internal capacity for modeling infectious diseases within CDPH was also a key feature in promoting crosssector communication and collaboration; the CDPH Modeling Team played a key role in translating requests from leadership to academic partners and synthesizing evidence from academic deliverables for leadership, thus amplifying the ability of partners to influence policy decisions and resource prioritization. Our experiences working together have demonstrated tangible benefits for both sides: academic trainees better understood and contributed to applied public health practice, and research was catalyzed to have real-world impact in the hands of practitioners and policymakers. Additionally, govemment workers were informed about cutting-edge research,while learning methodologies and approaches from academic colleagues. This training fostered workforce development and employment opponunities in public health that benefited CDPHandpublichealthmorebroadly.Expandingacademicincentives for this sort of public service and supporting publication of research for academic and public health scientists will support ongoing parmerships.

A key overall question is: what parts of the Modeling Consortium, and academic-public health modeling partnerships in general,should be preserved and fostered for work on current and emerging public health issues as well as pandemic preparedness going forward? CDPH occupies a unique and privileged position in having access to multiple world-class universities within the state of Califomia.Since the number of public health jurisdictions greatly exceeds the number academic centers with expertise in infectious disease modeling, national and regional coordination will be necessary for optimizing the performance and impact of such collaborations. Some of this work is just beginning through national scenario modeling and forecasting hubs, as well as dedicated efforts such as the National Outbreak Analytics & Disease Modeling Network (Insight Net). More work is needed to make sure that such collaborations are benefiting jurisdictions across a range of capacities and experience in infectious disease modeling. As others have suggested, highfrequency, real-time outbreak analyses are well-suited tasks for in-house modeling teams.[8] Therefore, modeling pipelines and tools should be built in a

available to academic investigators in re tbownföadeå tim P o personnel i irom ionin fitt dat Kine andand generalizable .way that can be further customized / to Virginia local health Polytechnic public contextInstitute and Ste maintaining data pipelines requires health department for improved performance,as circumstances allow.resources not traditionally covered by grants and other funding mechanisms. Future efforts should include support for this necessary aspect of collaboration with contingencies for changes in data sharing depending on whether a statewide public health emergency declaration order is in effect. Health departments should also be encouraged to engage in robust and ongoing data govemance practices, so that data sharing questions can be quickly evaluated and approved when needed. Another key challenge was that incentives in state government and academia were not initially aligned; cooperation depended on both academics and CDPH setting aside other activities to focus on California's COVID-19 response. Modeling Consonium academics set aside or delayed writing publications to focus on providing model forecasts that were displayed on CalCAT, updated daily, and could be adjusted in response to feedback from CDPH leadership. The mutual engagement and singular focus in the early pandemic years paid large dividends but were unsustainable at that level beyond the crisis phase of the pandemic.

The most important outcome of the Modeling Consortium was stronger collaborations—trust, partnerships, and networks— between state-based academic and government institutions that are both focused on serving the health and well-being of Californians. Funding academics to work directly with a state health department on locally important public health problems is

Table 1. Modeling consortium successes, challenges, and opportunities in preparedness and response activities.

	Preparedness	Response
Accomplished	Stronger trust, partnerships, and networks between academics and govemment staff	Collaboration on emerging topics
	Increased internal CDPH capacity for advanced modeling and analytics	Regularly scheduled seminars and targeted small-group meetings for exchange of ideas and infonnation
	UC system academic training opportunities for CDPH staff	Funding ofrapid grants and contracts for UC investigators with ongoing engagement with project deliverables from CDPH staff
	Applied public health training opportunities for academic trainees	Generation of tailored nowcasting/forecasting/scenario deliverables specific to California context
Needs improvement		Sharing more granular data for UC investigators via secure server
	Rapid deployment of data use agreements	
	Health department personnel and capacity for data pipeline maintenance and provisioning	Faster engagement in cryptic phase
		Engagement with broader interdisciplinary fields
	Incentives for public health service for academics	
		Better mechanisms for sharing data with academic collaborators in real time with and without a public health order in effect
		Sustainability of collaborative pandemic response

To support this approach, many Modeling Consortium investigators participated in the national modeling hubs, and the CDPH Modeling Team engaged in dialogs with researchers about tooling that could be used by other jurisdictions.

Pandemic and public health emergency preparedness are widely shared priorities across sectors and jurisdictions. The successes of the Modeling Consortium in California during the COVID-19 pandemic highlight the potential value of synchronized academic-govemment partnerships in the face of new public health threats. Increased internal public health capacity for modeling and analytics, more rapid data sharing frameworks, fundingmechanismstoenable rapidsupportfor academicefforts, and incentives to facilitate close coordination between academic and government institutions will enable a better evidence-based public health response in California and throughout the United States during the next public health emergency.

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Conflict of interest

The authors declare no conflicts of interest.

Disclaimer

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mass of adult females; Beltran et al., 2022; Haley et al., 1994), male offspring are on average only 7%—8% heavier than females at the time of weaning (Le Boeuf et al., 2019). This difference in maternal allocation may be too small to be substantially influenced by maternal age. If elephant seals do adaptively modify offspring sex ratios, environmental conditions appear to be more influential than maternal age (Kretzmann et al., 1993; Lee & Sydeman, 2009).

Declining foraging efficiency with age is one mechanism for reproductive senescence (Lecomte et al., 2010). If older seals need additional foraging time to meet energy demands for maintenance and reproduction, then a greater portion of their annual cycle would need to be allocated to foraging trips. Since the breeding haul out is highly synchronous (Beltran et al., 2022), we hypothesized that older seals would reallocate time from the moulting haul out to foraging. However, the moulting haul out duration did not significantly change among females 11 years old and older. If seals skip breeding more often as they age, but are not altering their annual cycle, that suggests that the haul out durations are already as short as is physiologically possible. Skipped breeding may therefore become increasingly necessary with advanced age to reset seals' annual cycles.

5 | CONCLUSIONS

Northern elephant seals exhibit both fertility and maternal effect senescence. The rates of decline for these two processes (i.e. how rapidly fertility and offspring survival decline with maternal age) were not different from each other. Theory predicts maternal effect senescence should evolve to be more rapid than fertility senescence (Moorad & Nussey, 2015); similar analyses with larger sample sizes and more species are necessary to fully test this hypothesis. Furthermore, maternal effect senescence had a substantially larger impact on offspring production than fertility senescence. Although maternal effect senescence is relatively understudied, it appears to be highly prevalent, as it has been detected in 93% of studied populations (Ivimey- Cook & Moorad, 2020). Our results show that population growth rates for age- structured populations may be overestimated if only fertility senescence is considered.

AUTHOR CONTRIBUTIONS

Roxanne S. Beltran, Allison R. Payne and Patrick W. Robinson conceived the ideas and designed methodology; Allison R. Payne, Patrick W. Robinson, Cara M. O. Munro, Kelli Ong, Adrien Bastidas, Alegra O. Negrete, Brecken Theders, Bryn Stillwell, Danissa Coffey, Elijah Schweitzer, Elise Baugh, Jasmine Salazar, Keenan Chau- Pech, Mason Rodrigues, Mimi Chavez, Savanna Wright, Sofia Rivas, R Condit, Joanne Reiter, Daniel P. Costa and Roxanne S. Beltran collected the data; Allison R. Payne, Max F. Czapanskiy, A. Marm Kilpatrick and Roxanne S. Beltran analysed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to disclose.

DATA AVAILABILITY STATEMENT

Data and code available from the Dryad Digital Repository https://doi. org/ 10. 5061/ dryad. pg4f4 qrxl (Payne et al., 2024). Code is also available on GitHub (https://github. com/allis onpay ne/ seala ging).

ETHICAL APPROVAL

All research procedures were conducted under the National Marine Fisheries Service (NMFS) marine mammal permits 23188, 19108 and 14636. Animal care was authorized through the University of California, Santa Cruz Institutional Animal Care and Use Committee (IACUC). All projects were approved by the California State Park System and the University of California Natural Reserve System.

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Figure S2. Comparison of the coefficients (estimate and 95% Cl) for age, among post- senescent animals, for HI (fertility senescence) and H2a (offspring survival) for the base model and models including selective appearance, selective disappearance, or both. Figure S3. The probability that an animal was observed decreased throughout the animal's lifetime. Table Sl. Covariates for all models (fertility senescence, maternal- effect senescence, sex ratio, and phenology).

Table S2. Results for quadratic models.

Table S3. AIC comparisons of the quadratic and breakpoint models for the analyses with significant results (HI, fertility senescence and H2a, offspring survival). Both models have the same number of degrees of freedom. Table S4. AIC weights for threshold ages 6—14 for each hypothesis using the breakpoint model.

Table S5. Fitted model for HI (fertility senescence). Table S6. Fitted model for H2a (maternal effect senescence: offspring survival).

Table S7. Fitted model for H2b (maternal effect senescence: offspring recruitment).

Table S8. Fitted model for H3 (offspring sex ratio).

Table S9. Fitted model for H4 (phenology).

Table SIO. Fitted models accounting for selective appearance, disappearance, and combined for hypotheses with significant results (HI and H2a).

Table Sll. Fitted model for biological age.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article. Figure Sl. Coefficients for analyses with different threshold age breakpoints on a log scale.