CHANS: The Characteristics of Cost-Effective Policy Responses for Harmful Algal Blooms

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A growing concern for coastal management is the choice of appropriate human responses (public and private) to harmful algal blooms (HABs) as a marine natural hazard.

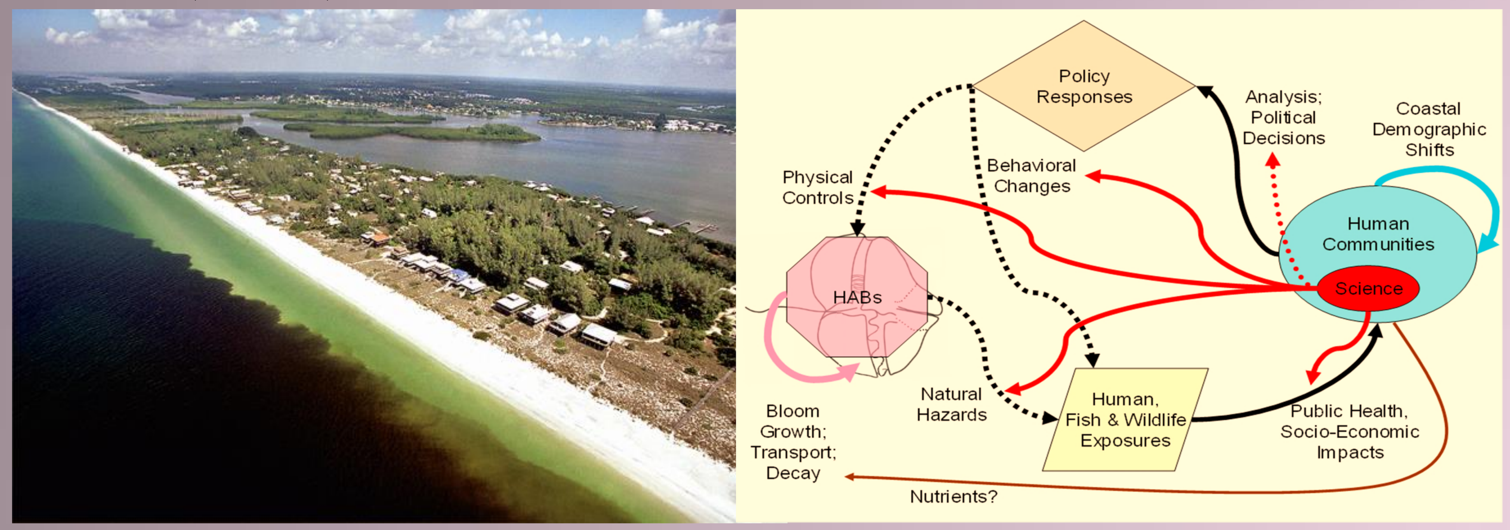

Fig. 1: A stylized representation of a coupled human and natural system (CHANS), comprising linked dynamic natural and human systems. For the case of Florida red tides, involving blooms of *Karenia brevis*, humans, and the ecosystem services upon which they rely, may be adversely impacted by the release of brevetoxins. In turn, humans devise and implement policies to respond to these hazards, aiming to mitigate their effects.

As one form of policy response, scientific research has been devoted to understanding the natural dynamics of HABs, including their distributions in space and time, their ecological roles, and their toxic effects, among others. Funding for scientific research may be motivated by bloom occurrences, following blooms at a lag.

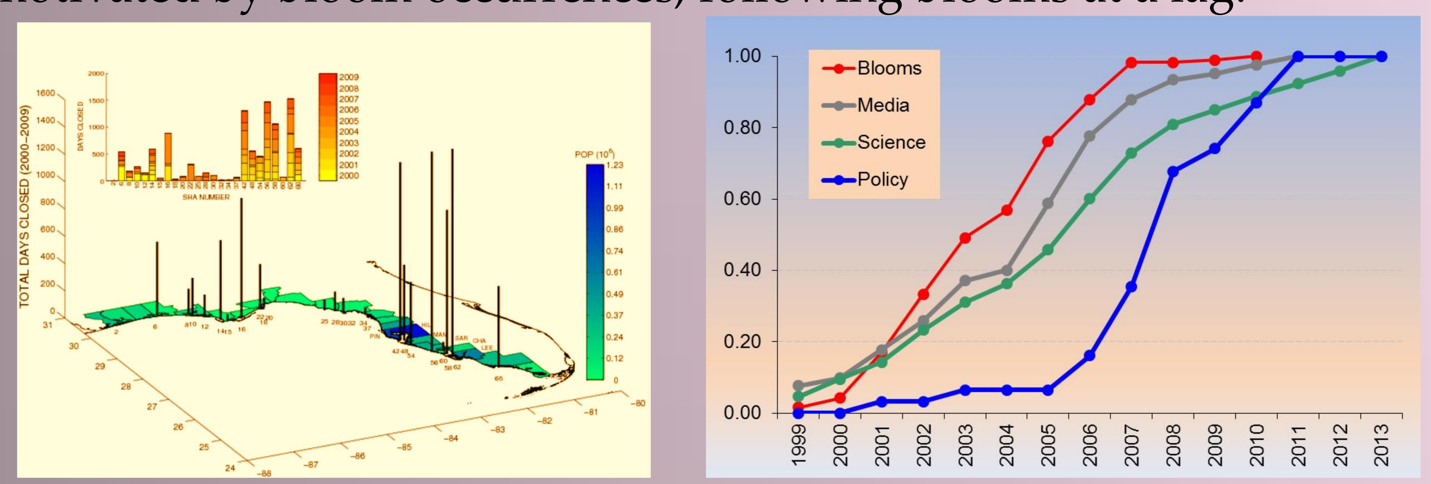

Fig. 2: On the left, the spatial and temporal distributions of Florida red tides. On the right, we find that measures (cumulative indexes) of human responses to Florida red tides (red) are lagged in time, including media coverages (gray), scientific research (green), and the implementation of public policies (blue).

Importantly, several new types of public health, environmental, and socio-economic impacts now are beginning to be revealed, including human gastro-intestinal and potential neurological illnesses; morbidities and mortalities of protected species, including manatees (Fig. 3), cetaceans, and sea turtles; increased numbers of hospital emergency room visits for the elderly; increased respiratory morbidities in workers, such as beach lifeguards; and potential reduced K-12 school attendance.

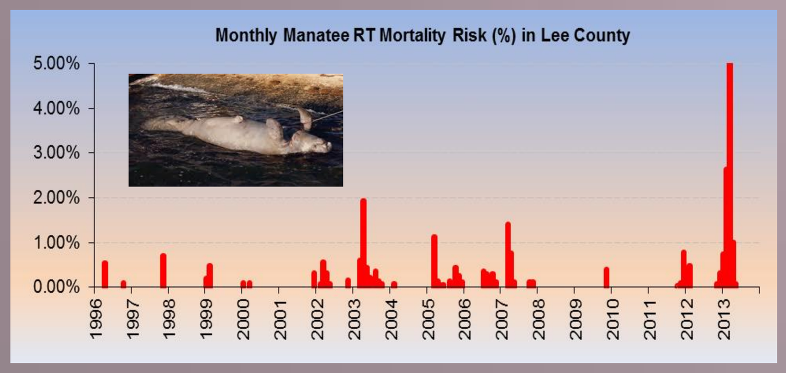

Fig. 3: Impacts of Florida red tide include those affecting human health (morbidities) and protected species (morbidities and mortalities). After controlling for increasing populations, we find that mortalities of the endangered West Indian manatee (*Manatus trichecus*) are the joint consequence of cold water temperatures and blooms of *K. brevis*.

Significant efforts have been directed at identifying potential management actions, including actions to prevent, control, or mitigate blooms. There are several critical points at which humans can intervene in an attempt to lessen the effects of blooms. All involve costs of implementation; most involve reductions in health impacts. ***Policy effectiveness***, or the extent to which human impacts are lessened upon implementation of a policy is a critical parameter.

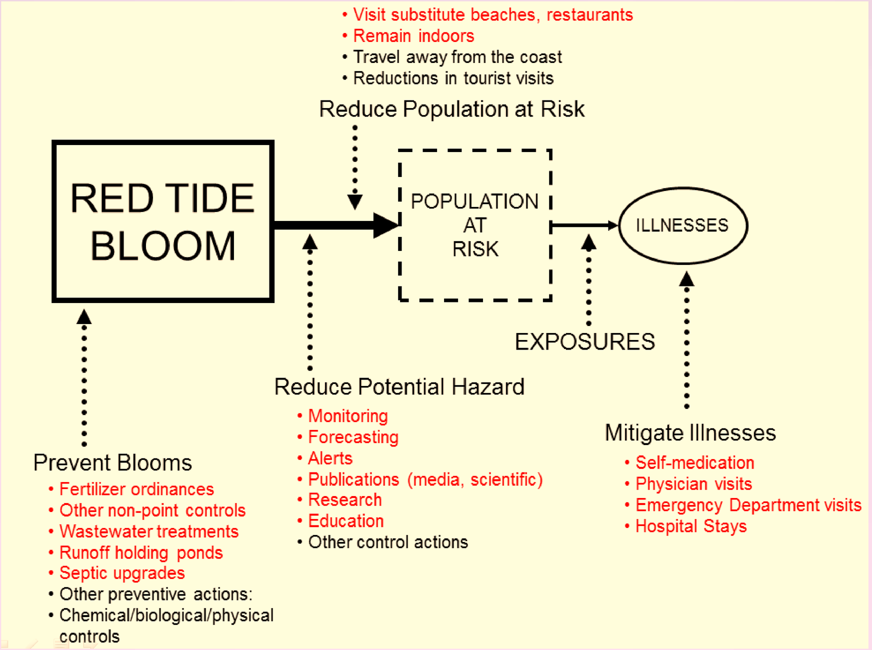

Fig. 4: Points of policy intervention. Current policy responses to blooms of Florida red tide are identified in red. The effects of policies to reduce blooms are highly uncertain. Policies to reduce the potential hazard can lead to actions to reduce the human population at risk, thereby lessening both health effects and, potentially, the costs of intervention.

Using blooms of Florida red tide (*K. brevis*) as a case study, we have developed an analytical decision framework for the choice of policy responses to HABs. Given the large array of feasible polices and steep information requirements, the framework can be cumbersome to implement. A simplified version of the framework can be used for pairwise policy comparisons.

$$\min_{P} \sum_{t} \left\{ c_t(I_t, \Gamma_t(P)) I_t + \sum_{t} w_{tj}(P_{tj}) \right\} (1+r)^{-t}$$

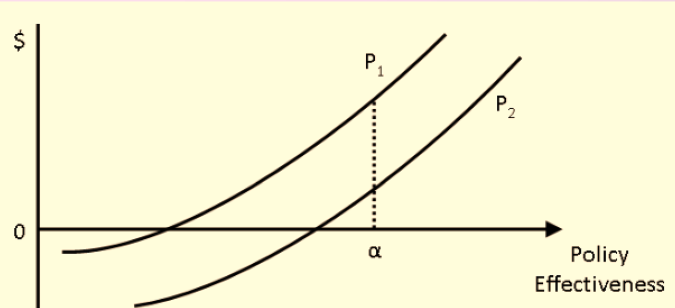

Fig. 5: An analytical framework for the selection of cost-effective policies involves the choice of a set of policies, *Γ(P)*, to minimize the discounted costs of the sum of human health effects, *I*, and implementation costs, *w*. In the diagram on the right, net economic benefits of policies are represented as a function of effectiveness. For any given level of effectiveness, α, Policy 1 is preferred to Policy 2.

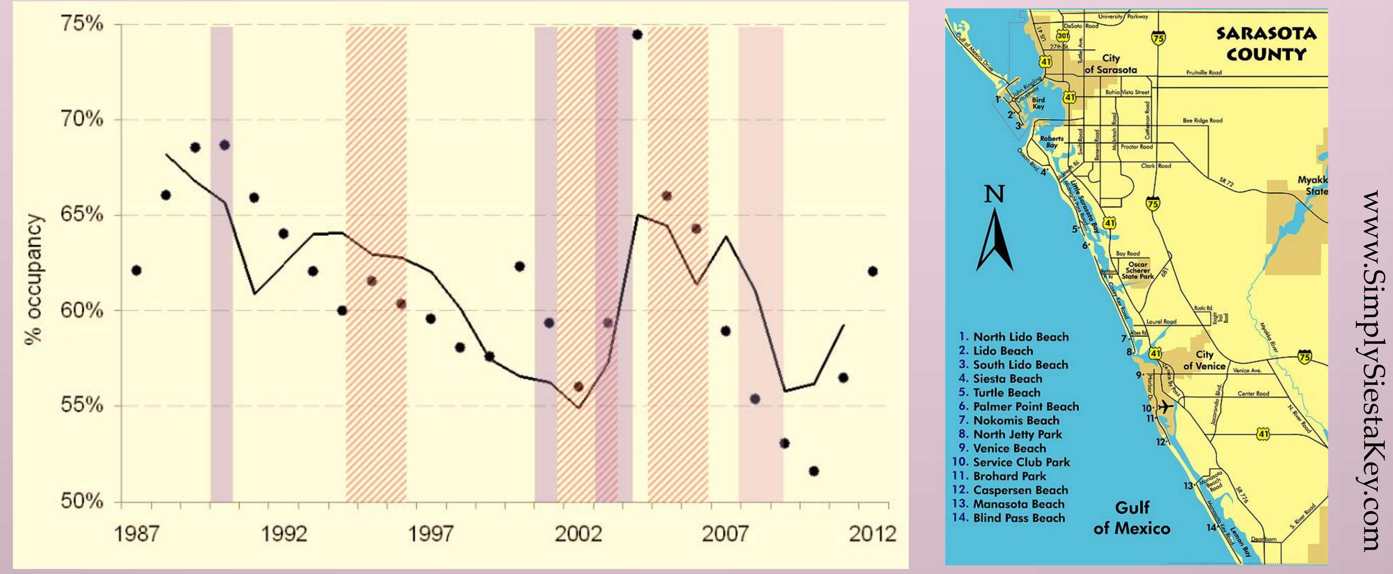

Fig. 6: Common perceptions are that Florida red tides lead to declines in coastal tourism, now the largest industry in Florida. At a regional (county) scale, we find that percent hotel room occupancy (a measure of coastal tourism, here for Sarasota County) is more sensitive to periods of economic downturns (purple bands) than to periods of red tide (pink bands). The line is a prediction from a multiple regression model.

One reason why tourism appears relatively unaffected at a regional scale may be the wide range of recreational opportunities available to Florida visitors. In such a case, policies involving a combination of environmental monitoring and public education and information provision may be optimal responses to the hazard.

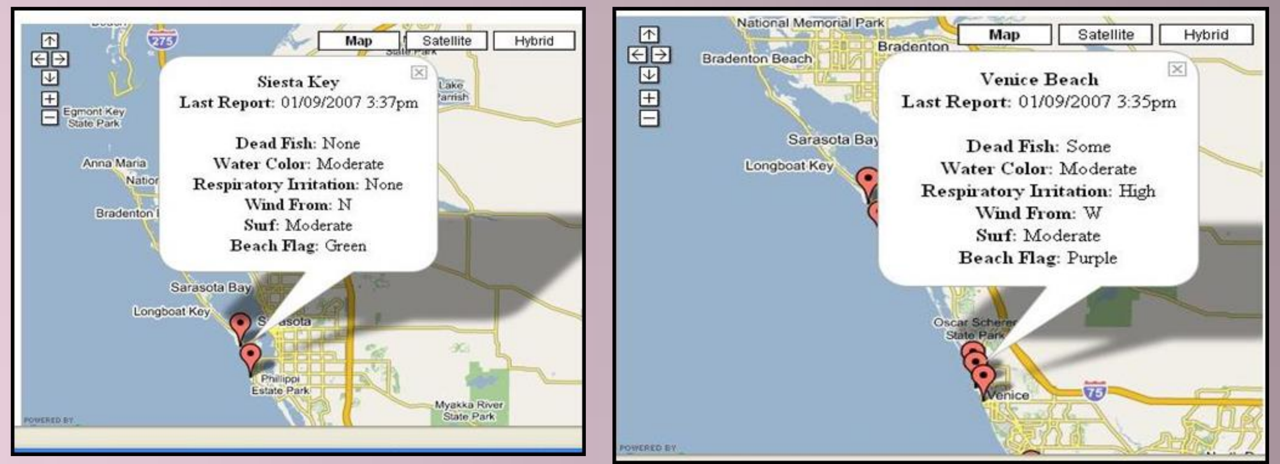

Fig. 7: The Southwest Florida Beach Condition Reporting System (BCRS), an environmental monitoring and public information program, is an example of a type of optimal policy response to the natural hazard comprising HABs. In this figure, outputs from the system on the same day and at the same time report high respiratory irritation, indicating a bloom of Florida red tide, at Venice Beach and no respiratory irritation at Siesta Beach, just to the north. The availability of this information allows tourists (and residents) to make informed choices in real time about where to recreate.

In the face of significant ongoing scientific uncertainties, and given estimates of impacts, we argue that likely optimal policies comprise:

- **Expanding the funding of and stabilizing scientific research programs and environmental monitoring efforts;**
- **Developing and implementing education programs for both residents and tourists; and**
- **Communicating the physical aspects of blooms to the public in a timely fashion.**

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