Ocean Acidification as a Priority in Mexico:

What we each need to know about how to understand, measure, and respond to this threat to food security, tourism, and natural storm resilience

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Ocean chemistry is changing, and what is needed is regional monitoring, capacity building, and transfer of technology to understand regional conditions and concerns, including shellfish, conch, spiny lobster, and coral reefs.

Ocean acidification poses a significant threat to the marine resources, food security, economic activities, and thus the jobs that depend upon them within Mexico.

What is The Ocean Foundation?

- The Ocean Foundation (TOF) is the only community foundation for the ocean
- Our mission is to support, strengthen, and promote those organizations dedicated to reversing the trend of destruction of ocean environments around the world

TOF's International Ocean Acidification Initiative

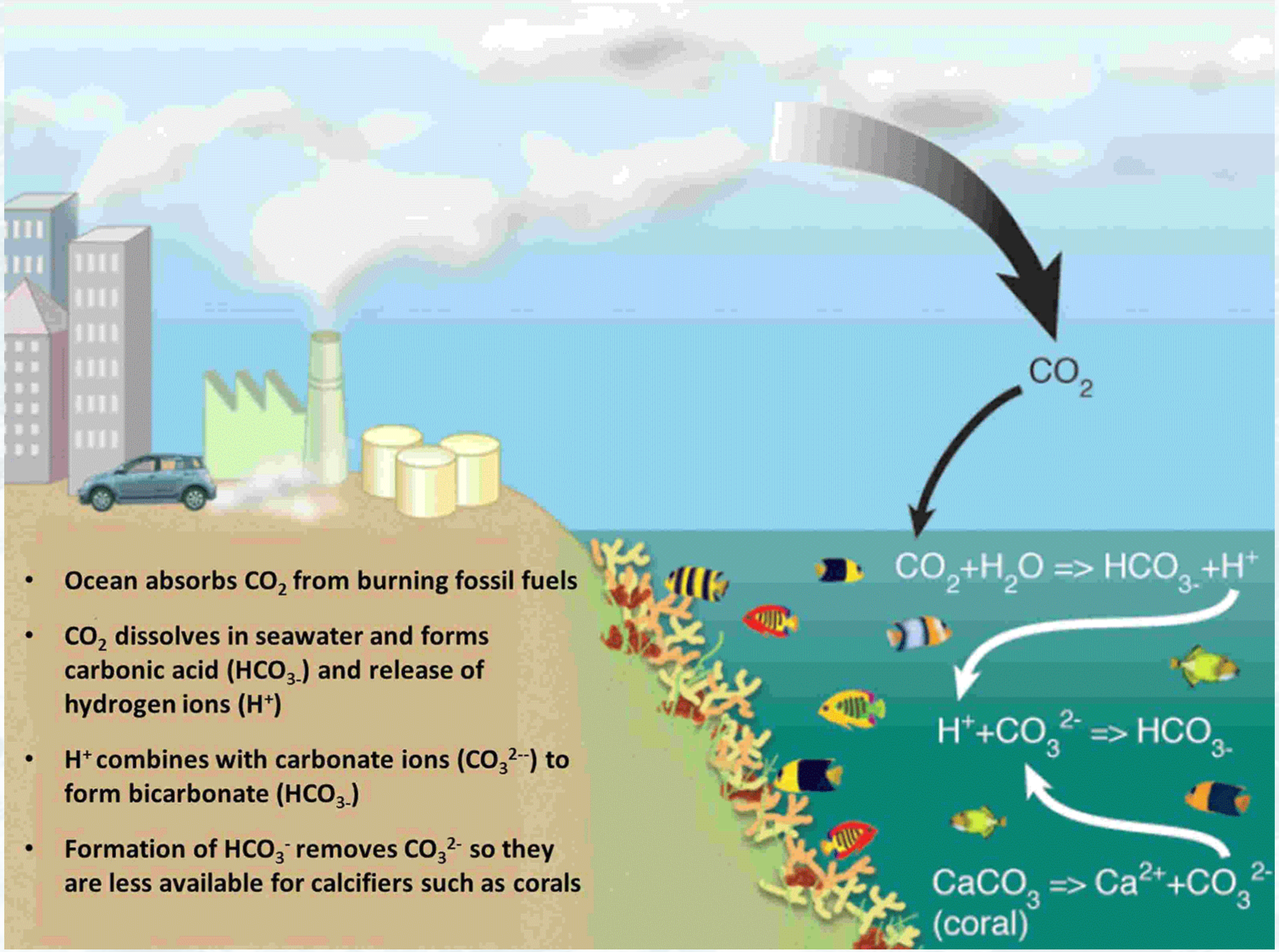
- Founded in 2003 to help vulnerable human communities understand changes in ocean chemistry, monitor the changes in their waters, assess the risks to their social and economic health, and address the effects with good policy based on strong science

What is Ocean Acidification?

Summary of OA Science

- Well documented, progressive increase in the acidity of the ocean
- Acidity increases as the pH decreases
- OA is also changing seawater carbonate chemistry. The concentrations of dissolved CO_2, hydrogen ions, and bicarbonate ions are increasing, and the concentration of carbonate ions is decreasing

We Are Changing Ocean Chemistry

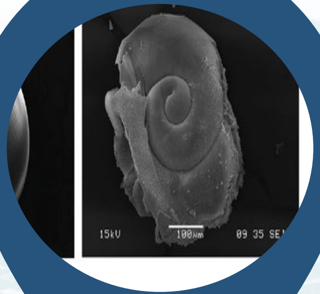


- The ocean absorbs approximately 1/3 of the CO_2 emitted into the atmosphere → more CO_2 in the atmosphere, more CO_2 in the ocean
- There is nothing in the historical record that equals our current rate of change in pH of the ocean
- Like climate change, caused primarily by carbon emissions and variable across space and time

Lack of Predictability

- OA (like rising sea levels, increased sea surface temperatures, increases in pollutants, and other physical disruptions) impacts ecosystems in a dynamic and non-linear way
- OA changes daily and seasonally
- Each marine organism and habitat structure will react to the varying impacts of OA differently, leading to some “winners” and some “losers”
- These different reactions will change both community and ecosystem structure in unpredictable ways

Ecosystem and Species Impacts



Direct Mortality

E.g. due to net dissolution or inability to form feeding parts in shellfish

Loss of Function, Fitness, or Quality

E.g. sensory disruptions, change in protein composition of species, change in reproduction

Food Web Impacts

Loss of key links in the food web

Loss of Biodiversity

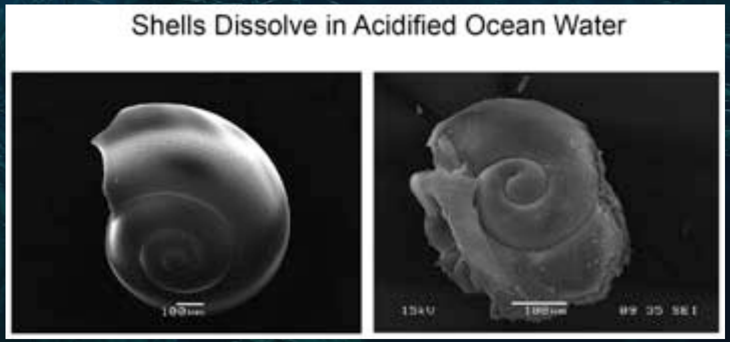
Unstable or new ecosystem regimes

Marine Food Chain

- OA affects the very base of the food chain: the krill and pteropods that bigger fish feed on that, in turn, allow them to grow big enough for human consumption.

- Studies estimate that by 2050, pteropods may be unable to form their calcium carbonate shells.[1]

- Eradicating the base of the food chain will have rippling effects throughout the food webs that depend on them.

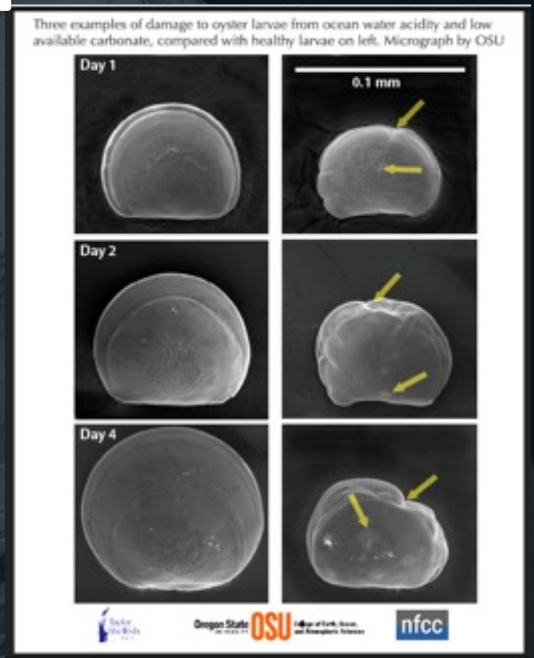


Healthy pteropod shell (left) and degraded pteropod shell due to OA (right). Source: NOAA

[1]Orr, J. C., et al. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature*, 437: 681-686.

Mollusks

- Mollusk: soft-bodied animals that typically have external shells, including oysters mussels, clams, and crustaceans.
- Mollusks and crustaceans show negative responses to acidification at various life stages.
- Scientists at James Cook University found that significant mortality in juvenile giant clams occurred at projected pH levels for 2050 & 2100.
- Scientists at Stony Brook University found that the larvae of bay scallops and hard clams grow best at pre-industrial pH levels, while their shells corrode at projected pH levels for 2100.[1]
- In the Pacific Northwest, oyster larvae death has been linked to the upwelling of acidic water.[2]
- Mollusks and crustaceans comprise 22.8% and 9.7% of the global marine catch, respectively, representing $15.857 billion and $30.864 billion.[3]



Three examples of damage to oyster larvae from ocean water acidity and low available carbonate, compared with healthy larvae on left. Micrograph by OSU.

[1]Talmage, S. C. and C. J. Gobler. 2009. The effects of elevated carbon dioxide concentrations on the metamorphosis, size, and survival of larval hard clams (Mercenaria mercenaria), bay scallops (Argopecten irradians), and Eastern oysters (Crassostrea virginica). *Association for the Sciences of Limnology and Oceanography*. 54(6), 2072-2080. doi:10.4319/lo.2009.54.6.2072

[2] Grossman, E. (2011). *Northwest Oyster Die-offs Show Ocean Acidification Has Arrived*. Yale 360.

[3]*The State of World Fisheries and Aquaculture: Opportunities and Challenges*. Rome: Food and Agriculture Organization of the United Nations, 2014. Print.

Jellyfish

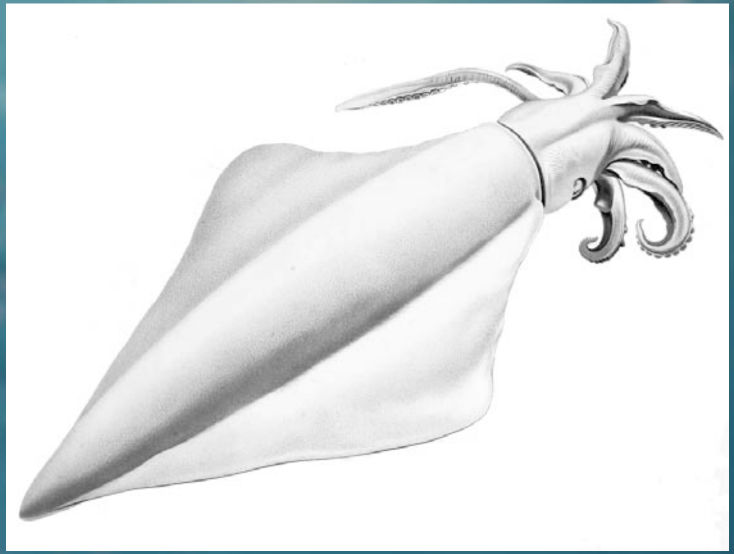
- Decreased ocean pH has been tenuously linked with increased jellyfish numbers, but it is unclear if a more acidic ocean is the direct cause.[1]
- Regardless, it appears that OA does not harm jellyfish reproduction or development as it does for many other marine organisms.[2]
- Being a key predator in pelagic systems, jellyfish affect the abundance of zooplankton, fish larvae and eggs (affecting fish population recruitment).

[1]Attrill, M.J. et al. 2007. Climate-related increases in jellyfish frequency suggest a more gelatinous future for the North Sea. *Limnol. Oceanogr*. 52, 480-485.
2Winanas, A. K., and J. E. Purcell (2010). Effects of pH on asexual reproduction and statolith formation of the scyphozoan, Aurelia labiata. *Hydrobiologia*, 645:39-52.

Squid

- Squid use a form of high-energy jet propulsion that requires them to consume large amounts of oxygen.

- Increased ocean acidity may inhibit squid’s ability to transport such large amounts of oxygen, impeding their hunting and survival behaviors.

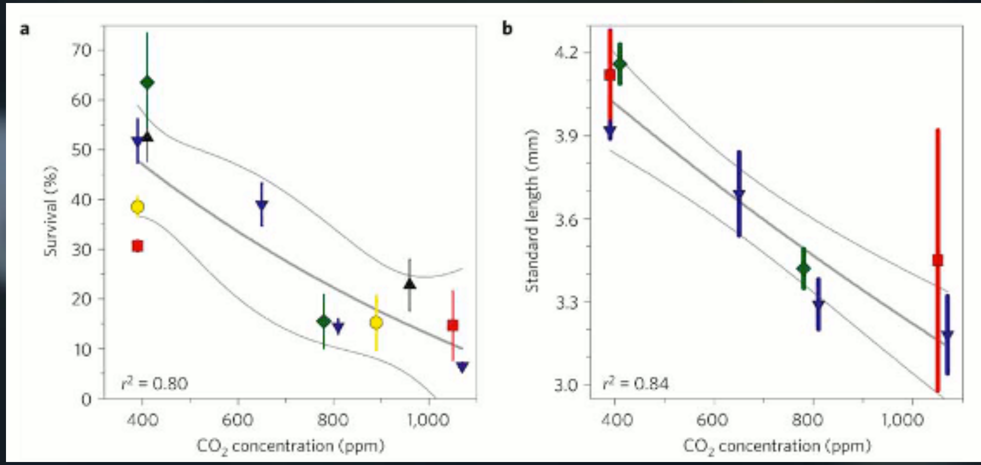


- A loss of squid would affect the commercial species that feed on it (tuna and swordfish) and would hurt the squid fisheries in the Gulf of California.

- Squid are a large food source for many toothed whale species: Sperm whales eat an estimated 220 billion pounds of squid per year.

Fish Biology

- Studies with clownfish larvae raised in a lab show that they lose their ability to both sniff out predators and find their way home when ocean pH drops below 7.8.[1]
- Similar studies show fish may have orientation problems due to variable otolith growth rates caused by OA.[2]
- Multiple studies show that decreased pH may be fatal to several fish species at various stages of their life cycle.[3]



Increased mortality (a) and shortened length (b) of fish larvae (inland silverside) with rising CO_2. Each color and shape represents a different experiment. Points represent means ±1 standard deviation. Source: Baumann (2011).

[1]Munday, P. L. et al. 2009. Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. *Proceedings of the National Academies of Sciences*. 106(6): 1848-1852. doi:10.1072/pnas.0809996106
[2]Checkley, D.M. et al. 2009. Elevated CO2 enhances otolith growth in young fish. *Science*. 324, 1683.
[3]Baumann, H. et al. 2011. Reduced early life growth and survival in a fish in direct response to increased carbon dioxide. *Nature Climate Change*. 2:38-41. doi:10.1038/nclimate1291
[3]Frommel, A. Y. et al.2011. Severe tissue damage in Atlantic cod larvae under increasing ocean acidification. *Nature Climate Change*. 2: 42-46. doi:10.1038/nclimate1324

Coral Reefs (As Fish Habitat)

- In a 2011 study of coral reefs off Papua New Guinea, scientists found that when pH dropped to 7.8, reef diversity declined by as much as 40%.[1]
- One study estimates that reef-building corals and calcifying macroalgae will calcify up to 50% less relative to pre-industrial rates by the middle of this century.[2]
- A loss of reef building organisms threatens both the geological and biological identities of coral reef ecosystems.

[1]Fabricius, K. E. et al. 2011. Losers and winners in coral reefs acclimatized to elevated carbon dioxide concentrations. *Nature Climate Change*. 1, 165-169. doi:10.1038/nclimate1122
[2]Kleypas, J.A., and C. Langdon. 2006. Coral reefs and changing seawater chemistry. 73-110 in *Coral Reefs and Climate Change: Science and Management*. J.T. Phinney, W. Skirving, J. Kleypas, and O. Hoegh-Guldberg, eds, American Geophysical Union, Washington, DC.

Seagrasses (and Fisheries)

- Certain habitats and species of seagrass might “benefit” from increased CO^2 concentrations in seawater.
- Seagrasses sequester carbon dioxide and may now be able to thrive in areas beyond their historic range.
- However, many juvenile animals that live in seagrass habitat will be negatively affected.

Photo Credit: Heather Dine, NOAA

Social and Economic Impacts of Ocean Acidification

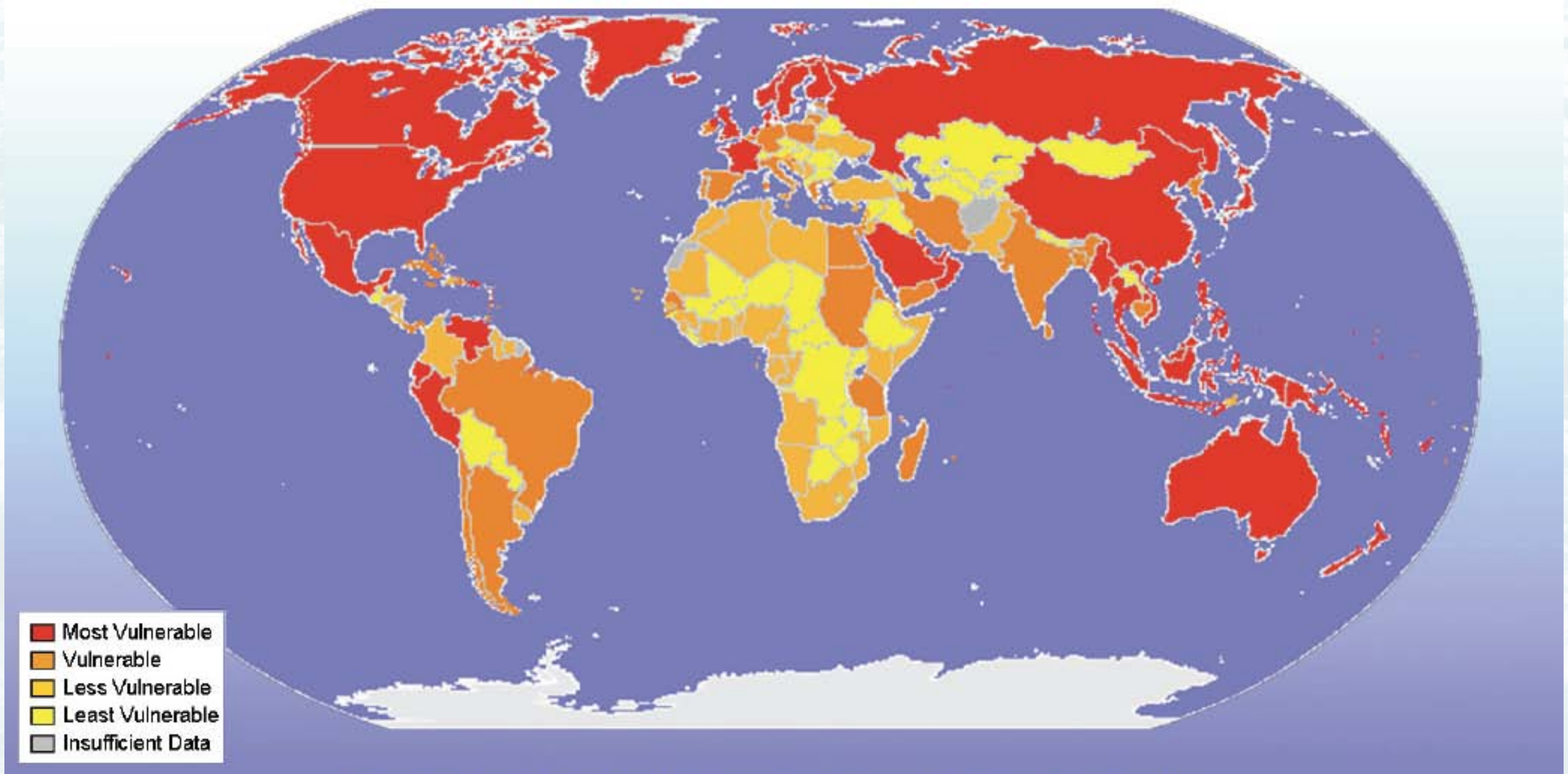
Social & Economic Activities at Greatest Risk

- “Small scale fisheries and mariculture…;
- Poorer communities and social groups dependent on subsistence fisheries, with potential gender inequalities;
- Economies reliant on aquaculture or threatened ecosystems, such as coral reefs;
- Poorly diversified local economies.”

What's at Risk?

- Ecosystem integrity
- Fisheries
- Food security
- Trade and commerce
- Tourism and infrastructure
- And many more activities…

More than a third of the world's population will be strongly affected by acidification



Most Vulnerable to Least Vulnerable Nations to Ocean Acidification

Ranked nations were placed in the four categories of Most Vulnerable (red), Vulnerable (deep orange), Less Vulnerable (orange), and Least Vulnerable (yellow). Each category represents a quarter of the nations studied, hence the "Most Vulnerable" counties are those that fell in the top 25 percent.

Social and Economic Impacts

Direct Harvest

Shellfish harvesters, fishers, pearl farmers

Ecosystem Services

Physical protection, tourism income, cultural value

Business and Community Services

Services and infrastructure built on or made possible by the industry

Food and International Security

Provision of protein, stability through stable food supplies

What's at Risk?

Seafood Jobs, Income, and Tax Revenue

Ocean acidification threatens the prosperity of all nations that catch, farm or eat fish, or depend on coral reefs for food

- Food Security Disruption
  - Need for more imports
  - Forced Migration (refugees)
  - Community Life Disrupted (political instability
- According to the FAO, in Mexico “Fishing and aquaculture are issues of national security, and essential sectors for the economic and social well being of the country.”
- Job Loss and Loss of Revenue
  (commercial fishing, artisanal, and aquaculture)

Vulnerable Fisheries in Mexico

- In 2016, Mexico had more than 294,000 fishers and fish farmers, making up a significant part of the workforce (FAO).[1]
- In 2017, aquaculture production in Mexico produced 157,388 tons of crustaceans and mollusks in marine areas. This production is valued at US $647,049,000 (FAO).[2]
- Wild capture of crustaceans and mollusks in marine areas of Mexico resulted in 309,813 tons (FAO).[3]

[1] FAO (2018). *The State of World Fisheries and Aquaculture 2018- Meeting the sustainable development goals.*
[2] FAO (2017). *Online Query Panel.*
[3] *Ibid*

What’s at Risk?

Tourism and Infrastructure

Ocean acidification threatens the health of all nations that depend on coral reefs for tourism or storm protection

- Decline of coral reef health & marine life that attract tourists
- Reduced profits, tax revenue, and employment in tourism industry
- Damage to tourist and community infrastructure due to loss of storm protection from reefs
- Loss of ocean-based cultural heritage and community benefits

Diving & Tourism

- Healthy coral reefs draw divers, snorkelers, and tourists from all over the world.

- Decreased reef diversity and calcification in acidic reefs threatens this tourism.

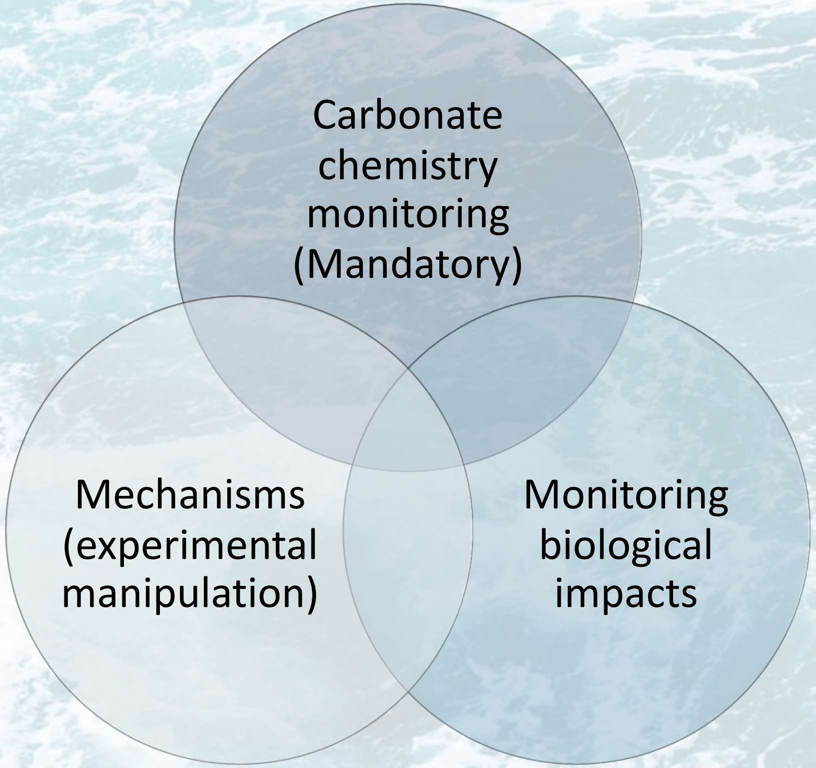
- According to a recent study, coral reef tourism accounted for 3% of Mexico's GDP. [1]

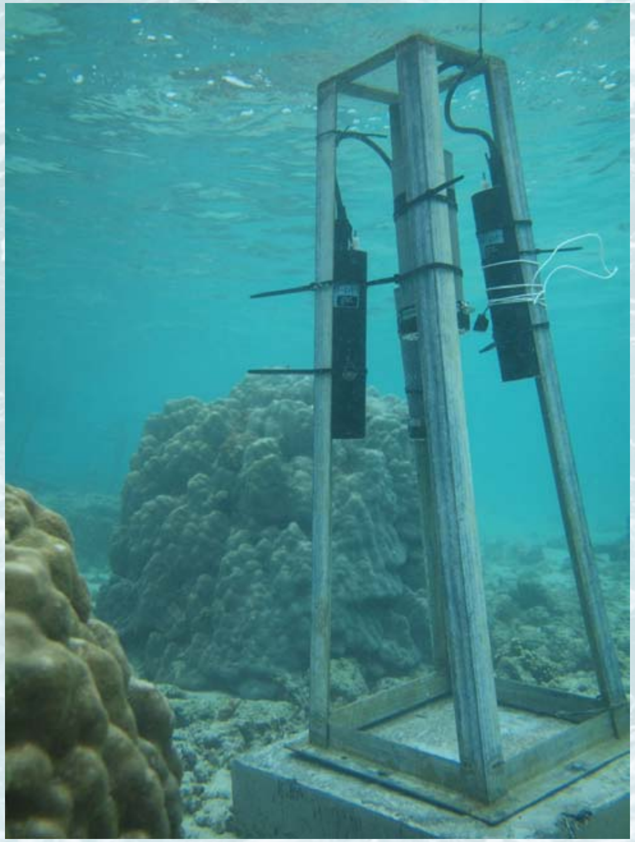
[1] Spalding, Mark et al (2017). Mapping the global value and distribution of coral reef tourism. *Marine Policy*, 82: 104-113.

SOLUTIONS:
Building Science Capacity

Why Monitor?

An Accessible Kit to Collect Weather-Quality Data (GOA-ON in a Box)





Approaches to Adaptation

Modifying the Growing Environment

- Creating hatcheries or growing facilities for vulnerable species
- Manipulating water chemistry based on species vulnerability

Management Strategies

- Continuous monitoring and forecasting in production regions
- Selective siting of farms or other production facilities
- Fisheries management that takes into account species vulnerability

Alternative Livelihoods and Financing

- Diversification of jobs in regions with high dependence on vulnerable species
- Alternative financing or insurance mechanisms (e.g. reef insurance)

Approaches to Mitigation

Reduction of Global Carbon Inputs

Transition away from fossil fuels at global scale

Reduction of Local Carbon Inputs

Regulation and reduction of nutrient inputs

Sequestration Through Blue Carbon

Local and global mitigation through mangrove, seagrass, or saltmarsh protection/restoration

Governance and Building Legislative Capacity

The Goal of Governance and Action

Promote More Resilient Coastal Communities

Protecting and defending coastal habitats, thus enhancing food security, improving resiliency, and protecting local economies

Bringing together scientists, business leaders, coastal and fisheries planners, as well as key decision-makers to enable cross-sector collaboration towards adaptation

Utilizing existing frameworks and meeting international commitments, such as UN SDG 14.3

Legislative Approaches

Approaches can include adoption of policies:

- Requiring **adaptation**, such as adoption of early warning systems, hatchery intake valve controls, adding alkaline materials to buffer water
- Requiring **mitigation**, such as actions that restore and protect blue carbon habitats; that address runoff and other land-based pollutants; and that otherwise enhance natural infrastructure to increase ecological and economic resilience for the communities
- Providing funding for long term, continuous **monitoring** or observations of ocean chemistry change
- Providing funding for scientific **research** study of the impacts of ocean chemistry change
- **Removing barriers** to research, such as reducing duties on imported monitoring equipment

We are in initial discussions to implement a second round of trainings with key decision-makers from Mexico, Fiji and the Republic of Marshall Islands. Participants will include actual decision-makers who have the authority to develop and advance important policy approaches for these two nations.

Governance Strategies

Incentivize development of adaptation strategies for aquaculture and fisheries

Bring ocean acidification considerations into the core of aquaculture and fisheries management decision processes

Consolidate and build on international cooperation

Reduce greenhouse gas emissions (even local emissions reductions make a difference)

Reduce local sources of acidification, if present and feasible (e.g. nutrient run off)

Reduce other (multiple and cumulating) stressors / threats to the marine environment to enhance overall ecosystem resilience

Restore coastal and ocean carbon sinks

Recognize ocean acidification as a root cause of current and potential food insecurity that could lead to food refuge migration and related security issues

Sufficient international planning and financing for adaptation with increased capacity building in vulnerable countries

Collecting and Sharing a Toolkit

- TOF created a toolkit for policy-makers designed to foster legislative and regulatory responses to ocean acidification including scientific research, monitoring, adaptation, and mitigation strategies (TOF OA Policy Toolkit).
    - Best practices and a comprehensive collection of examples of legislative approaches to date.
    - Fact sheets and international actions for context etc.
    - Draft adaptable templates for various elements of ocean acidification and blue carbon legislation
- At each TOF training, the toolkit is shared with region-specific examples of policies that could best fit their individual countries based on significant research and direct outreach to the participants.

Collaborating to Address Ocean Acidification

SDG 14: Life Below Water

SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Target	Indicator
14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	14.3.1 Average marine acidity (pH) measured at agreed suite of representative sampling stations

- SDG Target Indicator 14.3.1 was recently upgraded from Tier III to Tier II, meaning the "Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries." The custodian agency for this indicator is IOC-UNESCO.
- The Ocean Foundation's International Ocean Acidification Initiative, with partners such as GOA-ON and IOC-UNESCO, directly supports the ability of countries to meet this commitment.

Sources: IOC-UNESCO, UN DESA, IAEA OA-ICC

Deliverable	Achievement to Date
Capacity building through the training of 120 scientists in ocean acidification monitoring techniques through six regional training workshops (two in South America, one in the Artic, one in the Caribbean, one in Africa, and one in the Pacific Islands). Scientists who receive training will be eligible to receive all equipment and materials needed to collect high-quality ocean chemistry data.	• 6 regional trainings held • Over 100 scientists trained • One new regional monitoring hub formed
Increased monitoring capabilities through the development and delivery of 12 GOA-ON in a Box Kits.	• 17 kits delivered to 16 countries
Increased international collaboration and research through support for the Pier-2-Peer mentorship program, regional convening calls, five four-week internships for junior-level scientists per year, for a total of 12 internships and 18 travel opportunities.	• 9 Pier-2-Peer scholarships awarded • 4 travel grants awarded
Increased global policy and mitigation efforts through international and domestic stakeholder engagement, communication to policy makers, and support for drafting legislation (including one policy convening meeting per year, five international policy stakeholder trips, and five domestic policy stakeholder trips, for a total of three policy convenings, 15 international policy stakeholder trips and 15 domestic policy stakeholder trips).	• 2 regional policy trainings • 1 national policy training • 1 regional resolution introduced • Over 50 policymakers trained • 1 policy toolkit developed

International

- We worked with Mexico to insert OA into UNEA 4, we will be likely to succeed for UNEA 5
- Forthcoming Commonwealth Secretariat Background Document on Ocean Acidification

Wider Caribbean Region

- OA was named as a topic of regional concern at the UNESCO IOCaribe meeting in Aruba in May 2019

STAC to SPAW to CEPCOP15

- December 2018, TOF attended the Eighth Meeting of the Scientific and Technical Advisory Committee (STAC) to the Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region (the SPAW Protocol) and presented the following recommendations (and included in the Decision of SPAW COP10 without amendment on Monday, June 3rd):
  - Recognize ocean acidification as regional topic of common concern to be acknowledged by the SPAW Protocol.
  - Partner with The Ocean Foundation to implement ocean acidification monitoring and mitigation projects in key marine ecosystems.
  - Seek joint collaboration for proposals to expand funding opportunities.

Thus, Mexico and the meeting host Honduras presented a resolution that was adopted by unanimous consent:

COP15 Decision X on OCEAN ACIDIFICATION

Welcoming The Ocean Foundation's "International Ocean Acidification Initiative" to address ocean acidification as a regional topic of common concern as acknowledged by the Contracting Parties to the Protocol Concerning Specially Protected Areas and Wildlife;

Noting the Recommendation VIII of the Eighth Meeting of the Scientific Technical Advisory Committee (STAC) to the Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region to collaborate with The Ocean Foundation;

Recalling the 2030 Agenda for Sustainable Development, in particular Target 3 of SDG 14 which aims to "minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels";

Decides to:

1. Request the Secretariat to work with The Ocean Foundation including through the signing of a Memorandum of Understanding that facilitates collaboration on addressing ocean acidification and related issues within the Wider Caribbean Region (WCR). This may include the development and implementation of joint strategies and pilot projects.

Thus, The Ocean Foundation is ready to:

- Work with CEP and address ocean acidification as a regional topic of common concern
- Integrate and strengthen the region's Blue Economy by supporting adaptation, mitigation, and conservation through ecosystem-based management
- Implement strategies that predict, prevent, and reduce climate disruption effects on coastal communities and Blue Economies through adaptation and mitigation addressing harmful algal (macro and micro) blooms, ocean acidification, ocean warming, sea level rise, storm intensity, and other related phenomena
- Pilot coastal and nearshore restoration and protection as adaptation and mitigation strategies for climate disruption and for reduction of these other and cumulative stressors

Our work is made possible by our partners

GOA-ON Global Ocean Acidification Observing Network
OAP NOAA OCEAN ACIDIFICATION PROGRAM
Sida
DEPARTMENT OF STATE UNITED STATES OF AMERICA
IAEA Ocean Acidification International Coordination Centre OA-ICC
UNESCO United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
XPRIZE FOUNDATION
THE SUMMIT FOUNDATION

USP THE UNIVERSITY OF THE SOUTH PACIFIC
UNIVERSITY OF MAURITIUS
MOI MAURITIUS OCEANOGRAPHY INSTITUTE
SPREP Secretariat of the Pacific Regional Environment Programme
invemar
NCEL National Caucus of Environmental Legislators
Smithsonian Tropical Research Institute

UNIVERSITY OF GOTHENBURG
UNIVERSITY OF HAWAI'I
SCRIPPS INSTITUTION OF OCEANOGRAPHY UC San Diego
PMEL Pacific Marine Environmental Laboratory
Commonwealth Marine Economies Programme
Sunburst Sensors
ESCUELA SUPERIOR POLITECNICA DEL LITORAL ESPOL
Pontificia Universidad JAVERIANA Bogotá

UNIVERSIDADE EDUARDO MONDLANE
NRF National Research Foundation
SAIAB South African Institute for Aquatic Biodiversity
Palau International Coral Reef Center
"IA AO SAMOA"
UWI
NATIONAL FISHERIES AUTHORITY Papua New Guinea
CONICET CENPAT
TUVALU MO TE ATUA
UMAR UNIVERSIDAD DEL MAR OAXACA

CONCLUSION

Bridging the Gap: Collaboration as Key to Success

How We Can Help

- TOF's IOAI could support capacity development by replicating its cost-effective and efficient delivery of training and technical assistance
- TOF can provide one-on-one coaching from the experts who have drafted and successfully passed OA legislation
- TOF is working to establish a network of national centers of excellence on ocean acidification monitoring, mitigation, and adaptation

THE OCEAN FOUNDATION

Thank You

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