# CLIMATE CHANGE AND OCEANS

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**To be sustained by the sea, we must sustain the sea…**

## ABSTRACT

The oceans are in trouble. We have lost 90 percent of large fish, at least ten percent of the world's coral reefs have been degraded beyond recovery, and the oceans can no longer be considered an unlimited mixing zone for the dilution of pollution. Meanwhile less than one percent of the oceans are protected. To make matters worse, we now must recognize that there is an overarching layer of human-induced global climate change threats to coastal and marine ecosystems, which include sea-level rise, increased air and water temperatures, and changes in weather patterns. This paper reviews the relationship between the marine ecosystem and climate, and the very powerful transformations in their interactions as the result of climate changes. It then turns to some of the specific impacts of each on the other and the manner in which the traditional marine problems (over-fishing, habitat destruction, etc.) will be exacerbated. In the end, the need for an integrated set of strategies to both protect/enhance marine and address climate systems is described. This paper suggests that philanthropy support efforts that enhance the integration of climate in oceans conservation, so that the two realms are no longer considered separately. The goal is to present the climate and marine issues to funders in a way that demonstrates their interactions and synergies, making the case for collaboration and integration. And, where integration is not yet possible or underway, marine funders should consider whether their grants support enhancing the resilience of the ecosystems most at risk from climate change. While climate change is an ominous threat, "there's got to be a morning after"[i] the "Day After Tomorrow."[ii]

## INTRODUCTION: OCEANOGRAPHIC PERSPECTIVE ON CLIMATE VARIABILITY

The global ocean supports habitats and many forms of marine wildlife. In fact, the ocean hums with life in an interconnected web, from the tiniest shrimp to the great blue whales. Each whale plays a role in the delicate ecological balance of food, habitat, and successful reproduction that is critical to the survival of all species. Each coral reef is adapted to specific environmental conditions that allow it to provide a home for entire communities of fish.

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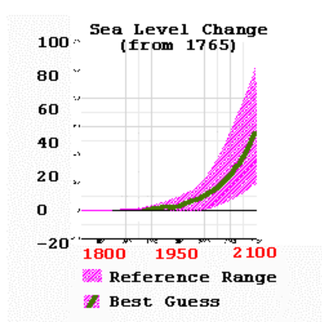
[i] "The Morning After" from The Poseidon Adventure (1972)
[ii] The Day After Tomorrow was released by Twentieth Century Fox on May 28, 2004

As humans we are immersed in this web, sustained by the ocean's bounty and inspired by its beauty. The ocean also provides us with a wide variety of goods and services including food, recreation, and transportation. Our use of those services has been profligate—and we have only recently begun to recognize and try to address the impact of our collective actions on marine species and habitats. We are also only just beginning to learn the details of how global climate change will affect the ocean. But we know enough to recognize our growing influence on its future.

Despite ongoing political debates, the unavoidable reality of global climate change has been documented by leading scientists and affirmed by international consensus. We can expect the unexpected—real climate change will include changes in weather patterns, changes in ambient temperatures, changes in precipitation and rises in sea levels.[iii]

With reluctant but steady momentum, the scientific consensus on global warming and its relationship to human activities (especially the burning of fossil fuels) continues to grow. According to a 2001 summary report by the Intergovernmental Panel on Climate Change (IPCC),[1] the 1990s were the warmest decade in the history of recorded temperature (since 1861). Based on extensive synthesis of current research on global warming, the IPCC also concluded that sufficient evidence exists to point the finger at human activities as the primary cause of "most of the warming observed over the last 50 years." These reports of the Intergovernmental Panel on Climate Change, (IPCC 1990, 1996 and IPCC 2001) predict future climate scenarios and in doing so assume various levels of human mitigation. Even the most optimistic of the scenarios predicts the earth will become a few degrees warmer in the next couple of decades.

A few degrees of warmth may not sound like much of a threat, or even necessarily a bad thing. But the overall effects on weather patterns, disease,[2] food production and coastal cities[3] could reach deeply into the economy and our daily lives, from Bangladesh to New York City. With the oceans, we already need to be planning for and investing in solutions to mitigate the impact of climate change—because the impact is being felt now, and more is coming. Over half of the world's population lives along the coast, increasing the threat of economic and social disruption from rising sea levels, storm systems that are more frequent and more intense, and the loss of productive coastal ecosystems.




(Expressed in centimeters, from http://www.odp.usyd.edu.au/odp_CD/who/whoindex3.html#top)

[iii] Sea level rise will gradually inundate existing coastal lands and coastal wetlands may extend further inland.

We are learning more and more about how tiny shifts in ocean currents, water temperature, and salinity affect the creatures of the sea. For example, critically endangered right whales have produced fewer offspring during recent food shortages caused by erratic climate shifts.[4] Whale experts emphasize that "Climate variability and change… may make this species more vulnerable to extinction."[5] And the right whale is just one species of millions whose existence may depend on how quickly we can respond to the impacts of climate change we are seeing now and are starting to anticipate in the future.

## CLIMATE TRENDS AND PROJECTIONS FOR THE GLOBAL OCEAN

### Oceans and Atmospheric Weather Systems

Climate change is expected to have an impact on a variety of different climate dependent services, including agriculture, water supply, ecosystem health, human health, and weather. Climate, weather and the state of the atmosphere are of prime importance in the economic, social and environmental health of our cities, coastal states and oceans. The ocean drives our planet's climate systems. Temperature differences between the ocean (which both heats and cools more slowly) and land create winds, and winds move air masses and their weather systems with them. Most of the precipitation that falls comes from evaporated seawater. The water we use to drink and bathe is linked to the ocean.[6]

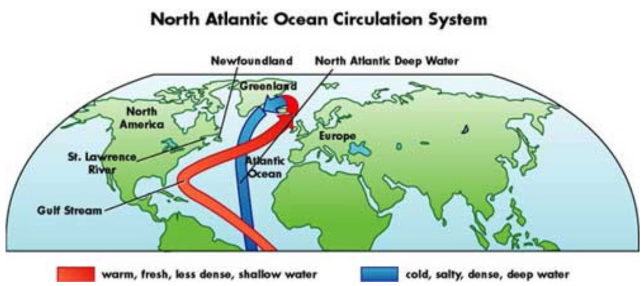
This excerpt from the 1998 Year of the Oceans report on the impacts of climate change explains the physics governing the behavior of the atmosphere and the ocean, thus how the ocean influences weather and climate:

> The Earth's weather and climate are the result of the redistribution of heat. The major source of heat to the surface of the Earth is the sun, principally through incoming visible radiation most of which is absorbed by the Earth's surface. This radiation is redistributed by the ocean and the atmosphere with the excess radiated back into space as longer wavelength, infrared radiation. Clouds and other gases,[iv] primarily water vapor and carbon dioxide, absorb the infrared radiation emitted by the Earth's surface and remit their own heat at much lower temperatures. This "traps" the Earth's radiation and makes the Earth much warmer than it would be otherwise.
>
> Most of the incoming solar radiation is received in tropical regions while very little is received in polar regions especially during winter months. Over time, energy absorbed near the equator spreads to the colder regions of the globe, carried by winds in the atmosphere and by currents in the ocean. Compared to the atmosphere, the ocean is much denser and has a much greater ability to store heat. The ocean also moves much more slowly than the atmosphere. Thus, the ocean

[iv] [This note was not part of the original quotation] The primary gasses which contribute to the greenhouse effect are: water vapor ($H20$), carbon dioxide ($CO2$), ozone ($O3$), methane ($CH4$), nitrous oxide ($N2O$), and chlorofluorocarbons (CFCs). Developed countries produce roughly 70 percent of the CO2 emissions (mostly from burning fossil fuels). The United States with only 5 percent of the world's population accounts for 22-26 percent of global CO2 emissions from human activities, and 20 percent of methane.

and the atmosphere interact on different time scales. The ocean moderates seasonal and longer variations by storing and transporting, via ocean currents, large amounts of heat around the globe, eventually resulting in changing weather patterns.[7]

In short, without the oceans to "bank" the heat from the sun and redistribute it globally, the Earth would be freezing by night, and unbearably hot during the day. In other words, the ability of the oceans to absorb and transfer heat tends to moderate the global environment.




The Gulf Stream transports warm equatorial water from the Gulf of Mexico to the west coast of Europe and considerably moderates the climate of Europe (it would be much colder without it). As the water moves north, evaporation makes the water more saline and denser so that it sinks off the Norwegian coast. This is a major contribution to the global circulation pattern.-from NSF

**Understanding Change, the Role of Warmer Oceans in the Alteration of the Global Climate Regime**

Scientists at NOAA have discovered that the world ocean has warmed significantly during the past 40 years. The largest warming has occurred in the upper 300 meters of the world ocean on average by 0.56 degrees Fahrenheit. The water in the upper 3000 meters of the world ocean warmed on average by 0.11 degrees Fahrenheit.[8]

As climate change warms the global ocean, it changes patterns of currents and gyres (and thus heat redistribution) in such a way that there will be a fundamental change in the climate regime as we know it, and possibly a powerful loss of global climate stability. The basic changes will be accelerated: sea-level rise, alterations of rainfall patterns and storm frequency or intensity, and increased siltation.

Long-term impacts of climate change in coastal areas, such as sea level rise or storm surges, could result in the increased erosion of shores and associated habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport, and increased coastal flooding. Such changes have considerable implications for U.S. coastal areas where the majority of the country's population and significant economic activity is concentrated.[9]

Trade routes, agriculture, and industry have all evolved to operate within relatively predictable seasonal patterns.[10] What happens when normal is altered? We know the answer to this from observing the impacts of floods, droughts or hurricanes when they hit our communities. Such events interfere with human infrastructure to disrupt tourism and trade, uproot trees, flood agriculture, shut down business, and harm human health. Human communities that have learned to expect such events have developed construction standards, emergency plans, and other means of limiting the adverse effects of such events. Now add the possibility that hurricanes might form more randomly (the ocean heat has moved) leading to entirely new landfall patterns or might be more frequent or more intense (due to increases in temperature differences). It quickly becomes apparent that the disruptions become harder to anticipate, and thus more expensive to plan for or to recover from.

The ocean is a significant, and an eventual, repository for the carbon emitted to the atmosphere by human activities.[v] This estimate of uptake capacity is based on well-understood physical and chemical processes that govern the exchange of CO2 between the atmosphere and the ocean.

> However, this uptake occurs quite slowly. For example, the ocean is presently taking up only 40% (with an uncertainty of plus or minus 16%) of the annual anthropogenic carbon emissions not removed by terrestrial processes. Because of the slow rate of mixing of the ocean, it would take many centuries for the ocean to realize most of its uptake capacity, even if anthropogenic emissions were to stop today. . . [F]uture predictions must take into account the warming of ocean waters (which reduces the oceans capacity to absorb CO2 and other gases), reductions in ocean mixing (which reduces the rate at which the oceans can absorb CO2 and other gases), and changes in biology that will likely take place as a result of global warming.[11]

**Global Climate Change, Warmer Oceans and the Loss of Local Weather Stability**

The key to understanding the loss of global climate stability is to compare global change to local change. The warming of the planet appears to be following a pattern that is statistically consistent with the increasing accumulations of CO2 in the atmosphere. As a result, the warming of the ocean is becoming more measurable and predictable. However, all these heat transfers create local dynamics that are significantly less predictable. At the local and regional scale, due to heat disparities and too numerous points of interaction, the indirect changes in local weather patterns will not be uniform, nor necessarily gradual, nor consistent over time. Rather than taking centuries to change, local weather changes are happening before our eyes. Less snow here, more rain there. Longer periods of drought, later arrival of spring rains. Earlier hurricanes and shorter winters. There is an accompanying loss of biodiversity as one of the most dramatic – and deleterious – impacts of climate change and increase in oceans temperature. In addition to such ecological impacts, these early symptoms of climate change are causing unanticipated problems economically, as it is difficult to adapt in a rapidly changing setting if you are dependent upon on the weather's stability and relative predictability (air travel, shipping, tourism, agriculture, and construction for examples).

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[v] In other words, oceans naturally uptake atmospheric carbon; a fact employed by some to urge the use of the ocean to sequester our carbon because most of it will eventually end up in the oceans regardless of whether we speed the process (discussed below).

### Current Ocean Climate Change Models are Obstacles to Good Planning, and Will Not Improve for Some Time

Simply stated, we do not fully understand how the ocean functions, and we know even less about the ocean/atmosphere interaction and its impact on climate. As terrestrial beings we have trouble observing and studying the ocean. Its physical, chemical and biological interactions are of magnitudes of difficulty to understand. For example, "motion instabilities are inherent properties of the nonlinear form of the governing equations of moving fluids" (in other words, liquid motion is inherently chaotic).[12] Thus, to design models with any kind of predictive capability is very demanding. And the only way to test our models is to apply them to known historical data. Unfortunately, detailed historical climate records for the ocean are limited at best and water inherently leaves few ways to do historical research. Thus, we are limited to data from ice, coral and sediment cores—and a finite amount of information can be drawn from those sources.

For example, the most studied aspect of ocean-atmosphere climatology is the El Niño cycle in which parts of the Pacific ocean's coldest, richest waters are replaced by nutrient-poor warm water at such a scale that the globe's climate is shifted—causing stronger storm systems, heavier than normal rainfall in some places, and drought in others. However, the results from our best models still show mixed results in our ability to predict what change will happen where.[13] Thus there is a "danger of drawing conclusions about extreme events with too little data or with poorly performing models."[14]

## CONSEQUENCES OF SYSTEM DESTABILIZATION DUE TO CLIMATE CHANGE

### Affected Marine Ecosystems and Species

Global climate change, with its associated sea-level rise, increased air and water temperatures, and changes in precipitation patterns, is predicted to alter marine environments through a variety of direct and indirect impacts.

Global climate change introduces new instabilities into systems that are already greatly disturbed and altered by over-exploitation. As a result, marine ecosystems are being simplified[vi] and becoming less stable and less productive in all climate zones.[15]

> The Arctic Ocean, too, will likely become warmer and wetter. Sea ice will continue to thin and retreat, to the extent that by 2050, sea-ice cover in the Arctic Ocean may be reduced to about 80 percent of the area it covered in the mid-twentieth century. Such sea-ice declines may well have negative repercussions for many species of marine wildlife, including seabirds and marine mammals: seal species, for example, that use the sea ice as a platform on which to rest, and polar bears that prowl the ice to prey on seals.[16]

The table below lists marine ecosystems and species that are especially sensitive to global climate change. This list is just a sample of the many affected animals and ecosystems. The complexity of interactions between species and global climate change will require ongoing learning and adaptation of our conservation efforts.

[vi] Less complex systems either lack fully functioning predator-prey food webs, or are completely missing their top predators, or basically have fewer species than before they were disturbed.

**Table 1. Ecosystems and species sensitive to climate change**

| Living Coast | | Open Ocean |
|---|---|---|
| Coral reefs | | Whales |
| Beaches and bluffs | | Sea turtles |
| Arctic and Antarctic sea ice and ice shelves | | Marine mammals |
| Mangroves and marshes | | Salmon (and other fish) |
| Tide pools[17] | | Penguins (and other birds) |
| River deltas | | Polar bears |

**Threats Analysis**

There are eight key threats to the integrity and survival of marine ecosystems as a result of climate change. Basic physical changes caused by global warming include more frequent storms, shifting ocean currents[vii], melting polar ice, and rising sea level. Negative consequences of this uncertain environment are already becoming apparent for marine life as illustrated in the chart below.

These physical changes threaten food supplies, species health, habitat, and reproduction. It remains unknown whether these impacts will be gradual or abrupt, but certain regions have already seen dramatic change. For example, rapid sea level rise is currently underway in the United States, China, and Argentina,[18] increasing flood risk in coastal areas. Temperature changes are also taking their toll:

> As water temperatures have risen, the base of the marine food chain off the coast of California has crashed. And, one by one, the fish and birds farther up that food chain are crashing too.[19]

The following list of threats summarizes some of the current literature regarding oceans and climate change.

**Table 2. Summary of threats**

| Threats | Impacts |
|---|---|
| Erratic Ocean Currents (Coastal ecosystems) | Temperatures of a few degrees change can alter major currents and thus species viability in estuaries and other coastal areas—affecting all coastal plant and animal species and reducing resilience to other human impacts, such as sewage, non point source pollution, etc.). |
| Erratic Ocean Currents (Food Supply) | Temperature related changes have caused shortages in the food supply (krill, prey fish, phytoplankton) for whales, penguins, salmon, and marine mammals. Changes in the distribution of fish and other species could affect the global protein supply for humans as well. |

[vii] Climate change induced alterations in ocean circulation patterns can cause significant changes in regional ocean and land temperatures and the geographic distributions of marine species. Also included in the shifting of ocean currents is vertical movement of ocean waters (i.e., upwelling and down welling), which increase or decrease the availability of essential nutrients and oxygen for marine organisms.

| | |
|---|---|
| Erratic Ocean Currents (Reproduction) | Endangered whales, sea turtles, and birds require specific environmental conditions for the survival of their young. Elevated nest temperatures could disrupt sea turtle recovery efforts by altering sex ratios.[20] |
| Hot Water (Disease) | Outbreaks of disease in oysters, coral reefs, and other species have been on the rise with global temperatures.[21] |
| Hot Water (Ice melts) | Polar bears, seals, and sea lions may be cut off from coastal hunting and nursery grounds. Krill populations, which thrive under sea ice, will decline taking with them penguins, seals and whales.[viii] Ice-free seas also absorb more sunlight energy, thus escalating warming. |
| Hot water (Food Supply) | Although it may be counterintuitive, the coldest waters are the most biologically rich and nutritive. Less dense warm water floats on cold water, and cold-water nutrients may become too deep to enable photosynthesis to occur. Less plankton, less fish. Less fish, less birds and marine mammals. |
| Hot water (Habitat damage/loss) | High temperatures cause corals to turn white and "bleach." Bleaching has become widespread, adversely affecting dive tourism, reef species, and reef system resilience. Water expands as it warms, adding to sea rise inundation of coastal areas. |
| High water (Habitat damage/loss) | Beaches, bluffs, and wetlands are buffeted by increasing storm damage and wave action. Sea turtle nesting beaches already threatened by development may be lost to erosion and more nests are likely to be flooded. |
| High Water | Saltwater intrusion into coastal marshes and river deltas—increased mortality of freshwater/brackish species and reduced productivity of estuaries. Saltwater intrusion into water tables and aquifers – loss of potable water. |

SOURCES
- Intergovernmental Panel on Climate Change. 2001. Third Assessment Report.
- Intergovernmental Panel on Climate Change. 1998. Special report on the regional impacts of climate change: An assessment of vulnerability.

**Displaced Human Populations (due to Erosion, Permafrost Melts and Sea Level Rise)**

Changing climate, rising sea level, loss of ecosystem services, exposure to pathogens or toxic pollutants, lack of potable water, as well as the costs of mitigation strategies may force human populations to relocate. The two most famous examples are Vanuatu, which expects its island nation population will become sea-level rise refugees,[ix] and Shishmaref and Kivalina, two villages in northwest coastal Alaska, which are in the process of being

[viii] Blue whales for example consume 4 tons of krill per day. (From Motavalli page 161).
[ix] Kiribati, the Marshalls, and Tuvalu are likewise involved in diplomatic discussions to seek settlements for refugees once their islands are "subsumed by rising sea levels linked to fossil-fuel-driven climate change." (From Motavalli page 137).

dismantled and moved at a cost to U.S. taxpayers of more than $100 million – over $100,000 per resident – as the result of coastal erosion and melting permafrost. And, there are 20 other Alaska villages that are candidates (with similar costs) for relocation because of severe erosion.[22]

> [H]uman activities and alterations have rendered coastal resources more vulnerable to climate change-induced processes, such as accelerated sea-level rise, alterations of rainfall patterns and storm frequency or intensity, and increased siltation. Climate change and a rise in sea level or changes in storms or storm surges could result in the increased erosion of shores and associated habitat, increased salinity of estuaries and freshwater aquifers, altered tidal ranges in rivers and bays, changes in sediment and nutrient transport, a change in the pattern of chemical and microbiological contamination in coastal areas, and increased coastal flooding.[23]

Rapid sea level rise is currently underway in the United States, China, and Argentina,[24] increasing flood risk in coastal areas. While over 50 percent of the world's population lives near the ocean, it can be assumed that there will be some need for the safe resettlement of displaced human populations due to such coastal system changes, even though most human migration tends to happen gradually. The great issue is that increased population means increased pressure on the coast, including land-based pollution, which then combines with sea-level rise to wreak havoc within natural systems.

**Cultural and Subsistence Hunting and Fishing**

Alterations to the land and the animals on which native peoples depend mean that climate change is disrupting traditional food gathering and cultural practices. In Alaska, according to the US National Ocean and Atmospheric Administration (NOAA), temperatures are up ten degrees in the winter and five degrees the rest of the year, which explains some of the dramatic changes observed there:

> Native leaders say that salmon are increasingly susceptible to warm-water parasites and suffer from lesions and strange behavior. Salmon and moose meat have developed odd tastes and the marrow in moose bones is weirdly runny, they say.
>
> Arctic pack ice is disappearing, making food scarce for sea animals and causing difficulties for the Natives who hunt them. It is feared that polar bears, to name one species, may disappear from the Northern hemisphere by mid-century.
> As trees and bushes march north over what was once tundra, so do beavers, and they are damming new rivers and lakes to the detriment of water quality and possibly salmon eggs.[25]

Travel on iced-up rivers and on permafrost is no longer safe due to thinning. Oral histories regarding animals and nature are becoming less useful to younger generations in the face of rapid change.

> Changes as a result of rising temperatures are much more than an inconvenience to the peoples of the Bering, Beaufort, and Chukchi Seas. They are a profound threat to the very way of life they have practiced for centuries. Thinning and retreating sea ice, for example makes it dangerous to hunt walruses, seals and whales; in 1998 whalers from the village of Wainwright had to be rescued after the ice floe they were on broke up and drifted out to sea.[26]

**Human Health Aspects of Climate Change Induced Ocean Alterations**

Health problems (e.g. red tides, ciguatera[x], cholera) could increase as a result of climate change and harm fish stocks and consumers. However, direct impact on human health is difficult to anticipate. Where climate change enhances the ability of disease to be carried by fish, mosquitoes and other species, human health will obviously be adversely affected. In addition, it is possible that where warmer water temperatures cause more marine species diseases, those species may become unsafe for human consumption—much as "red tides" and other algal outbreaks have already affected the food supply. Further disruption to the food supply and thus to human health could come from saltwater intrusion into coastal agriculture lands, destruction of agriculture and transportation infrastructure in storms and floods, and changes in precipitation patterns that reduce agricultural productivity.

We expect to observe changes in the seasonality and geographic range of malaria transmitted by cold-blooded mosquitoes, due to sea level rise impacts on coastal wetlands as well as more traditional concerns related to altered patterns of temperature and precipitation. In addition, if the global climate becomes wetter there is a much higher likelihood for the spread of infectious disease. "Among the diseases that have been predicted to be more severe or move into more populated areas of North America are the mosquito-borne viral diseases dengue, St. Louis encephalitis, and yellow fever; the sand fly-borne protozoal disease leishmaniasis; the water-associated disease cholera; and the bat-borne vampire bat rabies."[27, 28]

Patterns of mortality in large urban populations, which may change as a result of hotter summers and less cold winters, could cause higher death rates in the very old and the very young (witness the deaths associated with the heat wave in France last year). If a region becomes dryer or the rainfall less regular, there may be more particulate matter in the air and thus there will be increased problems related to respiration. In addition, if the heat reduces ultraviolet radiation protection in the atmosphere, it can be expected we will see more skin cancer in some regions. We have already observed this with the case of ozone depletion in which some countries have had to adopt new health policies in respond.

Coastal flooding and the offshore formation of hurricanes and all the other ocean-related extreme weather events are sources of human mortality that may increase. And such events, in conjunction with other forms of food supply disruption, could increase forced migration and relocation—which often generates conditions that increase the risk of disease.[xi]

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[x] Ciguatera is a type of food poisoning from eating marine species that harbor toxins originating in warmer waters.
[xi] Hurricane Mitch is casebook example of how this happens.

Adding to the difficulty in predicting the impacts of climate change on human health is the outside possibility that there will be some benefits. In some circumstances, climate change may improve health conditions, or reduce the number of weather related deaths (for example, cold-weather mortality).[29]

**Political Instability (from Pentagon analysis)**

> Recent research . . . suggests that there is a possibility that . . . gradual global warming could lead to a relatively abrupt slowing of the ocean's thermohaline conveyor, which could lead to harsher winter weather conditions, sharply reduced soil moisture, and more intense winds in certain regions that currently provide a significant fraction of the world's food production. With inadequate preparation, the result could be a significant drop in the human carrying capacity of the Earth's environment.[30]

There are some indications today that global warming has already reached the threshold where the thermohaline[xii] circulation could start to shift. The North Atlantic is substantially less salty as the result of "being freshened by melting glaciers, increased precipitation, and fresh water runoff . . . over the past 40 years."[31]

The Pentagon report analyzes how such an abrupt climate change scenario could de-stabilize current geo-politics, leading to skirmishes, battles, and even war over resource constrictions such as:

1) Food shortages due to decreases in net global agricultural production
2) Decreased availability and quality of fresh water in key regions due to shifted precipitation patterns, causing more frequent floods and droughts
3) Disrupted access to energy supplies due to extensive sea ice and storminess[32]

Specifically, with regard to the oceans, the report prepared for the U.S. Department of Defense predicts that:

> As glacial ice melts, sea levels rise and as wintertime sea extent decreases, ocean waves increase in intensity, damaging coastal cities. Additionally millions of people are put at risk of flooding around the globe (roughly 4 times 2003 levels), and fisheries are disrupted as water temperature changes cause fish to migrate to new locations and habitats, increasing tensions over fishing rights.[33]
>
> Commercial fishermen that typically have rights to fish in specific areas will be ill equipped for the massive migration of their prey.[34]

The study done for the U.S. Department of Defense has, of course, been criticized. The theory it suggests is a plausible and valid one, but many climate scientists agree that an abrupt change resulting in a new ice age is well over 100 years away, and is not as proximate or as severe as the

[xii] Thermohaline circulation refers to the movement of ocean water as the result of "density differences (caused by temperature and salinity differences)" which engage the full depth of the ocean in a "large-scale slow overturning motion" (From Field et. al. at page 101).

defense preparedness scenario calls for.[35] On the other hand, two recent publications offer confirmation of the use of the theory behind the Pentagon scenario.[36] These two sources rely on some of the same research and models as the secret Pentagon report and predict an abrupt cooling of Western Europe caused by the break down of the Gulf Stream's functions. What these and the Pentagon report indicate is that a significant cooling in some places could be part of climate change, that both global warming and cooling will disrupt the balance of natural systems and thus international relations, and that we must act to reverse the trends to avoid political instability.

## OPPORTUNITIES FOR EFFECTIVE MARINE RESOURCE MANAGEMENT IN A TIME OF CHANGE

### Protect Our Global Ocean for its Own Inherent Value; and Can We Survive Without a Healthy Ocean?

The ocean provides many benefits in terms of resources, climate moderation, and aesthetic beauty. Frankly we cannot survive without the ocean and its marine environmental services. It serves up 17 percent of human protein consumption. It absorbs CO2, it dilutes pollution, and its edges, the estuaries and wetlands, filter pollution from water, provide nursery and feeding grounds for key food species, and assist with flood control. If we do not sustain the sea, it will not sustain us. Through human-induced warming of the ocean, we have perturbed its natural balances at a scale way beyond the pollution, siltation, predation, and other human insults. In fact, we may be unleashing a terrible set of oscillations that exceed natural background ones.

We can make the argument for protecting the ocean, or at least to try to reverse the damage already inflicted, or to at least mitigate its effects for the sake of the services it provides.
But there is also the stewardship argument – we should protect our ocean for its own inherent value; in other words, nature for nature's sake. It is the wildness, beauty and awe inspiring aspects of the ocean that attract us. It is full of species for which we cannot define a "service" to humans, but who have a place in a complex system or systems, and thus have value.

The good news is that the damage done may be reversible—we do have evidence that there is greater resilience than might have been predicted, and thus, there is expanding support for ocean conservation before we "know" what every species' value is to humans or regardless of that form of valuation.

For example, in the late 1800s and the mid-1900s humans nearly exterminated the Pacific Gray Whale to reduce its blubber to oil for foodstuffs and to make corsets from its baleen. By 1946 there were fewer than 2,500 Gray Whales left. Since then, merely by virtue of a moratorium on hunting them, the Gray Whale has recovered to what some believe to be its pre-exploitation population level of over 25,000. A ten-fold population increase in about 50 years!

It is clear that one path to investing in conservation efforts is to focus on increasing the resilience of ocean species and ecosystems by reducing the immediate stresses of excess human activities. In this way, we can increase ocean health and its "immune system" or resilience by eliminating or reducing the myriad of smaller ills from which it suffers.

## Fisheries

### *The Potential for Continued Viability of Key Fisheries*

> The one thing that can be certain is that climate will continue to change, and fisheries distributions and abundances will continue to respond as they have in the past.[37]

Fisheries are already under tremendous pressure. Industrial over-capacity and related overfishing as well as the use of destructive fishing gear on fragile and irreplaceable habitat or the bycatch of large numbers of non-target species have already depleted the world's fisheries. In addition, non-fishing activities such as ocean pollution and coastal development increasingly impact fisheries. If we then introduce climate change forecasts, we begin to see that some species viability may be threatened. Specifically, some migratory species may be able to move to new places, or deeper into the water column (cooler) which may make them unreachable or at least unsustainable on an economic level. However, even for migratory species, climate change-related dynamics of ocean motion may affect fisheries production variability and changes in vulnerability.[38]

> Freshwater flow is critical to many fisheries, such as shrimp, crabs, and anadromous species such as salmon and eels. Even seasonal ice formation has its ecological consequences. Any climate processes that shift climate zone boundaries will affect precipitation patterns and will therefore affect these species' fisheries. Regional and global climate can and does change rapidly if certain thresholds are crossed. Certain fisheries systems reflect these changes quite dramatically . . .[39]

The bottom line here is that some fisheries will be more impacted by climate change than others. Meanwhile, some more migratory species may shift to new locations, which will impact their commercial accessibility for good or for bad. Thus, we need to examine which fisheries to avoid in our effort to promote increased resilience and survival for fisheries and the global ocean.

### *Fisheries to Avoid (Those that are Already Depleted and those that are Sensitive to Climate Change)*

> Most ocean species thrive near the middle of their temperatures tolerance ranges… For most local species, increased thermal stress occurs at or beyond either warm or cold extremes… Species with broader tolerances often have unique physiological and anatomical features, and many of this group have evolved large adult sizes, and wide migrations. There are not really many generalities about where in the food web that these species are most likely to be found, as most of the fishes start life as small, lower trophic level feeders, and work their way upwards. Others, like the baleen whales, whale shark and manta rays, never graduate from their need to filter feed on planktonic forms.[40]

> Impacts of climate change on regional fisheries can be ranked in terms of likelihood (for either warming or cooling) of impacts. Most of this knowledge comes from empirical studies over the recent 50 years, when weather and environmental records became fundamental to explaining individual species' behaviours and population responses to changes in local conditions.
>
> Fisheries most responsive to climatic variables are listed below in descending order of sensitivity:
>
> (a) Freshwater fisheries in small rivers and lakes, in regions with greater temperature and precipitation change.
> (b) Fisheries within Exclusive Economic Zones (EEZ),[xiii] particularly where access regulation mechanisms artificially reduce the mobility of fishing groups and fleets and their abilities to adjust to fluctuations in stock distribution and abundance.
> (c) Fisheries in large rivers and lakes.
> (d) Fisheries in estuaries, particularly where there are species sans migration or spawn dispersal paths or in estuaries impacted by sea-level rise or decreased river flow.
> (e) High-seas fisheries.
>
> [Because of its being listed last] One can quickly see that the larger scale production sea fisheries are not under any direct or immediate threat due to climate changes. The fisheries most sensitive to climate change are also amongst the most affected by human interventions such as dams, diminished access to up- or down-river migrations, filling in of wetlands, and other issues of human population growth and habitat manipulation, particularly expanded agricultural water use and urbanization.[41]

In addition, those species that are dependent on ocean currents and gyres for larval transport during stages of development should be closely monitored in case climate changes cause shifts in the currents, leaving the young fish in new habitats that may not be as hospitable.

***Sustainable Fisheries and Aquaculture to Adopt***

Over-capacity in the fishing sector has already led to declines in worldwide commercial catches.

> [T]echnologies were developed, allowing fleets and new methods to spread unrestrained, until fleet growth and landings from the sea finally began to slow down in the mid 1980s, and eventually, decline – as fished populations responded, and quantities and qualities of products shifted.[42]

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[xiii] [This note was not from the quote] Under the UN Convention on the Law of the Sea, each nation may declare an Exclusive Economic Zone, beyond its 12 mile territorial seas, of up to 200 miles over which it can exercise limited jurisdiction (economic only). Even though the US is not a party to UNCLOS, the US has a 200-mile declared EEZ as the result of a Presidential "Executive Order."

With climate change it is even more crucial to seek out sustainable fisheries, or manage our wild fisheries at a sustainable level. For example, we must design management systems to recognize shifting species ranges. And we need to adjust the reference points, such as fishing rates and ensure that they become limits rather than target points.

While the subject remains very controversial we will probably need to carefully augment wild stocks of fish, and expand aquaculture to increase and even out seafood supplies. At the same time, given the pressures on ocean fisheries and the declines we have already observed, there is a fundamental need to shift any aquaculture to herbivorous fish.

> The now obvious fact is that with the present leveling off and declines of some ocean fisheries production options have begun to run out as habitats are shifted from agricultural emphasis and as more food fish is used to support fish and shrimp culture. Under the pressures of today's human population growth, perhaps better use could be made of fish protein if a larger portion of the fish catch were sold for direct human consumption rather than used to support culture of higher value products via the added inefficient conversion step of feeding it to another species.[43]

**Non-fish Marine Resources**

Plants and algae form the ocean's primary productivity. Temperature change has an impact on these species, and they are limited in their ability to migrate rapidly.

> The oceans, and therefore their all-important plants, also respond to local weather such as wind speed, cloud cover, and incident sunlight. Primary production is only the first of several stages in transformation of nutrients and carbon dioxide into living cell building blocks . . .[44]

As with fish, the more mobile and adaptable species are more likely to survive, while locally adapted species, those less capable of moving from location to location are more likely to go extinct.[xiv] In other words, non-migratory or very slow moving species may not move or adapt fast enough to survive. If they are to adapt, conservation work must also identify ways to give them more time to do so—time which may prove critical for other species as well. Because we know that the oceans form a delicately balanced web of life, even the survival of migratory species may be completely dependant upon non-migratory species. For example, the rockfish, which are dependent on coral habitat for protection from predators, may be able to move to more favorable climes, but not so the coral and other sedentary species.

What we know about coral ecosystems, both the tropical and northern, deep sea corals, is that they are highly vulnerable—to suffocation from nutrient overload, siltation, and algae blooms, to permanent damage from destructive fishing gear, and to ocean temperatures. The shallower,

[xiv] Of course climate change is speeding up the human induced sixth great global chain reaction of extinctions. (From Motavalli page 164).

tropical coral systems appear to be particularly vulnerable to ocean temperature changes of even a degree or two. How those warm water systems recover from warming events seems to be directly related to how much stress they were already under from other human activities.[xv]

These correlations of resilience and mitigation of existing human impact seem to recur throughout the marine world. Marine mammals, seagoing birds, coastal habitats, and deep sea habitats all need to be managed so that their functions are as healthy as possible—for our sake and theirs.

## ADDRESSING CLIMATE CHANGE AS AN OBSTACLE TO OCEAN CONSERVATION

We must recognize that there is an inherent conflict between mainstream recommendations for addressing climate change and some mainstream aspects of ocean conservation. On one hand, if we fail to stop the progress of climate change, the ocean could be ruined regardless of efforts to reverse or minimize the damage we have already done. On the other hand, some of the clean energy recommendations may require placing structures on the sea floor, or in the water column, or in coastal habitat—solutions that the ocean conservation community normally views as environmental threats. However, it seems clear that we cannot slow climate change without clean energy.

We are entering an era where energy issues have a growing connection to marine conservation efforts. Proposals for new oil and gas rigs and pipelines as well as facilities for liquefied natural gas have appeared up and down our coasts. There are also increased risks and impacts from seismic surveys on the continental shelf, particularly for marine mammals. There also is an increasingly vocal interest in tapping the oceans for alternative energy sources such as wind, seabed methane hydrates and tidal/wave power.

There are numerous reasons to be concerned about the potential expansion of energy infrastructure in marine and coastal ecosystems. They include: disruption of the benthic communities and other ecosystems on the ocean floor, disturbance of toxic muds along coastal waters that would release PCBs and other poisons now capped, disruption of migratory paths for large pelagic species (and interference with their ability to communicate); additional release of mercury into the oceans through oil drilling; mortality of marine mammals and seabirds, other animals; and possible permanent changes to near shore fisheries through alteration of key ecosystems.

At the same time, scientists tell us that climate change could be the single biggest threat to the oceans in the near future—making reducing the emission of greenhouse gases an apparent priority. Tapping the ocean's methane and alternative energy reserves could displace fuels that are far more dangerous from a climate change perspective and thus may be worth the immediate environmental risk. Wind farms cause local disruption to marine ecosystems and coastal communities, but may bring regional improvements in air quality and reductions in nitrogen deposition into watersheds, as they replace "dirtier" sources of electric power.

[xv] There have been some anomalies, such as several instances in the Pacific where the most stressed reefs were most resilient to climate change and were able to recover from bleaching, precisely because they had built up resistance to anthropogenic impacts, in this case sedimentation from run-offs.

A deep skepticism of all energy development has affected views on an "energy policy for the ocean". The track record of oil production and transport reinforces this skepticism. However, the complex intersection with the climate change issue and the promise of cleaner fuels argue for a careful, thoughtful reassessment of the "no way, no how" attitude towards coastal energy development. This is particularly true since having a positive environmental agenda with regards to energy may help leverage progress on marine protected areas, ecosystem-based planning and vital reforms to ocean governance.

**Offshore and Coastal Use of the Ocean as a Carbon Sink**

Because carbon dioxide (CO2) is one of the major greenhouse gases causing the gradual warming of the Earth's surface and potentially disastrous changes to global climate, CO2 ocean sequestration is being explored as one possible approach to limit the accumulation of greenhouse gases in the atmosphere. CO2 released in very cold deep-water forms ice-like solids known as hydrates. [xvi] There are a number of experiments ongoing to inject carbon dioxide into the deep ocean, and to then gather data in the vicinity of the CO2 injection point to improve our understanding of the basic physical phenomena, and to apply this data to refine the accuracy of predictive computer models that are needed to evaluate environmental impacts. Model validation is a first and necessary step to assess the physical, chemical and environmental effects of CO2 sequestration in the deep ocean.[45]

CO2 ocean sequestration is a concept that was conceived in the early 1980s to avoid the rapid build-up of carbon dioxide in the atmosphere. However, there is rather daunting amount of scientific uncertainty surrounding impacts on the marine environment. Full-scale sequestration requires a lot more research before this concept sees the light of day. Using relatively shallow oceans (at roughly 800 meters) as a massive sink for removing immense amounts of CO2 pollution from global industry is merely transferring contaminants from land to sea. And

anything stored that deep will be very difficult to recover and may well leak. Moving the problem of CO2 pollution encourages the continued use of fossil fuel for power generation. It would be much better to address climate change through clean energy solutions like hydrogen fuel cells, avoiding CO2 production in the first place.[46]

In addition to increasing hydrates, the injection of CO2 results in lower pH (more acidic) waters. Creatures living on the sea floor (benthic communities) near the injection point could be affected by the acidic water; more mobile (swimming) animals are not expected to be harmed. An increase in atmospheric CO2 transfer into shallow waters has also been identified as an inhibitor in coral calcification, the building material for coral reefs.

## PREVENTION/MITIGATION

There is still some hope that we have the capacity to avoid accelerating climate change or at least, to slow the rate of change and improve our odds of addressing its impact. However, this issue lies at the intersection of social/political and biological/physical systems. An overwhelming majority of scientists think that continued growth of greenhouse gas emissions

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[xvi] Ice-like solids formed when CO2 forms new compounds with water – they exist now, but we do not know what will happen if there are more.

will certainly raise average global temperatures and change regional climates; the only questions are how much and how fast this will occur under various scenarios. The uncertainties associated with each modeling scenario have become an obstacle to adoption of a regulatory structure and related policies to reduce greenhouse gas emissions, even though the scientists have clearly called for human action to reduce greenhouse gas pollution as an imperative. While there is a lack of absolutes in scientific advice, the scientists have achieved a widespread consensus on the overall expected effect.[47]

We are operating with a lack of political will to reverse perverse subsidies[xvii] together with unsustainable assumptions and trends built into our economic structure, such as ever-expanding consumption. There are in fact several good processes currently underway to deal with perverse fisheries subsidies, including at UNEP, FAO and WTO. However, these efforts tend toward the lowest common denominator; they will also have to run a gauntlet of domestic implementation legislation before they become a reality. There is an almost complete lack of long-range planning, certainly a significant lack of ecosystem planning, and very little precaution built into our human development model. The precautionary approach and ecosystem management are the two pillars of sustainable management of marine resources, as embodied in international law that must be followed. Among other consequences, we may risk political instability through failure to address climate change induced degradation of our ecosystem supports for human health and economic well-being.

Our policymakers need to find the right incentive structures to get everyone to move in the right direction. There are two choices: change our lives through the exercise of restraint, or change in response to environmental catastrophe. Human capacity to exercise restraint is a source of hope, whether the restraint comes from new knowledge or gut-level compassion. Most of us do not live anywhere near the poverty level, we have room to reduce our consumption without undercutting our quality of life – "all but the poorest of us could choose to lead materially simpler lives, and thereby do less harm and reap more joy."[48] But this is a hard sell to the general public unless such "joy" is truly and clearly attainable—and feels as much like independent choice as current lifestyles. For example, there are:

> five key actions that grantmakers can target to accelerate meaningful change in the area of sustainable production and consumption: Increase consumer awareness and choice...promote innovation policies...accelerate demand for green products...demand corporate accountability...encourage sustainable business practices...[49]

**Assume We Must Learn to Adapt to Change**

The fundamental climate change adaptation message is about coping with constant change in comparison to what we have come to expect. The past 10,000 years, during which modern civilization arose, has been a period of climate stability relative to what we know of earth's history. However, that stability, and the predictability for food production, travel, and where and how we build things, may be put into question when we ask what the oscillations from our perturbation of the climate system will look like.

[xvii] Improper incentives used in the blind search for economic expansion.

Mitigation technologies have been proposed that include: nuclear power, fuel switching (using fuels with lower carbon content, such as replacing oil or coal with natural gas), reforestation, renewable energies, energy conservation and improved energy efficiency.. In addition, to address shocks to our system such as human health impacts, we will need to focus on the maintenance and improvement of our public health care systems and their responsiveness to changing climate conditions and to identifying vulnerable populations.

More coastal areas will need to build structures to withstand stronger storms. We will have to retreat from the beach, giving the ocean the room it needs to expand. In 1998, NOAA summarized the coastal responses as follows:

> (1) ***Accommodate.*** Vulnerable areas continue to be occupied, accepting the greater degree of effects, e.g., flooding, saltwater intrusion, and erosion; advanced coastal management used to avoid the worst impacts; improved early warning of catastrophic events; and building codes modified to strengthen structures
>
> (2) ***Protect***. Vulnerable areas, particularly population centers, high-value economic activities, and critical natural resources, are defended by sea walls, bulkheads, saltwater intrusion barriers; other infrastructure investments are made; and "soft" structural options such as periodic beach re-nourishment, landfill, dune maintenance or restoration, and wetlands creation are carried out
>
> (3) ***Retreat***. Existing structures and infrastructure in vulnerable areas are abandoned, inhabitants are resettled, government subsidies are withdrawn, and new development is required to be set back specific distances from the shore, as appropriate.[50]

**While We Assume that All Science and Policy Cooperation Must Be International, We Must Act Locally and Nationally Immediately**

Historically, environmentalists have opposed development, yet they have slowly begun to see that poverty often exacerbates environmental degradation, which in turn limits the resources available for economic development. Indigenous peoples in many countries cut trees in national parks and protected areas for use as firewood, clear rainforest for farmland, and so on. In doing so they release the carbon stored in those trees and eliminate the trees as a sink for natural carbon sequestration.

Massive logging in developing nations, often promoted to provide short term income to address international debt loads, both reduces the global carbon sequestration capacity and has adverse longer-term effects on both inland and coastal communities. Logging exacerbates the degradation of coral reefs and other marine ecosystems on which many coastal communities rely and which have already suffered from over-harvesting of fish and other marine species.[xviii] The loss of natural carbon sequestration also puts pressure on finding ways to further abuse the oceans by manually storing our carbon emissions in the deep sea waters.

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[xviii] Clear cutting causes siltation, and agriculture results in nutrient runoff; both of which negatively impact coastal marine ecosystems.

We must find ways to alleviate poverty and its threat to the environment without harm to society, culture, or biodiversity. This effort will undoubtedly include an emphasis on sustainable development including long-term planning and public participation, and some grants or other financial assistance directed toward those in need.[xix]

However, as undeniable as poverty's environmental consequences may be, they pale in contrast to the problems caused by excess consumption, which must be more aggressively addressed than it has been. Rapacious appetite for farm-raised shrimp has caused the destruction of critical mangrove habitat in Thailand, Ecuador, and other countries, which both destabilizes the local subsistence economy and harms the marine species that depend on mangroves—communities and species already vulnerable to even small changes in temperature.[xx] Farm-raised salmon has risen dramatically in popularity, and its production has adverse effects on the resilience of local marine ecosystems, and worse, the salmon are fed fishmeal made of prey fish such as anchovies whose populations have also proven to be particularly vulnerable to climate events. Clearly, more sustainable means of production must be found quickly.

The carbon-based sources of energy needed to support a consumer society, from electricity to transportation, have continuous negative effects on marine ecosystems that must be addressed. Airborne nitrogen deposition from power plants and other sources contributes to the degradation of such key estuaries as Chesapeake Bay, Mobile Bay, and Florida Bay. Emissions from ocean-going vessels also contribute to the air-borne pollutants that find their way into marine ecosystems, reducing their resilience to climate change and increasing marine species' vulnerability to disease.

## OPPORTUNITIES FOR PHILANTHROPY AND PHILANTHROPIC COLLABORATION

The marine conservation community obviously has a key role to play in dealing with climate change. While many of the necessary actions lie outside the traditional realm of ocean conservation – and thus marine funders should partner with others around general climate intervention strategies – there are some particular oceans-related opportunities.

There are only a few examples of marine funders taking on climate change, tweaking their extant marine grantmaking and/or adding new areas to portfolios to specifically try and mitigate or forestall some of the bad effects of climate change. For example:

- The ***Oak Foundation*** undertakes both marine and climate change related grantmaking in two distinct programs.
- The ***Kendall Foundation***, a long-time marine funder, is now a leader in regional climate change funding.
- The ***Surdna Foundation*** has initiatives going in both areas, but has not yet linked them – "We are looking at the climate links to our energy and transportation/land use funding, but as yet have not done anything specific on the biodiversity front which includes our marine work."[51]

[xix] The scope of this paper does not allow the time or space to go into the myriad of sustainable development programs and initiatives.
[xx] The clearing of mangrove forests, as with all forms of deforestation, also reduces natural carbon sequestration.

- The ***Munson and Henry Foundations*** look at marine ecosystems from a conservation view point, but also as a victim of climate change – "We continue to believe that healthy systems are and will continue to respond better to change than systems under stress from human activity. While the Munson and Henry Foundations haven't adopted a specific climate change policy or program focus, we are trying to ensure that 1) discussions about climate change solutions address the potential conflicts within the conservation community and within specific conservation goals that coastal energy issues represent; 2) that both the funding of essential fish habitat protection and predator-prey work have the goal of promoting resilience in fisheries; and 3) that site specific work promotes resilience in coral reef species and other ecosystems."[52]
- The ***Alaska Conservation Foundation*** has initiatives in both areas – "As a result of our triennial strategic planning process, the Alaska Conservation Foundation added climate change to our new initiatives list in 2001. Because Alaska is ground zero for the measurable impacts from global warming, and because global warming – if unabated – will irreparably harm our magnificent terrestrial and marine ecosystems, we felt that our foundation had an obligation to become engaged in addressing this tremendous problem. Since then, we have funded conferences, media education, global warming tours, renewable energy solutions work, and other efforts, with excellent results including extensive national and local media coverage; several successful wind power demonstration projects; being well positioned for a huge wind project in Anchorage; and telling the Alaska story to persuade in legislative and other fora."[53]

Because of the importance of climate change impacts upon economic activities, public health, natural resources, ecosystem health, and social benefits, including cultural values, we need to be proactive and preventative:

- We know what the environmental problems are (see Table 2 above).
- The technology for public and private solutions and improvements exist, whether we call it sustainable technology, natural capitalism,[xxi] sustainable development, smart growth or "thinking outside the box."
- There are existing institutions and international agreement frameworks to implement solutions.
- Our challenge is to find ways to overcome structural and philosophical obstacles to the solutions.

What is the role of philanthropy in overcoming these obstacles? First, we must continue to support climate change science and its interpretation for the public and policy makers. Second, we must support research that makes clear the adverse economic impact of climate change. Even though the costs of taking steps to mitigate climate change seem localized, cumulatively the costs of not acting to address its causes are broad, universal and overwhelming. Third, we must support a new policy-level, non-technical dialogue regarding climate change. For too long, we have been relying on the weight of science to overcome policy stagnation. Instead let us support

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[xxi] Increased resource productivity; industrial ecology and/or closed-loop production in which every output is either returned harmlessly to the ecosystem as a nutrient, like compost, or becomes an input to manufacturing another product; and shifts from selling to leasing durable, reusable, non-toxic products, owned by the manufacturer throughout their lifecycles. Interestingly, such environmentally wise moves increase profitability while reducing the risk of exposure to environmental liabilities.

a dialogue on the ethics and efficacy of our actions in relation to others and to future generations. Let us speak affirmatively that this is the question, not whether climate change is coming. After all, climate change is here.

In the context of a more traditional role for philanthropy, a diversified portfolio of grant making approaches is needed to address global change and its effects on ocean ecosystems. Reducing greenhouse gas emissions and the human contribution to global warming is a top priority. Rebuilding ecosystem resilience that has been eroded by other human impacts is equally important because of the delay between emissions control and future stabilization of global temperatures. Finally, new initiatives in policy, public literacy and university-level education are needed to develop a broader commitment to ocean conservation in the age of global climate change.

We should support efforts to enhance the integration of climate change in oceans conservation, so that the two realms are no longer considered separately. Many of the top non-government organizations working in one arena have equally strong, but separate programs in the other. And often those programs are working and thinking independently, rather than integrating strategies and goals.

And where integration is not readily achievable, it is still vitally important to support projects that enhance the health, and thus the resilience of ecosystems most at risk from climate change, including coral reefs. For example, such projects would include promoting land use planning that leaves room for coastal habitat where human development occurs or addressing nutrient and other forms of land-based pollutant run-off into marine ecosystems.

**Table 3. Factors affecting climate change impacts on the oceans**

| Mediating Factors | Impacts |
|---|---|
| Slow adoption of renewables and energy efficient technology | Acceleration of the human contribution to global warming |
| Expanding consumption of fossil fuels | Acceleration of the human contribution to global warming |
| Loss of ecosystem resilience | Other impacts make it harder for ocean ecosystems to adapt to climate change |
| Expanding coastal development | Human infrastructure leaves little room for coastal ecosystems to move landward in response to rising sea level |
| Lack of awareness of climate change impacts on the oceans | No commitment to address these impacts through policy; regulation |

## CONCLUSION

The ocean, which covers roughly 71 percent of Earth's surface, has the thermal inertia and heat capacity to help maintain and ameliorate climate variability. However, greenhouse gas emissions from human activities are projected to cause global climate change in excess of normal patterns, which in turn will alter coastal and marine ecosystems that are already stressed from human development, environmental pollution, and over-fishing. We need to act now if we hope to avert far worse perturbations of the natural climate system.

Unfortunately, fundamental societal change is required—the political will to adopt cleaner fuels (gasohol, alcohol), increase the use of wind and solar energy, and increase the efficiency of the technologies that do use fossil fuels. All of these solutions are at hand, available, and even economical—especially when all costs are considered. There is a clear role for philanthropy in moving us forward in this shift.

Some examples of philanthropic investments that will lead to positive climate change outcomes for our global ocean are:

- Research and Monitoring Investments
  - Global Ocean Observing System (GOOS)[xxii]
  - Polar and sea ice coverage monitoring
  - Carbon sequestration research[xxiii]

- Regional Investments
  - Alternative transportation thinking
  - Land use planning in coastal areas, including integrated coastal zone management techniques
  - UN Global Programme of Action on Land-Based Sources of Marine Pollution
  - Wet land and coastal protections
  - Coastal renewable energy development
  - Appliance standards

- Limit Carbon Emissions in General
  - Address marine vessels as very significant (and largely ignored) emitters of pollutants[xxiv]
  - Use of low carbon fuels
  - Pollution prevention
  - Energy efficiency and renewable energy (fuel cell technology investments) in General

In addition to these energy-related investments, there are the investments in resilience—promoting the ability of ecosystems and species to adapt to climate change or at least better withstand the adverse affects of climate change:

- Promote marine protected areas to increase survival prospects for species and habitat types
- Promote ridge to reef integrated management (e.g. White Water to Blue Water project[54])

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[xxii] The Global Ocean Observing System (GOOS) is slowly beginning to afford us an in-depth look at the world's oceans and weather systems. The $4 billion UN International Oceanographic Commission project integrates several isolated weather monitoring systems into a single network. With the addition of robot sensors deployed across notoriously under-observed areas, the system will be enabled to predict the behavior of entire oceans and produce reliable routine weather forecasts for up to two years in advance. The sensor data on winds, barometric pressure, air and water temperature provide at least a few months' advance notice of increased risk of climate-related disasters. Please see the UNESCO Global Ocean Observing System web site for more information, http://ioc.unesco.org/goos/

[xxiii] Although the ocean aspects remain very controversial, there is a great need for marine conservation experts to be involved at an early stage in debates about C02 sequestration.

[xxiv] The Boston Clean Air Task Force notes that ship emissions of nitrogen oxides equal all US NOx emissions, and that overall ship emissions may be as large or larger in US coastal areas than all land-based emissions by 2015.

- Limiting coastal habitat development (to allow ocean expansion and sea level rise)
- Environmental, economic, and equity education to increase awareness (stories we can use – e.g. disappearing polar bears, relocating Vanuatu, etc.)
- Continue to support efforts to reduce or eliminate non-climate stresses to marine life (such as dead zones, habitat destruction, contaminated runoff, sedimentation, overfishing and bycatch).

The complex web of currents, temperatures, salinity levels, and chemistry that fosters life in the ocean is at risk of being irreversibly ruptured by the unpredictable, unstable, and overwhelming consequences of climate change. We have the opportunity to ensure that the oceans continue to provide us with critical food and other services, even as we work to limit the damage caused by our own excess. Each new report on the anticipated and projected effects of this new era of climate unpredictability seems to underscore the futility of conservation efforts—on land and at sea. In the long term, philanthropy's clear goal is to help bridge the gap between marine conservation and energy policy. However, focusing on resilience, on improving our knowledge of the oceans, and on fostering the ethic of moving quickly to limit human insult to our marine neighbors gives us more than a place to start—it gives us a strategy that improves sustainability in the short-term and in the long run—and that is as much as we can ask for.

## INTERNET RESOURCES

- See the website of Global Warming Early Warning Signs at http://www.climatehotmap.org
- Intergovernmental Panel on Climate Change, http://www.ipcc.ch
- To track the events around politics of global warming go to the International Institute for Sustainable Development website at http://www.iisd.ca
- IUCN World Conservation Union Climate Change Initiative, http://www.iucn.org/themes/climate/
- The Pew Center on Global Climate Change, http://www.pewclimate.org
- The Union of Concerned Scientists pages on climate change, http://www.ucsusa.org/global_environment/global_warming/index.cfm?pageID=27
- US Climate Change Science Program (which includes the US National Assessment of the Potential Consequences of Climate Variability and Change), http://www.climatescience.gov/
- The USEPA has created a climate change glossary that is available at http://www.climatenetwork.org/canglossary.html
- The USEPA has created a web page entitled "Sea Level Rise Reports" to help people in the coastal zone prepare for the possible adverse effects of rising sea level, http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsSeaLevelRiseIndex.html

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