HJR

10

<TARGET><BILL>HJR 10</BILL><SUBJECT>HJR
10</SUBJECT><COMM>HFSH27</COMM></TARGET>

Representative Beth Kerttula

House Minority Leader

Sponsor Statement

Joint House Resolution HJR10 "Ocean Acidification Research"

"Supporting expanded research concerning the detrimental effects of ocean acidification."

House Joint Resolution 10 recognizes the threat ocean acidification poses to Alaska's marine ecosystems, tourism industry and fisheries. The resolution supports research of ocean acidification to understand the effect ocean acidification would have on Alaska's economy.

Alaska may be particularly vulnerable to ocean acidification because of its unique climate. Ocean salinity can act as a buffer against carbon dioxide absorption; however, Alaska's cold ocean temperature creates a lower salinity content, and allows more carbon dioxide to be absorbed into the water. When carbon dioxide is absorbed by the ocean, it has the potential to harm marine ecosystems. Marine organisms, such as plankton and shellfish, and other foods that form the marine food base are at risk of being affected by ocean acidification. Alaskan marine ecosystems may be more susceptible to the effects of carbon dioxide absorption and more research needs to be done to establish how ocean acidification may affect various sector of Alaska.

Alaskan oceans serve Alaska in many ways. In 2007 Alaska accounted for more than 62 percent, by volume, of the commercial seafood harvested in the United States. The jobs that are created by the seafood industry out-number the number of jobs created by any other industry in the state. Many tourists come to Alaska to see Alaska's marine wildlife. Tourism is Alaska's third largest private sector and supplies 26,000 full time jobs. The oceans are also a critical food source for many Alaskans. This resolution would promote research that supports protecting all these activities and industries.

Because of Alaska's unique situation, ocean acidification could be more severe in Alaska and could pose a larger threat to Alaska's marine ecosystems, fisheries and tourism industry which all play a large role in Alaska's economy, and Alaskan's way of life.

Thank you for your support of House Joint Resolution 10

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2/21/12

CS FOR HOUSE JOINT RESOLUTION NO. 10(FSH)

IN THE LEGISLATURE OF THE STATE OF ALASKA

TWENTY-SEVENTH LEGISLATURE - SECOND SESSION

BY THE HOUSE SPECIAL COMMITTEE ON FISHERIES

Offered:
Referred:

Sponsor(s): REPRESENTATIVES KERTTULA, Miller

A RESOLUTION

Supporting expanded research concerning the detrimental effects of ocean acidification.

BE IT RESOLVED BY THE LEGISLATURE OF THE STATE OF ALASKA:

WHEREAS ocean waters and resources are vital to the economy, cultural identity, and daily lives of many Alaskans; and

WHEREAS it is estimated that the seafood industry contributed a total of $5,800,000,000 to the state's economic output in 2007, including an estimated $3,600,000,000 in wholesale value and $2,200,000,000 in indirect and induced economic output; and

WHEREAS Alaska is home to eight of the 20 largest seafood ports in the United States; and

WHEREAS, in 2007, Alaska seafood accounted for more than 62 percent, by volume, of the commercial seafood harvested in the United States; and

WHEREAS the seafood industry employs more workers than any other industry in the state; and

WHEREAS tourism is a major economic engine in the state, with a direct economic contribution that exceeds $1,600,000,000 annually and an induced effect that exceeds $2,000,000,000 annually; and

WHEREAS tourism is the state's third largest private sector employer, supplying more than 26,000 full time equivalent jobs; and

WHEREAS recreational fishing, whale watching, and other ocean-related activities constitute critical sectors of the state's tourism industry; and

WHEREAS coastal residents of the state depend on ocean resources for subsistence, recreation, and other uses; and

WHEREAS tourism, fishing, subsistence, and recreation are supported by healthy ocean ecosystems; and

WHEREAS the world's oceans have absorbed more than a quarter of the carbon dioxide released into the atmosphere since the start of the Industrial Revolution; and

WHEREAS carbon dioxide absorbed by the oceans has altered ocean chemistry, increasing the acidity of the ocean by 30 percent on average since the start of the Industrial Revolution; and

WHEREAS the acidity of surface water could double by the end of this century if current trends continue; and

WHEREAS the process of ocean acidification is accelerated in Arctic waters because carbon dioxide is more soluble in cold water, and lower salinity diminishes the capacity of oceans to buffer against acidification; there is evidence that ocean acidification is both more severe and occurring more rapidly in the state's ocean waters than in tropical waters; and

WHEREAS the effects of ocean acidification could create conditions detrimental to marine ecosystems in the state within decades; and

WHEREAS ocean acidification will affect the growth, reproduction, behavior, disease resistance, and other biological and physiological processes of many marine organisms; and

WHEREAS ocean acidification threatens carbonate-forming species, such as coral, shellfish, and many species of marine plankton, and changes to those species may cause significant detrimental effects throughout marine ecosystems and food webs, affecting the largest marine organisms and many commercial fisheries; and

WHEREAS plankton, which form the base of the marine food web, King, Tanner, and Dungeness crab, deep-sea coral gardens, and pteropods, which serve as important prey for whales, salmon, and other marine life, are all at risk because of the effects of ocean acidification; and

WHEREAS the North Pacific Fishery Management Council, in its 2007 Aleutian Islands Fishery Ecosystem Plan, highlighted ocean acidification as both very likely to occur and likely to cause significant ecological and economic effects; and

WHEREAS, because there is a scarcity of relevant data necessary for assessing the potential effects of ocean acidification in the state, the North Pacific Fishery Management Council has recommended ocean acidification be a research priority;

BE IT RESOLVED that the Alaska State Legislature recognizes that ocean acidification is a threat to the state's marine ecosystems, tourism industry, and fisheries; and be it

FURTHER RESOLVED that the Alaska State Legislature supports the monitoring and research that are necessary to study the effects of ocean acidification on the state's marine ecosystem to determine potential effects on the state's economy and to assess opportunities to address the effects of ocean acidification.

COPIES of this resolution shall be sent to the Honorable Barack Obama, President of the United States; the Honorable Joseph R. Biden, Jr., Vice-President of the United States and President of the U.S. Senate; the Honorable Hillary Rodham Clinton, United States Secretary of State; the Honorable John Boehner, Speaker of the U.S. House of Representatives; the Honorable Harry Reid, Majority Leader of the U.S. Senate; the Honorable Lisa P. Jackson, Administrator of the U.S. Environmental Protection Agency; Dr. Jane Lubchenco, Under Secretary of Commerce for Oceans and Atmosphere and National Oceanic and Atmospheric Administration Administrator; Samuel D. Rauch III, Acting Assistant Administrator for Fisheries, National Oceanic and Atmospheric Administration; Julia L. Gourley, U.S. Senior Arctic Official, Office of Ocean and Polar Affairs, U.S. Department of State; the Honorable Patrick K. Gamble, President, University of Alaska; and the Honorable Lisa Murkowski and the Honorable Mark Begich, U.S. Senators, and the Honorable Don Young, U.S. Representative, members of the Alaska delegation in Congress.

FISCAL NOTE

STATE OF ALASKA
2012 LEGISLATIVE SESSION

Bill Version	HJR10
Fiscal Note Number	
() Publish Date	

Identifier (file name)	HJR10-LEG-COU-2-22-12
Title	"Supporting expanded research concerning the detrimental effects of ocean acidification."
Sponsor	Representatives Kerttula and Miller
Requester	House Special Committee on Fisheries
Dept. Affected	Legislature
Appropriation	Legislative Council
Allocation	Session Expenses
OMB Component Number	782

Expenditures/Revenues (Thousands of Dollars)

Note: Amounts do not include inflation unless otherwise noted below.

	FY13 Appropriation Requested	Included in Governor's FY13 Request	Out-Year Cost Estimates				
OPERATING EXPENDITURES	**FY13**	**FY13**	**FY14**	**FY15**	**FY16**	**FY17**	**FY18**
Personal Services							
Travel							
Services							
Commodities							
Capital Outlay							
Grants, Benefits							
Miscellaneous							
TOTAL OPERATING	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

FUND SOURCE		(Thousands of Dollars)						
1002	Federal Receipts							
1003	GF Match							
1004	GF							
1005	GF/Prgm (DGF)							
1037	GF/MH (UGF)							
1178	temp code (UGF)							
TOTAL		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

POSITIONS							
Full-time							
Part-time							
Temporary							

CHANGE IN REVENUES							

Estimated SUPPLEMENTAL (FY12) operating costs ________ *(separate supplemental appropriation required)*
(discuss reasons and fund source(s) in analysis section)

Estimated CAPITAL (FY13) costs ________ *(separate capital appropriation required)*
(discuss reasons and fund source(s) in analysis section)

Why this fiscal note differs from previous version (if initial version, please note as such)

Initial Version

Prepared by	Jessica Geary, Finance Manager	Phone	465-6626
Division	Legislative Affairs Agency	Date/Time	2/22/12 4:30pm
Approved by	Pamela Varni, Executive Director Legislative Affairs Agency	Date	2/22/2012

(Revised 1/17/2012 OMB)

FISCAL NOTE

STATE OF ALASKA
2012 LEGISLATIVE SESSION

BILL NO. HJR10

Analysis

This Legislation has zero fiscal impact on the Legislative Affairs Agency.

ORAL TESTIMONY OF
RICHARD A. FEELY, Ph.D.
OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S DEPARTMENT OF COMMERCE

HEARING ON

BEFORE THE
STATE OF ALASKA HOUSE FISHERIES COMMITTEE
ALASKA HOUSE OF REPRESENTATIVES

February 23, 2012

Good afternoon Chairman Thompson and members of the House Fisheries Committee. My name is Dr. Richard Feely. I am a NOAA Senior Fellow and head of the Carbon Program at the Pacific Marine Environmental Laboratory in Seattle, Washington. My expertise is in ocean carbon measurements and ocean acidification. Thank you for giving Dr. Mathis and myself the opportunity to speak with you today on ocean acidification, its impacts on marine life, and potential economic impacts.

Fundamental measurable changes in seawater chemistry are occurring throughout the world's oceans. Over the past two and a half centuries, the release of 2 trillion tons carbon dioxide from our industrial and agricultural activities has resulted in atmospheric carbon dioxide levels that have increased from about 280 to 392 parts per million. To date, the oceans have absorbed about one third of the carbon emissions released by human activities during this period. This natural process of absorption has benefited humankind by significantly reducing the greenhouse gas levels in the atmosphere and reducing some of the impacts of global warming. However, decades of ocean observation and research sponsored by NOAA, the National Science Foundation and the Department of Energy show that the ocean's daily uptake of 22 million tons of carbon dioxide is having a significant impact on the chemistry and biology of the oceans.

When carbon dioxide reacts with seawater, chemical changes occur that cause a decrease in seawater pH and carbonate ions. These chemical changes are commonly referred to as "ocean acidification." Scientists have estimated that surface ocean pH has fallen by about 0.1 units since the beginning of the industrial revolution. Since the pH scale, like the Richter scale, is logarithmic, this change represents approximately a 30 percent increase in ocean acidity. Future predictions indicate that the oceans will continue to absorb carbon dioxide and become even more acidic. Estimates of future carbon dioxide levels, based on business as usual emission scenarios, indicate that by the end of this century the surface waters of the ocean could be nearly 150 percent more acidic, resulting in a pH that the oceans haven't experienced for more than 20 million years.

Many marine organisms that produce calcium carbonate shells or skeletons, such as crabs, oysters, scallops, and pteropods, are negatively impacted by the increasing carbon dioxide levels and decreasing pH in seawater. For example, increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons. Coral biologists have reported that ocean acidification could compromise the successful fertilization, larval settlement and survivorship of Elkhorn coral, an endangered species. These research results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance. Other research indicates that, by the end of this century, coral reefs may erode faster than they can be rebuilt. This could compromise the long-term viability of these ecosystems and perhaps impact the estimated one million species that depend on coral reef habitat.

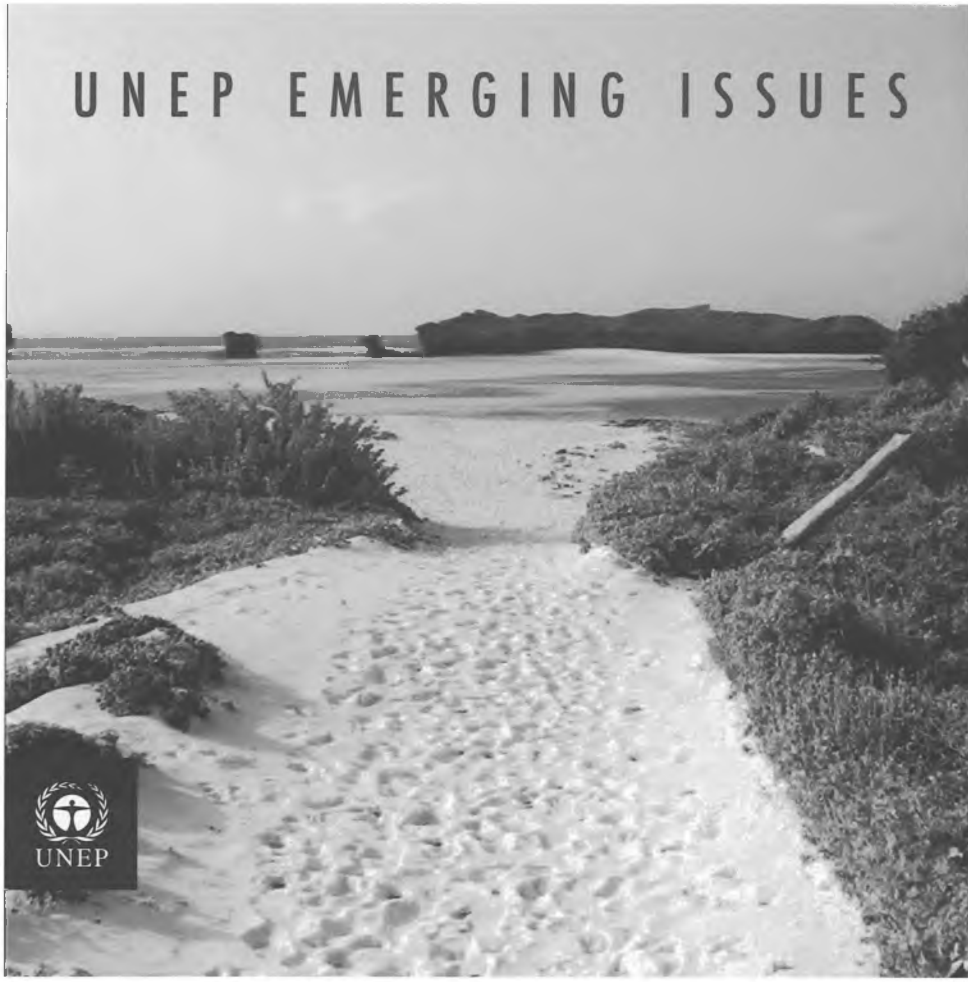
Ongoing research is showing that decreasing pH may also have deleterious effects on commercially important fish and shellfish larvae. King crab, herring and cod exhibit high mortality rates in carbon dioxide-enriched waters. The calcification rates of the edible mussel and Pacific oyster decline linearly with increasing carbon dioxide levels. Since 2006, some oyster hatcheries in the Pacific Northwest have experienced mass mortalities of oyster larvae in association with a combination of factors, including the upwelling of cold, carbon dioxide-rich waters. Scientists have also seen a reduced ability of some types of marine plankton to produce protective carbonate shells. These organisms are important food sources for other marine organisms. One type of free-swimming mollusk called a pteropod is eaten by organisms ranging in size from tiny krill to whales. Pteropods are a major food source for North Pacific juvenile salmon, and are also food for mackerel, herring, and cod.

Since ocean acidification research is still in its infancy, it is impossible to predict exactly how these impacts will cascade throughout the marine food chain and affect the overall structure of marine ecosystems. It is clear, however, from both the existing data and from the geologic record that some coral and shellfish species will be negatively impacted in a high- carbon dioxide ocean. The rapid disappearance of many calcifying species in past extinction events has been attributed, in many cases, to ocean acidification events. Over the next century, if carbon dioxide emissions are allowed to increase as predicted by business as usual carbon emissions scenarios, humankind may be responsible for making the oceans more corrosive to calcifying organisms than at anytime in the last 20 million years.

The impact of ocean acidification on fisheries and coral reef ecosystems could reverberate through the U.S. and global economy. The U.S. is the third largest seafood consumer in the world with total consumer spending for fish and shellfish around $70 billion per year. Coastal and marine commercial fishing generates upwards of $35 billion per year and employs nearly 70,000 people. The total value of U.S. commercial harvests from U.S. waters and at-sea processing was approximately $4 billion in 2007.

In conclusion, ocean acidification is caused by the buildup of carbon dioxide in the atmosphere and can have significant impacts on marine ecosystems. Ocean acidification is an emerging scientific issue and much research is needed before all of the ecosystems' responses are well understood. However, to the limit that the scientific community understands this issue right now, the potential for environmental, economic and societal risk is quite high, hence demanding serious and immediate attention. Thank you, Mr. Chairman and members of the committee, and I look forward to answering any questions.

UNEP EMERGING ISSUES



ENVIRONMENTAL CONSEQUENCES OF OCEAN ACIDIFICATION: A THREAT TO FOOD SECURITY

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Printing: UNON/Publishing Services Section/Nairobi, ISO 14001:2004-certified.

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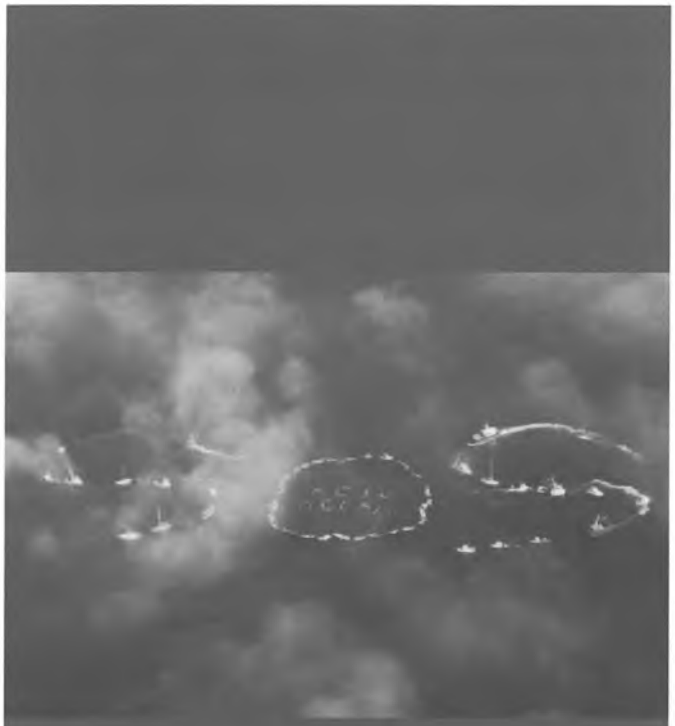


"Save Our Seas- Acid Ocean" *- Awareness of the ocean acidification issue is increasing. Following reports on the CO_2 rich waters off Alaska in 2008[20], commercial fishermen and other stakeholders recognised the potential impact of ocean acidification and aptly demonstrated their concern. In Homer, Alaska, commercial fishermen and other mariners formed an SOS to raise awareness about ocean acidification caused by fossil fuel emissions.*
Photo: Lou Dematteis (2009) Associated Press

1. Introduction

Increased carbon dioxide (CO_2) from the burning of fossil fuels and other human activities continues to affect our atmosphere, resulting in global warming and climate change[1]. Less well known is that this carbon dioxide is altering the chemistry of the surface oceans and causing them to become more acidic[2]. From scientists and marine resource managers, to policy and decision-makers, there is growing concern that the process called ocean acidification could have significant consequences on marine organisms which may alter species composition, disrupt marine food webs and ecosystems and potentially damage fishing, tourism and other human activities connected to the seas[3].

Ocean acidification, which affects the carbonate chemistry of the ocean, is directly caused by greater atmospheric emissions of CO_2 [4]. These emissions have increased over the last 200 years, primarily due to intensified industrialisation and agriculture resulting in greater burning of fossil fuels, cement manufacturing and land use change[4]. Many organisms depend on the relatively stable balance of carbonate chemistry which has endured for millions of years until the onset of the industrial revolution. Since then there has been a 30% decrease in pH and a 16% decrease in carbonate ion concentrations. Carbonate ions are used by organisms to make shells and reef systems thus it may be more difficult for organisms to do this in the future as carbonate ions decrease further. These organisms are a human food source (e.g. molluscs), provide food for fish (e.g. pteropods are eaten by salmon) and create ecosystems and refuges for fish (e.g. coral reefs). As CO_2 emissions continue to rise, ocean acidification is rapidly becoming a critical issue with the potential, if unabated, to affect many species and their ecosystems, pertinently including those associated with human food resources. Ocean acidification is happening now, is measurable and will increase as more CO_2 is emitted[5]; it is likely that if CO_2 emissions continue at the same rate ocean acidification will have a considerable influence on marine-based diets for billions of people worldwide.

Ocean Acidification: Simple chemistry - Global impact

The basic chemistry of sea water is being altered on a scale unseen within fossil records over at least twenty million years[6], and it is happening at an unprecedented rate not experienced in the last 65 million years[7]. The chemistry is straightforward: when CO_2 enters seawater it produces a weak acid known as carbonic acid, which is unstable and leads to an increase in hydrogen ions. These ions increase ocean acidity, measured as lower pH, and reduce carbonate ion saturation[3, 8].

The pH scale is logarithmic and measures how acidic or alkaline a substance is; it ranges from 0 - strong acid to 14 - strong base while 7 on the scale indicates neutral. The oceans are naturally alkaline, with a mean surface ocean pH of about 8.2 in 1750. Today surface ocean acidity has increased by 30% (resulting in a drop in mean pH of 0.1 to about 8.1 on the logarithmic pH scale) due to the vast amount of man-made CO_2 absorbed by the oceans since pre-industrial times – an estimated 500 Gigatonnes or 25% of that emitted to the atmosphere[4]. If we continue at this rate the ocean pH will decline by a further 0.3 by the end of this century, an unprecedented 150% increase in ocean acidity[2, 3]. This rate of change has not been experienced for around 65 million years, since the dinosaurs became extinct.

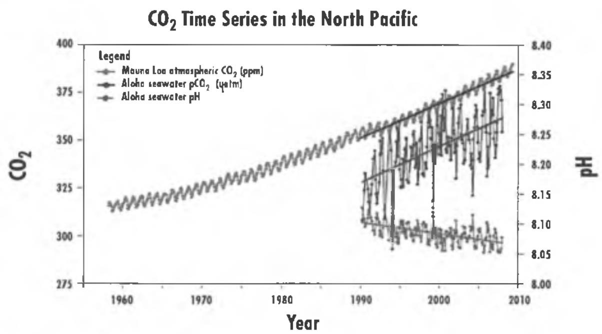
Such a major change in basic ocean chemistry is likely to have substantial implications for ocean life in the future, especially organisms that require calcium carbonate to build shells or skeletons[3, 9-11]. Not all organisms will react at the same rate or in the same way to decreasing carbonate ion concentration[12 13]. There are three naturally occurring forms of calcium carbonate used by marine organisms to build shells, plates or skeletons: calcite, aragonite and high-magnesium calcite. For example, microscopic plants called coccolithophores surround themselves with protective calcite plates; aragonite is used by pteropods to build their shells and corals use it to make their skeletons that help to form reefs; while some echinoderms – starfish, sea urchins, brittle stars - utilise magnesium calcite to form their exoskeletons[3, 10]. Magnesium calcite is more soluble and sensitive to ocean acidification than aragonite; with calcite being the least soluble of the three. A lowering of pH and reduction of carbonate ions will make it more difficult for organisms to sustain their calcified shells, and in undersaturated conditions, waters become corrosive to these minerals.

Additionally, most multicellular marine organisms have evolved a regulatory system to maintain the hydrogen ion balance of their internal fluids[14] and spend energy doing this so an increase in hydrogen ions in seawater means that they will have to divert more energy away from important processes such as growth and reproduction to do this. However, studies of mussels, crab and sea urchin species have shown they have only a partial or no, compensation mechanism[15] potentially making them more vulnerable than those organisms that possess a compensation mechanism.

2. CO_2, climate change and ocean acidification

Seawater acidity varies across the oceans with temporal changes reflecting seasonal changes in biological activity (Fig. 1) and geographical variations depending on other factors such as seawater temperature and depth[4, 5]. However, ocean observations at a station off Hawaii over the last 20 years show increases in seawater CO_2 and decreases in seawater pH clearly tracking increases in atmospheric CO_2 (Fig. 1). The global ocean average pH was 8.2 before industrialisation but ocean acidity has risen as the oceans have absorbed increased amounts of CO_2 emissions. Consequently, there has been a decrease in pH of 0.1 which, significantly, represents a 30% increase in seawater's acidity[2-4].

Figure 1: The Mauna Loa records of atmospheric CO_2 over the last 50 years with the surface ocean CO_2 and pH recorded off Aloha Station during the last two decades from the Hawaii Ocean Time-Series. Seawater CO_2 concentration mirrors the increases in the atmosphere and as seawater CO_2 concentration increases pH drops.

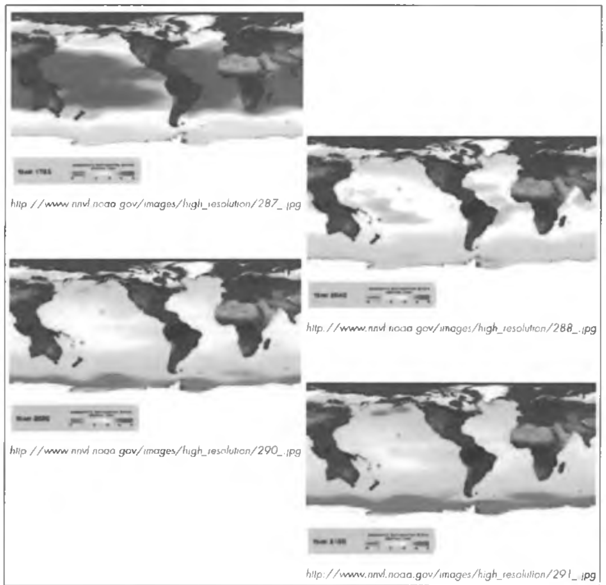


Source: Feely et al. (2009)[5].

Estimates[2] of future trends in ocean acidification can be made for different CO_2 emission scenarios, such as those published by the IPCC[1]. Based on current rates of CO_2 emissions, projections show that by the end of the 21st century, global ocean pH will decrease by a further 0.3 units, which represents a total increase in acidity of 150%[2] (Fig. 2). If ocean pH continues to decrease, this could lead to the loss of some shell or skeleton forming organisms[3, 9-11]. Eventually, the sediments in the oceans will buffer these chemical changes but chemical recovery from such events may take tens of thousands of years[16] while a return to the biological status quo, even if possible, could take millions of years[17].

However, organisms are already being subjected to higher levels of CO_2 and therefore lowered pH and increased acidity (Fig. 1)[2-5]. If these changes to ocean chemistry continue into the future they may affect the abundance, health, physiology, biochemical properties and behaviour of marine organisms, as adults and/or in their juvenile form[11, 18]. The key question regarding future food security is how ocean acidification will directly affect marine organisms consumed by humans or indirectly via the ecosystems that support them.

Figure 2: Model output showing the impact of ocean acidification on the ocean's carbonate saturation state (here showing aragonite saturation) in 1765, 2040, 2080, and 2100. The availability of calcium carbonate is predicted to decrease over the next century. Areas that are deep red are sufficiently acidic to dissolve unprotected calcium carbonate-based shells and skeletons. Most areas currently have enough calcium carbonate to support corals and other organisms, but all areas are predicted to decline by the year 2100 compared to pre-industrial values. The Arctic Ocean is not included in this model but other models focussing on the Arctic project that aragonite undersaturation will occur within decades even before the Southern Ocean[73].

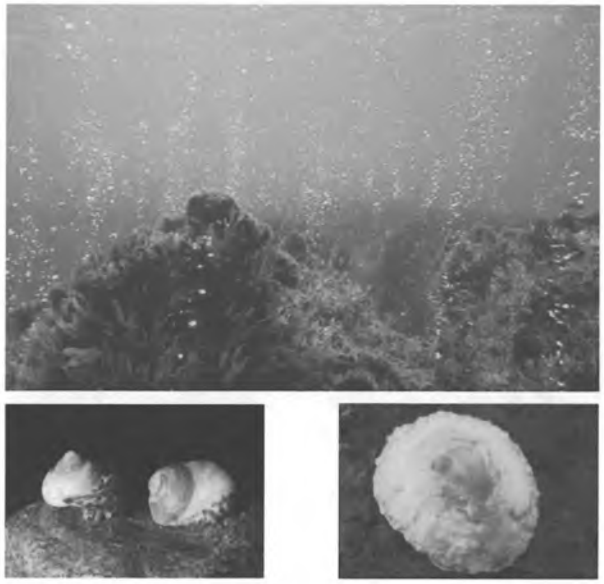


Source: Model courtesy of NOAA Environment Visualization Laboratory. Amended from Orr et al. (2005)[9]

CO_2 vents – an insight into how biology may react in a future high CO_2 ocean

In some areas of the world, volcanic vents are pouring almost pure CO_2 into the marine environment, so acting as 'windows' on how biology may react to a future 'high CO_2 ocean' (Fig. 3). Recent studies of a Mediterranean vent in shallow waters revealed key ecosystem changes in high CO_2 areas compared to normal CO_2 areas[19]. Certain algae and seagrasses were found to grow more efficiently closer to the vents where there was also a large reduction in biodiversity, notably a loss of calcifying organisms adjacent to the vents where the pH was lowest. Sea urchins were found to be the most sensitive to these changes.

Figure 3. Natural CO_2 vents from Ischia in the Mediterranean showing productive seagrass beds (top) but shells of calcifying organisms are pitted and corroded (below) due to the increased acidification of these waters.



Source: Hall-Spencer et al. (2008) Nature[19]

A significant combination of ocean stressors

Ocean acidification is occurring alongside other climate-related stressors, such as ocean warming, sea-level rise, and, possibly, changes to precipitation and increased storminess[1]. These are compounded by other non-climate related impacts, including over-fishing and pollution, which add pressure to already strained marine ecosystems that provide food for human consumption[20]. The combination of rising temperature and increasing acidity on organisms is likely to be worse than either on its own, for example, the range of temperature tolerance for the edible crab may be reduced in more acidic waters[21].

3. Marine food resources and ocean acidification

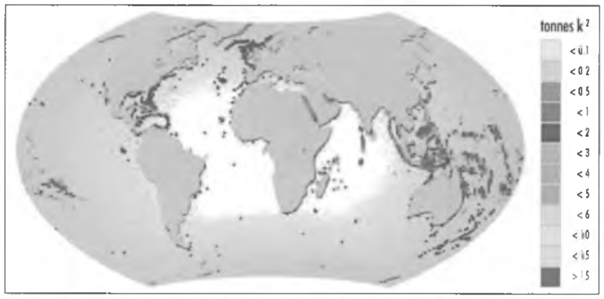
The significance of the marine environment as a food source

The contribution of marine protein to global food security is substantial. Fish, including shellfish, contribute 15% of animal protein for three billion people worldwide[22]. A further one billion people rely on fisheries for their primary source of protein. Fish are even more important in countries where other protein sources decline seasonally[23].

Primary production forms the basis of the marine food web and is of great importance to maintaining fish stocks. Production is highest in areas rich in nutrients, such as upwelling zones and continental shelf areas. Globally approximately 80% of fish catch are from such areas (Figure 4).

Productivity 'hotspots' such as upwelling regions where cold water is rich in both nutrients and CO_2, coastal seas, fronts, estuaries and sub-polar regions often supply the main protein source for coastal communities. However, many of these areas are also projected to be very vulnerable to ocean acidification this century[24, 25]. As world populations rise alongside a predicted growth in coastal populations due to internal migration, the demand for ocean protein products is also likely to rise[23, 26]. Fish stocks, already declining in many areas due to over-fishing and habitat destruction[20, 22, 27], now face the new threats posed by ocean acidification[28].

Figure 4: The world's most productive fishing grounds are confined to major hotspots, less than 10% of the World oceans. The map shows annual catch (in tonnes per km^2) for the World's oceans. There is a strong geographic concurrence of continental shelves, upwelling and primary productivity and the amount of fish caught by fisheries. The map shows global fisheries landing annual average for the period 2001 to 2006 (updated August 2010).



Data source: Sea Around Us project, (University of British Columbia, http://www.seaaroundus.org). Map designed by Dr. Reg Watson (http://ecomarres.com). Used with permission

It may therefore be no surprise that the aquaculture industry is the fastest growing food producer worldwide, increasing at a rate of 7% per annum, and is widely touted as the panacea for dwindling fisheries. The proportion of fish produced by aquaculture and consumed by humans worldwide rose to 50% of total production in 2009[29].

Food Security

"Food security is a condition when all people, at all times , have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active healthy life"[30].

In local communities, the smaller fish species are often exploited because they are usually the most numerous and accessible[22, 23, 27]. Frequently eaten whole, they also provide other dietary requirements, such as essential oils, minerals and trace elements. Fish are not only the single most important source of protein for some subsistence communities; they also may provide a small income stream that enables the purchase of other staple foods like rice.

However, as small fish occur in large numbers they are also targeted by industrial fisheries to manufacture fish oil and meal for use as a food stock, for example in aquaculture, where fish are used to feed fish[29]. Fish such as trout, tilapia and salmon, and an increasing number of marine species rely on this fish meal, thus placing local resources under an accumulation of pressures.

Invertebrates such as mussels, lobsters and shrimp may be regarded as niche luxury foods but also provide significant income for many poor coastal peoples. As shell growth and physiology are sensitive to increases in ocean acidity, the production and quality of many of these invertebrate species is at risk; they are the most vulnerable group in the aquaculture sector. Some cultured invertebrates also rely on those same small fish used to feed cultured finfish, as well as local human populations, so adding to the accumulation of pressures facing these limited but important fish resources.

Wild fisheries, shellfisheries and aquaculture are therefore of great importance to current and future food security[27]. However, these industries are now also at risk from future ocean acidification both directly through the impact on the organisms themselves and indirectly through the food webs and habitats they depend on.

Threats of ocean acidification

Although studies about the effects of ocean acidification on marine resources are comparatively new, early results indicate there is no room for complacency. The effect of increased acidity on adult finfish seems minimal in the species investigated[14]. However, their orientation and balance mechanisms as well as behaviour may be sensitive to ocean acidification[31, 32, 74]. The effects on finfish larval and egg stages are not yet understood. However, valuable breeding and feeding habitats are at risk. For example, coral reefs, which underpin many marine fisheries in the tropics, are already under pressure due to destructive fisheries practices, land based pollution and sediment loading, heat stress and coral bleaching[33]. These delicate ecosystems are especially prone to the effects of ocean acidification[34, 35].

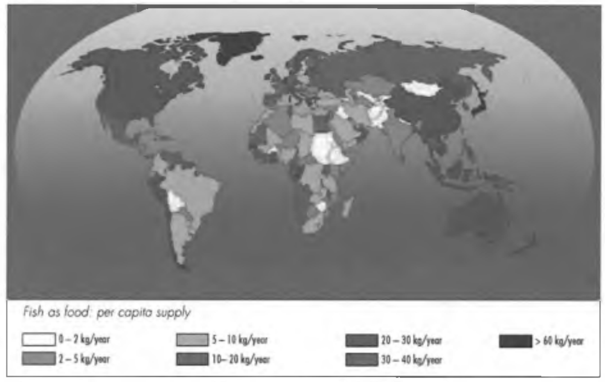
Certain habitats and species of sea grass might 'benefit' from increased seawater CO_2; however many animals that rely on these for food and shelter may be negatively affected[19]. The impact of ocean acidification on ecosystems, with the possible exception of coral reefs, is largely unknown. The ability of many planktonic organisms to build skeletons decreases as seawater becomes more acidic but the response is not uniform[12, 36]. Marine ecosystem responses are speculative due to their complexity. However, polar and sub-polar marine ecosystems are projected to become so low in carbonate ions within this century (Fig. 1) that waters may become corrosive to unprotected shells and skeletons of organisms currently inhabiting these waters[9, 73]. Also changes in reproduction, larval development, growth efficiency, behaviour and competition may affect the number and kinds of species in existence, while all of these factors could potentially affect food chains.

a. Fishery threats

Finfish make up the majority of the global catch (over 80%) and are the most significant source of marine protein for human consumption (Figure 5). Most finfish are carnivorous and so depend on the healthy functioning of complex marine food chains. Direct effects on swimming performance of adult finfish such as cod are unlikely due to their inbuilt ability to regulate their internal pH[75]. However, in young clownfish there may be orientation problems due to variable otolith growth rates[31] and altered behaviour towards their predators through impacting their olfactory cues which may increase mortality and impact replenishment of fish populations[32, 74].

The indirect effects of changes in their prey, and loss or damage to their habitats are currently considered more significant than direct impacts. For example, shelled pteropods produce aragonite shells, and observations and controlled experiments show that they will be particularly sensitive to ocean acidification[9, 37]. Pteropods often occur in high densities and form a major dietary component for higher predators such as herring, salmon, whales and seabirds[9].

Figure 5: Average per capita fish supply 2003-2005 (in live weight equivalent)



Source: The State of World Fisheries and Aquaculture, 2008, World Fisheries (FAO22).

Ocean acidification has also been tentatively linked to increased jellyfish numbers[38] and changes in fish abundance. Jellyfish are key predators in many of the world's pelagic systems; they can affect the abundance of zooplankton, fish larvae and eggs, which affects the survival to the adult stage (or recruitment) of fish populations[39]. As jellyfish are rarely the preferred food for other marine animals[40], any significant increase in their numbers could have major consequences for pelagic ecosystems and fisheries.

Furthermore whilst echinoderms such as sea urchins, starfish, brittle-stars and sea cucumbers are locally significant as a food source, globally they make up only a small percentage of overall catch. However, these species are a critical link in fish food chains; the majority of those studied show great vulnerability in adult, juvenile and egg stages to future levels of ocean acidification[41-45].

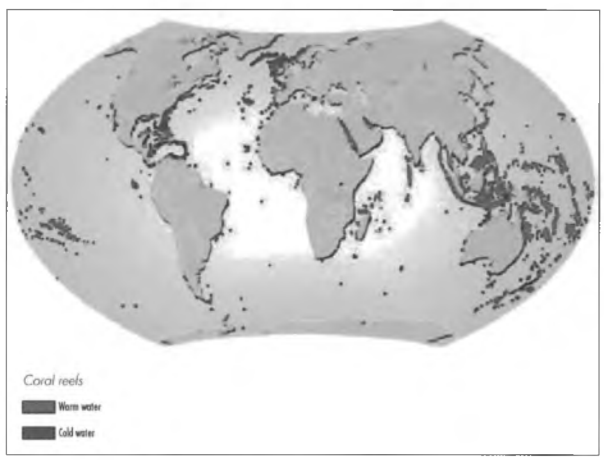
b. Coral reef threats

Corals form the most biologically diverse marine ecosystems and grow from the tropics and mid-latitude to even high latitude cold waters (Fig 6). Tropical reefs provide shelter and food for an estimated 25% of known marine fish species, and account for between 9-12% of world fish landings. Consequently, these coral reefs provide food and livelihood security for some 500 million people worldwide. Significant reef loss would, therefore, impact marine biodiversity, threaten the survival of coastal communities through reduced food sources and reduce the capacity of nearby coastlines to buffer the impact of sea level rise, including increased storm surges[33].

It is anticipated that future ocean acidification will affect adult and juvenile coral growth and recruitment[46], coralline red algae growth[47], reef structural integrity[48] and potentially even the density of bio-eroding grazers and predators[34].

Scleractinian corals and algal assemblage, including coralline algae. Growth and skeletal integrity of scleractinian corals and coralline algae are likely to be compromised by ocean acidification.
Source: Andrey Ringler / UNEP

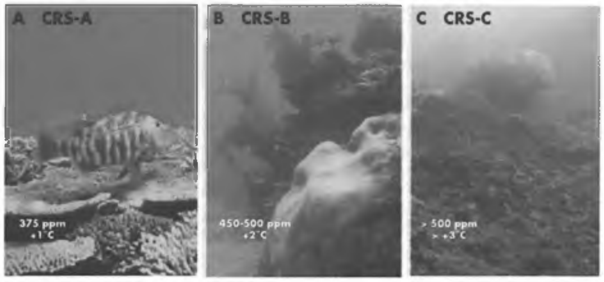
Figure 6. Distribution of coldwater and tropical coral reefs. The coldwater reefs are highly susceptible to ocean acidification, which has its greatest impacts at high latitudes. Tropical reefs will become severely damaged by rising sea temperatures.



Data source: UNEP World Conservation Monitoring Centre, 2005. Map by Hugo Ahlenius, UNEP/GRID-Arendal. http://maps.grida.no/go/graphic/distribution-of-coldwater-and-tropical-coral-reefs

This challenge to coral reefs is in addition to the threat of increasing sea surface temperatures, a major cause of coral bleaching[34]. The combined impact of ocean warming and acidification as well as over-fishing and pollution increases the stress on coral reef ecosystems. Researchers estimate that a CO_2 stabilization scenario of less than 450 ppm is essential for the survival of many coral reefs[34, 35], and more reefs will decline (Fig 7) if CO_2 concentration exceeds this limit[49].

Figure 7. Examples of reefs from Australia's Great Barrier Reef which are used as proxies to indicate what future coral reefs may look like in a high CO_2 world under different CO_2 scenarios. The atmospheric CO_2 and temperature increases shown relate to the scenario, not the locations photographed. (A) Reef slope communities at Heron Island; (B) Mixed algal and coral communities associated with inshore reefs around St. Bees Island near Mackay; (C) Inshore reef slope around the Low Isles near Port Douglas.



Source: Hoegh-Guldberg et al. (2007) Science[34].

Even cold water corals which generally live in deeper and colder waters (Fig. 6) are important feeding and nursery grounds for finfish and like their tropical cousins are vulnerable to ocean acidification[50-52].

c. Threat to aquaculture

Marine invertebrates like molluscs and crustaceans (Fig 8), increasingly used in aquaculture, show negative responses to acidification at various life stages. An organism's success depends on more than just the growth of its adult form. The life cycle of invertebrates from egg fertilization and development, to growth and timing of different juvenile larvae stages to their settlement, are critical to their own survival as well as that of both their prey and predators[11]. As most shellfish eggs and larvae are planktonic, these species are prone to the negative effects of ocean acidification. One study on the early development of the oyster (*Crassostrea gigas*) shows that shell calcification is reduced in juveniles; their body shape and size are altered, which suggests serious consequences for their survival into adulthood[53].

Figure 8: Some invertebrate food species that have shown sensitivity as adults or in other parts of their life cycles to ocean acidification.

Top left: Mussels beds (Rob Ellis/PML), Top right: Oyster tables (Steve Widdicombe/PML), Mid left: Lobster (Kelly-Marie Davidson/PML), Mid right: Spiny lobster (Kelvin Boot/PML), Bottom left: Sea urchin (Kelvin Boot/PML) and Bottom right: Edible crab (Kelvin Boot/PML).

Molluscs account for 8% of the global marine catch, but are increasingly important in the growing aquaculture industry. Clams, scallops, mussels, oysters, abalone and conchs provide direct protein sources for various island and coastal communities and are valuable commercial fisheries. As well as providing food some species play an important role in forming and maintaining habitats for other species (e.g. mussel beds, Fig 8). Many mollusc species at the adult and juvenile stages have shown reduced growth and/or health under projected ocean acidification scenarios[53-63].

Crustaceans such as prawns, lobsters and crabs currently comprise 7% of global seafood consumption through both wild and aquaculture species. They are significant locally for subsistence fishing and at larger commercial scales. Studies on the effects of ocean acidification have only been conducted on a few crustacean species[13, 64-68]. However, some of these studies show their vulnerability to elevated seawater CO_2 as adults and juveniles while another shows that the ability to tolerate a range of temperatures is reduced[66].

4. Conclusion

There are numerous reasons to be concerned about ocean acidification and its future impact at the species and ecosystem level. If ocean acidification continues disruptions to food chains and direct and indirect impacts on numerous species are considered likely with consequent risk to food security.

Habitat destruction, overfishing, climate change and pollution are significantly impacting fishery products and food security and national economies[69-71] and mitigation of these impacts requires coordinated action at the highest levels. Ocean acidification acts in addition to these stressors[28]. All marine environment stakeholders and the policy makers responsible for environmental or food security issues need to become more aware of the potential effects and consequences of ocean acidification[72].

Emerging challenges and their implications

There is a need to more fully understand the effects of ocean acidification on various marine organisms at different stages of the lifecycle including the ecosystem level impacts. Critical species within ecosystems or food chains that act as food sources should be a priority for research. Impacts from ocean acidification must be understood within the wider context of other real and potential threats such as from climate change and pollution as well as global trends in world fisheries and aquaculture[69-71]. The obvious solution to the potential threats posed by ocean acidification is to make rapid and substantial cuts to anthropogenic CO_2 emissions to the atmosphere and hence, oceanic CO_2 concentrations. However, the likelihood is that this will not occur in the immediate future. Ocean acidification is a rapidly emerging issue with many nations starting to invest in research into the potential future impacts on organisms, ecosystems and food providing products in earnest[72]. So, based on existing information, which may change as new data emerges, the following actions are judged necessary to mitigate the risk of effects of ocean acidification:

- Recognize the security, economic and cultural importance of those marine species and habitats that are currently exploited.
- Determine the vulnerability of fish-dependent human communities in terms of exposure, sensitivity and the capacity to adapt to changes resulting from ocean acidification.
- Identify species that are more flexible to change and which may encroach on habitats and survive in altered conditions and assess how these may affect ecosystems and food security.
- Reduce other pressures on food fish stocks to provide the best chances of success through, for example, marine spatial planning or re-evaluating available resources and their usage.
- Assess the options for development of environmentally sustainable 'aquaculture' options using species that are resistant to lowered pH or can be kept in conditions of controlled pH.
- Consider the positive and negative impacts of a chain of substitute habitats such as artificial reefs to provide the diversity of niches that are found in existing habitats.
- Embrace the science and ramifications of ocean acidification and climate change into fisheries management tools.
- Alongside efforts to further investigate the effects and consequences of ocean acidification, foster increased awareness of this issue through diverse media.

Further Reading

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Robert Himschoot

Box 1061

Dillingham, Ak 99576

Representative Beth Kerttula

State Capitol Rm 404

Juneau Ak, 99801

Dear Representative Kerttula,

I am writing in support of your Resolution recognizing the potential threat and supporting increased research of Ocean Acidification, HJR10.

As a resident of Dillingham and a commercial fisherman I share your concern. I believe the effects of Ocean Acidification pose the gravest risk to the way of life I love, the community and region I call home.

The State of Alaska needs to recognize the danger and accept responsibility for mitigation, along with Federal government. This Resolution is a responsible step towards that goal.

Robert Himschoot

City Councilman

Dillingham, Alaska

Alaska Conservation Alliance

"A Strong Economy and Healthy Environment Go Hand in Hand"

March 24, 2011

Representative Beth Kerttula
State Capitol, Rm. 404
Juneau, AK 99801

Dear Rep. Kerttula:

The Conservation Alliance supports HJR 10, recognizing the threat of ocean acidification to Alaska and urging the Federal government to increase monitoring and research on the topic. The Alaska Conservation Alliance is an umbrella group for approximately 40 member organizations with a combined membership of over 38,000 Alaskans. We serve to advance conservation with decision-makers in Alaska. The Alliance believes that a healthy environment and a strong economy go hand in hand.

Ocean acidification poses a threat to marine ecosystems in Alaska and, in turn, threatens coastal communities, businesses reliant on the ocean, and subsistence. Our oceans are already becoming noticeably more acidic and this is starting to harm base species in the food chain. Disruptions to the food chain will negatively affect fish, whales, walruses, seals, and sea birds among other species. Acidification may also improve conditions for invasive species. If other states' dealings with invasive species are an indication, the economic cost to businesses, local communities, and the state could be in the millions. These impacts will harm Alaskan fisheries and subsistence lifestyles.

Addressing ocean acidification requires coordination between the state and Federal government, and among countries to decrease carbon emissions. The Federal government must increase efforts to monitor and research ocean acidification's effects particularly in more sensitive areas like the Arctic and Northern Pacific. Strong action must also be taken to climate change pollutants like carbon dioxide.

The Conservation Alliance strongly supports the Alaska State Legislature taking a stand against ocean acidification and directing the Federal government to increase efforts on the issue.

Sincerely,

Caitlin Higgins

Caitlin Higgins
Executive Director
Alaska Conservation Alliance

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www.akvoice.org | www.twitter.com/ACAAlliance
www.facebook.com/AlaskaConservationAlliance

Dear Representative Kerttula:

I am a retired Professor Emeritus of Marine Science at the University of Alaska Fairbanks. I have spent many years studying carbon dioxide in the atmosphere and ocean especially in the polar regions. Early in my career I conducted a monitoring program for carbon dioxide in the atmosphere at Barrow, AK and on various floating ice stations on the Arctic Ocean. I have read House Joint Resolution No. 10 which you are sponsoring and wish to endorse support of this resolution for expanded research concerning the detrimental effects of ocean acidification.

It is a well documented fact that carbon dioxide has been increasing in the atmosphere since the industrial revolution in the 19th century. Some of that carbon dioxide is absorbed in the world's oceans which should lead eventually to a more acid environment. This process is well summarized in the HJR Resolution No. 10. It has only been in recent years that slight shifts in oceanic pH to a more acidic ocean have been noticed with implications for damage to sealife. HJR 10 correctly cautions that increased ocean acidification will have a widespread ripple effect on fisheries from the smallest organisms to the commercial fisheries. Implications for economic consequences of ocean acidification are obvious.

Research and monitoring related to ocean acidification is still at a very early stage world-wide especially as to how the effects of ocean acidification can be best addressed. Potential damage to Alaska's marine ecosystems will translate to losses to the state's economy through effects on fisheries and tourism. The data base for an increasing ocean acidic environment has improved in recent years, but is far from adequate to meet the assessment needs. I strongly support HJR No. 10.

John J. Kelley, Ph.D.
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Letter of support for resolution HB10 from Dr. Switgard Duesterloh, Kodiak, Alaska
02/11/2012

Dr. Switgard Duesterloh
P.O. Box 2787
Kodiak, AK 99615
(907) 481 3867

Representative
Beth Kerttula
State Capitol Room 404
Juneau AK, 99801

Regards: **Resolution HB10 Ocean Acidification**

To whom it may concern,

I would like to thank representative Kerttula for her efforts in drafting HB10, and express my support for this much needed resolution regarding the recognition of the effects of ocean acidification on Alaska's residents and economy.

Before I get into my reasoning, allow me to introduce myself and explain my stake in this issue. My name is Switgard Duesterloh, I am a fisheries scientist, and currently work in science education. Over the last three years, I have initiated an Ocean Science Discovery Program in Kodiak, working closely with the school district and the research community, introducing hands-on marine science units for all students in grades 3,4,5,6, and 7, and some high school classes, in the public school system. Working closely with the researchers at the NMFS Kodiak laboratory, I have developed ocean acidification science units for 6th and 7th grade, and taught these for the past two years. I live in and love Alaska for its natural beauty, breathtaking magnificence and abundant life forms, which I work hard to protect and preserve for future generations. I am writing this letter of support in my roles as a concerned Alaska citizen, parent, educator, and Board member of the Alaska Marine Conservation Council.

HB10 summarizes distinctly the results and conclusions of the early phases of research into Ocean Acidification. While there is much that remains unknown and researchers continue to struggle to collect much needed oceanographic and bioscience data, many of the described effects of OA are based in simple chemical reactions, which can be modeled with relative certainty. When researchers present time lines of temperatures, atmospheric CO_2 content and average global ocean pH, the message is not that present concern is based on change, but rather the unprecedented rate of change in these parameters. We are presently experiencing conditions in the world oceans that are unprecedented for not only the timeframe humans have lived on earth but even millions of years into the past. This, combined with research showing that species extinction in the world's rainforests proceeds at a rate faster than any accounted for in fossil records, should warrant concern and political action. I support HB10 to recognize OA and anticipate the effects of these global changes to the economy and quality of life in the state of Alaska.

Sincerely,

Switgard Duesterloh

UNIVERSITY OF ALASKA FAIRBANKS

Dr. Jeremy T. Mathis
Assistant Professor
(907) 474-5926
jmathis@sfos.uaf.edu
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School of Fisheries and Ocean Sciences
245 O'Neill Building, University of Alaska Fairbanks, P.O. Box 757220, Fairbanks, Alaska 99775-7220

February 8th, 2012

Subject: Letter of Support for HJR 10

Dear Representative Kerttula,

I am writing to express my strong support for House Joint Resolution 10 that outlines the need for additional research funding for ocean acidification and its impacts to Alaska. I am the director of the Ocean Acidification Research Center and a Professor of Chemical Oceanography at the University of Alaska Fairbanks. I have spent my entire career working on the issue of ocean acidification in Alaska, and I can tell you unequivocally that the State is not yet prepared to deal with the potential consequences of this phenomenon.

The World's oceans have absorbed more than a quarter of the carbon dioxide released into the atmosphere from the burning of fossil fuels and changes in land use. This excess, or anthropogenic carbon dioxide has fundamentally altered ocean chemistry, making ocean surface waters 30 percent more acidic than they were at the start of the Industrial Revolution. If left unchecked, acidity near the surface could double by the end of this century. Even more alarming for Alaska is that the process of ocean acidification is accelerated in the Pacific-Arctic region because carbon dioxide is more soluble in colder water, and lower salinity waters from rivers, glacier discharge, and sea ice melt diminishes the capacity of our coastal seas to buffer against acidification. There is now clear and indisputable evidence that ocean acidification is both more severe and occurring more rapidly in the coastal waters of Alaska compared to other places in North America.

It is very likely that ocean acidification will create conditions that are detrimental to marine ecosystems in the Gulf of Alaska, the Bering Sea and the Arctic Ocean within a few decades, if not sooner by impacting the growth, reproduction, and physiological processes of many marine organisms. The most direct impacts will likely be felt by carbonate-forming species, such as crabs, clams and oysters but it will also effect marine plankton that occupy the base of the food webs that support the vast commercial fisheries around the State, such as salmon and Pollock.

We cannot afford to wait any longer to make the necessary investments that will allows us to develop sound management strategies to keep our fisheries sustainable as the oceans become more acidic. To do this, we need a better fundamental understanding of ocean acidification in Alaska through increased observations, species studies and economic modeling. HRJ-10 is an excellent step towards achieving these goals. Please let me know if there is anything I can do now or in the future to support this effort.

Sincerely,

Jeremy T. Mathis – Ph.D.

Kachemak Shellfish Mariculture Association
3851 Homer Spit Road, Homer, Alaska 99603 (907)-235-1935 AlaskaOyster.org

Alaskans

Please know Kachemak Shellfish Mariculture Association is in support of increased research devoted to the understanding of ocean acidification as identified by the Alaska House Joint Resolution number 10 as introduced in the twenty-seventh legislature-first session.

Today the effects of ocean acidification are being seen worldwide and in Alaska. In 2011, Alaska's mariculture industry experienced a drastic shortfall of seed. As highlighted in the joint resolution, ocean acidification impacted industry and the available of seed from hatcheries supplying Alaska shellfish growers. For background information, in 2007, Whiskey Creek Shellfish Hatchery in Netarts Bay, Oregon, first drew attention to the issue of seed security and ocean acidification. With high mortality in their juvenile oysters the hatchery staff thought it was due to bacteria or other pathogens. Finding nothing, they turned to the ocean acidification issue and the pH levels of the water. Their research has identified this as the cause of the mortality. Acidic water, with a low pH, is suspected to be responsible for a significant decline in oyster larvae production as with many other shellfish hatcheries. It's also likely responsible for the lack of natural oyster recruitment in the Willapa Bay region of Oregon, as spawning events have not naturally occurred there in the past six years.

The mariculture industry in Kachemak Bay is very concerned about the impact ocean acidification will have in the coming years. Out of this concern, Kachemak Shellfish Mariculture Association in partnership with Kachemak Shellfish Growers Cooperative and the Alaska legislature has developed an oyster seed security demonstration project. With this it is anticipated that Alaska will have to develop several shellfish hatcheries to insure seed security as national and international seed sources are affected by ocean acidification.

In closing, we encourage sufficient funding for needed research into the cause, effects and options to address ocean acidifications impact on Alaska's mariculture industries. We know the research in this area is highly warranted as Alaska has the most to gain with our abundant shoreline and resources.

Thank you,

Gerald Andrews
KSMA President

Alaskan Shellfish Growers ASSOCIATION

February 10, 2012

Rep. Beth Kerttula
State Capitol
Juneau, AK 99801

Re: Support for HJR 10

Dear Rep. Kettula:

Just a few years ago ocean acidification seemed like a vague future concern to most Alaska shellfish farmers, but it has rapidly become a threat to our livelihoods.

Changing current ocean currents along the Oregon and Washington coasts have created upwelling events, bringing acidic water to the surface that has interfered with the delicate transition of free swimming larvae into tiny shellfish. This has resulted in oyster seed or "spat" shortages from California to Alaska.

The Alaskan Shellfish Growers Association recently launched an initiative to bolster in-state production of seed for shellfish farmers. In a report submitted to the legislature in January, ASGA found Alaska growers received only 40 percent of the 10 million oyster spat needed in 2011 and projected the shortages will result in $1.6 million over the next five years.

While ocean acidification wasn't the only reason behind the spat shortages, it was a major factor, and the problems along the Pacific Northwest coast show no signs of going away. We are concerned about increasing signs of potential problems with ocean acidification along our own coastline.

Unfortunately, there is very little monitoring of ocean acidification in the Gulf of Alaska and even less in our nearshore waters. That's why ASGA strongly supports HJR 10. Thank you for elevating this important issue.

Sincerely,

Rodger Painter
ASGA President

Rodger Painter, president rodgerpainter@hotmail.com
P.O. Box 20704 Juneau, AK 99802-0704 (907) 957-0704

ScienceDaily

Your source for the latest research news

Increased Ocean Acidification In Alaska Waters, New Findings Show

The pteropod (also known as a sea butterfly or swimming sea snail) may be one of the first marine organisms affected by ocean acidification. Pteropods make up nearly half of the pink salmon diet. This particular pteropod is the Limacina helicina helicina. (Credit: Photo by Russ Hopcroft, UAF School of Fisheries and Ocean Sciences)

ScienceDaily (Aug. 13, 2009) — The same things that make Alaska's marine waters among the most productive in the world may also make them the most vulnerable to ocean acidification. According to new findings by a University of Alaska Fairbanks scientist, Alaska's oceans are becoming increasingly acidic, which could damage Alaska's king crab and salmon fisheries.

This spring, chemical oceanographer Jeremy Mathis returned from a cruise armed with seawater samples collected from the depths of the Gulf of Alaska. When he tested the samples' acidity in his lab, the results were higher than expected. They show that ocean acidification is likely more severe and is happening more rapidly in Alaska than in tropical waters. The results also matched his recent findings in the Chukchi and Bering Seas.
"It seems like everywhere we look in Alaska's coastal oceans, we see signs of increased ocean acidification," said Mathis.

Often referred to as the "sister problem to climate change," ocean acidification is a term to describe increasing acidity in the world's oceans. The ocean absorbs carbon dioxide from the air. As the ocean absorbs more carbon dioxide, seawater becomes more acidic. Scientists estimate that the ocean is 25 percent more acidic today than it was 300 years ago.

"The increasing acidification of Alaska waters could have a destructive effect on all of our commercial fisheries. This is a problem that we have to think about in terms of the next decade instead of the next century," said Mathis.

The ocean contains minerals that organisms like oysters and crabs use to build their shells. Ocean acidification makes it more difficult to build shells, and in some cases the water can become acidic enough to break down existing shells. Mathis' recent research in the Gulf of Alaska uncovered multiple sites where the concentrations of shell-building minerals were so low that shellfish and other organisms in the region would be unable to build strong shells.

"We're not saying that crab shells are going to start dissolving, but these organisms have adapted their physiology to a certain range of acidity. Early results have shown that when some species of crabs and fish are exposed to more acidic water, certain stress hormones increase and their metabolism slows down. If they are spending energy responding to acidity changes, then that energy is diverted away from growth, foraging and reproduction," said Mathis.

Another organism that could be affected by ocean acidification is the tiny pteropod, also known as a sea butterfly or swimming sea snail. The pteropod is at the base of the food chain and makes up nearly half of the pink salmon's diet. A 10 percent decrease in the population of pteropods could mean a 20 percent decrease in an adult salmon's body weight.

"This is a case where we see ocean acidification having an indirect effect on a commercially viable species by reducing its food supply," said Mathis.

The cold waters and broad, shallow continental shelves around Alaska's coast could be accelerating the process of ocean acidification in the North, Mathis said. Cold water can hold more gas than warmer water, which means that the frigid waters off Alaska's coasts can absorb more carbon dioxide. The shallow waters of Alaska's continental shelves also retain more carbon dioxide because there is less mixing of seawater from deeper ocean waters.

Ask any coastal Alaskan and they will tell you that Alaska's waters are teeming with biological life, from tiny plankton to humpback whales. All of these animals use oxygen and emit carbon dioxide. Mathis and other scientists call this the "biological pump."

"We are blessed with highly productive coastal areas that support vast commercial fisheries, but this productivity acts like a pump, absorbing more and more carbon dioxide from the atmosphere," said Mathis. "Because of this, the acidity of Alaska's coastal seas will continue to increase, and likely accelerate, over the next decade."
Mathis said that it is still unclear what the full range of effects of ocean acidification will be, but that it is a clear threat to Alaska's commercial fisheries and subsistence communities.

"We need to give our policy makers and industry managers information and forecasts on ocean acidification in Alaska so they can make decisions that will keep our fisheries viable," said Mathis. "Ecosystems in Alaska are going to take a hit from ocean acidification. Right now, we don't know how they are going to respond."

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Web address: **http://www.sciencedaily.com/releases/2009/08/090813163158.htm**

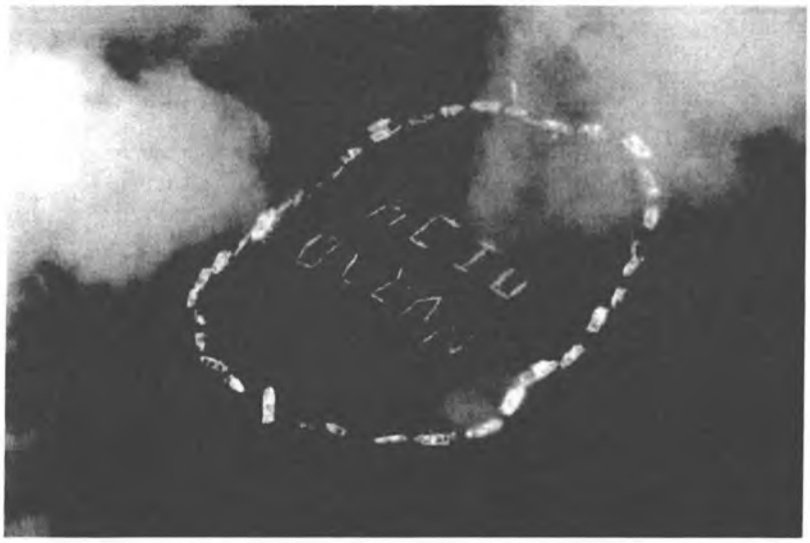
SOS! Aerial Art Event, Homer, AK-September 2009

by Kelly Harrell— last modified October 06, 2010 05:43 PM

More Than 100 Boats Gather to Send Message of Protection from Acidification to Leaders

More than 100 fishing boats sail boats, skiffs and kayaks took to the waters of Homer Alaska on Sunday, September 6, 2009 as commercial fishermen, mariners and others from coastal communities spelled out an urgent message to protect jobs and fisheries from the threat of ocean acidification. The boats arranged themselves in the ocean to spell out "Acid Ocean SOS" as part of a 'Voices for the Ocean' event hosted by the Alaska Marine Conservation Council (AMCC) and Sustainable Fisheries Partnership (SFP) with International Aerial Artist John Quigley (www.SpectralQ.com).

Timed to spell out the message "Acid Ocean SOS" in the tight window that tides permitted, this Labor Day weekend event marked a rare collaboration between commercial fishermen and the conservation community in the region. Participants hope the 'SOS' will be heard by the US Congress and international leaders participating in the upcoming United Nations climate negotiations in Copenhagen, and that their call for help will result in definitive action to curb ocean acidification, referred to by scientists as the 'evil twin' of climate change.



“Fishermen and others who depend on Alaska’s rich marine resources are coming together as one voice in support of reducing fossil fuel consumption and moving to a renewable energy future. This is the only real solution to ocean acidification and the time to act is right now,” said Alan Parks, a small-scale family fisherman from Homer whose primary source of income is commercial fishing in Alaska. Parks helped organize fisherman for the event with Alaska Marine Conservation Council.

"Alaska's senators know that ocean acidification is a looming danger to our fisheries,” said Parks. “This message from fishermen is to support our leaders in taking the necessary action now to reduce carbon emissions. Time is of the essence.”

Parks and others are asking leaders to follow science and not politics, and with this ‘SOS’ are calling on state, national, and international leaders to protect the ocean from the acidifying, oxygen-depleting, and climate-altering impacts of uncontrolled fossil fuel emissions.

“This is the first significant show of numbers, vessels, and determination from the north pacific fishing industry, but it is not the last,” said Brad Warren of the Sustainable Fisheries Partnership. “Some 3 billion people get their food from the sea and there are a lot of a people who want to keep it that way. We expect to see people from the seafood industry around the world taking up this same issue of ocean acidification with the same intent—to get a strong international carbon policy that protects oceans, fisheries and fishing industry jobs.“

Aerial artist John Quigley, who has done similar actions on land and ice, but never before at sea, said, “This message from the sea is a call for people around the world to join in a visual declaration to urge leaders to immediately adopt a treaty that reduces greenhouse gas emissions, stabilizes the climate, and protects the oceans.”

Recent research confirms that acidification is caused by billions of tons of carbon dioxide that rise from smokestacks and tailpipes every year and mix into the sea. In seawater, the gas forms an acid that attacks the foundation of marine food webs. The same pollution that drives climate change also undercuts fisheries around the world, especially in the vulnerable North Pacific off

Alaska and the Pacific Northwest, which produce more than two thirds of the U.S. seafood harvest. The North Pacific is a global repository for carbon dioxide in the oceans.

Supporters of the Homer event included the Alaska Marine Conservation Council (AMCC), the National Fisheries Conservation Center, the Sustainable Fisheries Partnership (SFP), and many participants from the fishing industry, Alaska coastal communities, and conservation groups.

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For more information contact Alan Parks, AMCC Homer Outreach Coordinator at 907.399.3096, alan@akmarine.org

4:54PM

Fri March 26, 2010

Ocean acidification a threat to local fisheries

By KUCB News

Unalaska, AK – The cold waters and currents of the North Pacific Ocean make the ecosystems around the Aleutians more susceptible to ocean acidification. Brad Warren with the Sustainable Fisheries Partnership spoke about the issue at the Western Alaska Interdisciplinary Science Conference Thursday.

"It's a cross cutting threat to food webs that support fisheries. It affects the physiologies of many species in the marine system - gill function, reproduction, growth rates, blood chemistry, heart functions. The primary cause of death for fish exposed to high CO2 is heart attacks. It's really a wide band of effectors of harm."

Ocean acidification is caused by rising carbon dioxide levels in the atmosphere. It's absorbed into the ocean, which creates carbonic acid. That acid increases the pH of the ocean waters. The most obvious and best understood problem is its affect on calcification of shells. Warren said the acid corrodes the shells of large species, like crabs and oysters, but also the shells of smaller organisms that are important links in the food web.

"Many of the things that fish eat are experiencing conditions that may be fatal to them, particularly at early life stages," he explained. "If that's persistent for long enough, it's likely to cause recruitment problems in fisheries. Whether it has already caused them, no one knows. There's not enough information."

Preliminary research in the Bering Sea shows corrosive acid in all levels of the water column. Warren said it's unclear if the acidification is already causing problems, like the smaller fish some fishermen are reporting. This could be caused by many things there isn't enough research to say yet.

But Warren said it's important to stop the acidification and monitor its levels and effects on the ecosystem before it becomes a huge problem, because it's not something that can be fixed. "This is a change that takes geologic time to correct itself. There is no system for accelerating the ocean's return to a normal pH balance. And that balance is critical for much of the life support system for the fisheries that we depend upon."

Warren said that unlike thermal change, which could bring new species to the area, acidification could make the ocean inhospitable to all species. "This is fundamentally reducing the ocean's ability to make commercially harvestable quantities of the things we eat."

Commercial fisherman and Alaska Marine Conservation Council representative Alan Parks said that's why fishermen need to spread the word now and contact their leadership to protect their livelihoods.

"What we need to do is just think about it in terms of our legacy. What do we want our kids' opportunities to look like? We're at a point now where we can make a huge difference for the sustainability and the legacy that we leave behind."

You can learn more about ocean acidification by attending the free showing of A Sea Change at 8 pm Friday in the Makushin room at the Grand Aleutian. You can also attend a climate change information panel and teleconference with scientists from around the world at 10:30 am Saturday at the Grand.

Volume 25 • Number 1 • 2009

Ocean Acidification's Impact on Fisheries and Societies: A U.S. Perspective

By Sarah R. Cooley and Scott C. Doney

Many valuable commercial fisheries and aquaculture facilities

harvest ocean shellfish (e.g., clams, scallops) and crustaceans (e.g., lobsters, crabs) that form calcium carbonate shells. These animals, along with corals, may be particularly sensitive to changes in seawater chemistry driven by human fossil fuel use. Finfish may also be affected indirectly owing to loss of prey and habitat. Ocean acidification impacts could decrease future fishing revenues and harm communities that depend economically and culturally on marine resources.

In many parts of the United States, the word "seafood" is nearly synonymous with carbonate shell-forming marine species—shellfish like oysters, clams and scallops, and crustaceans like lobster, crabs, and shrimp. Adults and juveniles of these very economically valuable animals, along with less familiar shelled creatures like sea urchins, planktonic snails called pteropods, and some types of phytoplankton, are food for a variety of predators and fuel food webs. Commercial harvests of shellfish, crustaceans, and finfish sustain seafood industries that support many coastal economies. If ocean acidification slows the growth of marine organisms' carbonate shells and skeletons, it will endanger many individual plants and animals, whose declines will in turn harm entire marine food webs, aquatic environments, and economies (Doney et al. 2009).

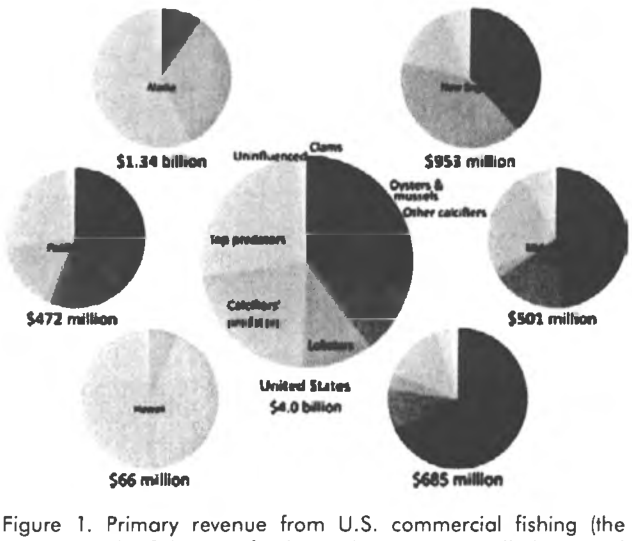

Figure 1. Primary revenue from U.S. commercial fishing (the amount paid to fisherman for the catch, sometimes called ex-vessel revenue) for the U.S. as a whole and broken up by region. Data are for 2006 from National Marine Fisheries Service statistics. The pie charts are divided into groups of species and the darker colors indicate those groups that are directly sensitive to ocean acidification, such as shellfish and crustaceans.

Recreational	Total economic impact (sales, income, jobs)	$82 billion
	Jobs supported	~530,000
Commercial	Primary sales (the amount paid to fishermen for catch)	$4 billion
	Retail seafood sales	$70 billion
	Net contribution to GNP	$35 billion

Table 1. Revenues from U.S. recreational (Gentner and Steinback 2008) and commercial (NMFS statistics) fishing (US dollars).

An Economic Assessment of U.S. Commercial Fishing and Aquaculture

Commercial fishing is a big business today in the United States, and carbonate shell-forming species provide a large portion of its revenues. In 2006, the total value of commercial sales from fishermen to middlemen was $4.0 billion; shellfish and crustaceans provided 50% of that amount (Figure 1; Andrews et al. 2007). The contribution varies by region around the country (Figure 1); shellfish are more important in the New England and mid- to south Atlantic, crustaceans contribute greatly to New England and Gulf of Mexico fisheries, and predatory finfish (e.g. pollock, salmon, and tuna) dominate the Alaskan, Hawaiian, and Pacific-territory fisheries. Subsequent processing, wholesale, and distribution of all harvests generated retail sales of $70 billion in 2006, leading to $35 billion added to the U.S. gross national product that year (Table 1; Cooley and Doney, submitted).

Across the country, the number of jobs generated by U.S. commercial fisheries also grows markedly from catch to retail sale. The total number of jobs in the United States supported by commercial fishing is difficult to constrain, because industry surveys do not count self-employed fishermen and may not count all middlemen. However, the efforts of a few fishermen support many jobs in seafood processing, transportation, preparation, and sales. Commercial fish processing and wholesaling nationwide supported about 70,000 jobs in 2006.

Recreational fishing also adds economic benefits because recreational fishermen travel, purchase permits and equipment, and patronize supporting industries (Figure 2). This results in the generation of jobs, profits, tax revenues, and business-to-business revenue. In 2006 (the latest date for which data is available), $24 billion of income, a total impact of $82 billion from sales and services, and almost 530,000 jobs (Table 1) were created in the United States by recreational saltwater fishing for a total economic impact of $82 billion that year (Gentner and Steinback 2008).

Figure 2. Saltwater recreational fishing is critical to local and regional economies throughout the United States (SE Alaskan waters pictured). The National Marine Fisheries Service estimates that 25 million saltwater anglers fished 127 million days in the coastal states of the U.S. in 2006.

Figure 3. The American lobster (*Homarus americanus*). Found along the Atlantic coast of North America, American lobsters live a solitary and largely nocturnal existence, feeding on crabs, mollusks, sea urchins, fish, and even macroalgae. Changes associated with ocean acidification may impact lobsters both directly since they use calcium carbonate to form their shells and indirectly through impacts to their food sources.

Growing aquaculture industries worldwide also depend heavily on carbonate-forming organisms like shellfish and crustaceans. In total, 20-25% of the global per capita human consumption of animal protein comes from marine harvests, but patterns of consumption vary widely, and developing and coastal nations often consume high per capita quantities of aquaculture products. In the United States, aquaculture generated $1 billion of primary sales in 2005 (Andrews et al. 2007), approximately 25% of the value of commercial wild fish harvests. Most aquaculture facilities are located in coastal areas, which will also experience ocean acidification.

	Species	pH	Shell dissolution	Increased mortality	Other
Mussel	*M. edulis*	7.1	yes	yes	25% decrease in calcification
Oyster	*C. gigas*	7.1	n/a	n/a	10% decrease in calcification
Giant scallop	*P. magellanicus*	< 8.0	n/a	n/a	Decrease in fertilization, development
Clam	*M. mercenaria*	7.0-7.2	yes	yes	
Crab	*N. puber*	6.0-8.0	yes	n/a	Lack of pH regulation
Sea urchin	*S. purpuratus*	6.2-7.3	yes	n/a	Lack of pH regulation
Dogfish	*S. canicula*	7.7	n/a	yes	
Sea bass	*D. labrax*	7.25	n/a	n/a	Reduced feeding

Table 2. Responses of commercially harvested species to laboratory ocean acidification experiments "n/a"—not available, response is unknown.

DIRECT CONSEQUENCES FOR SHELLFISH AND CRUSTACEANS

Although the full consequences of ocean acidification are not yet known for most commercially valuable species, trends for a few species (determined from laboratory studies) are alarming, indicating that the number and quality of many carbonate shell-forming species may decrease (Table 2; Doney et al. 2009). Because ocean acidification decreases seawater pH and carbonate saturation state, the carbonate shells of many marine plants and animals grow more slowly, or even shrink below certain pH and saturation state thresholds (Figure 3; see Guinotte and Fabry, this issue). The effects of acidification on juvenile marine organisms, however, are largely unknown; if acidification damages juveniles at a key developmental stage, entire populations could be threatened. One cause for concern is that many shellfish grow their juvenile shells from a more soluble form of carbonate and thus may be more susceptible to changes in chemistry. In the worst-case scenario, multiple recruitment failures could cause a population to collapse even if ocean chemistry remains in a range acceptable for adults. In other cases, carbonate-forming organisms that are able to maintain their shells and skeletons in acidified conditions may expend so much energy doing so that their reserves for survival and reproduction may become limited.

Protecting vulnerable marine organisms grown in aquaculture facilities from the effects of ocean acidification may be possible in theory, but it presents practical challenges. Aquaculture is often conducted in tanks or ponds on land that are filled with coastal seawater or within coastal ocean pens. Adjusting seawater chemistry before supplying culture tanks on land would require a great deal of equipment and monitoring that would dramatically increase the overhead of aquaculture operations. Aquacultured animals in nearshore pens cannot be shielded from ocean acidification.

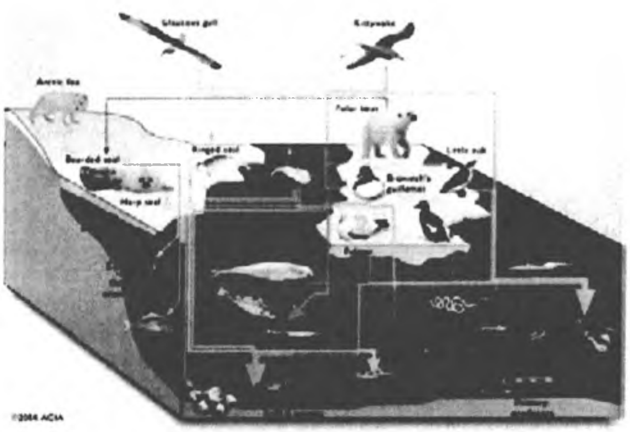

Figure 4. Trophic linkages in the Beaufort Sea. The food web of polar areas such as the Beaufort Sea demonstrates the complex interconnections that are at risk from ocean acidification. Because many Arctic animals depend either directly or indirectly on shellfish for food, reductions in the productivity of these waters due to ocean acidification and changing climatic conditions threaten the base of this and other marine ecosystems.

Laboratory experiments show that oysters and mussels' growth rates decrease and their calcification rates decline by 10% and 25%, respectively, in simulated future ocean conditions when atmospheric pCO_2 reaches 740 ppm, a level that would occur by about 2060 in seawater unless CO_2 emissions are controlled. If decreasing calcification rates observed in the laboratory cause comparable population losses in nature, a 10-25% decrease in all shellfish and crustacean harvests in 2006 would have decreased primary sales from U.S. commercial fisheries by $200-500 million (Cooley and Doney, submitted). In the future, economic losses will likely vary as marine ecosystems respond and adapt differently to acidification and as economic conditions change. Refining economic loss estimates requires knowing the responses of organisms to ocean acidification, the effects of adaptation or conservation measures enacted in the next 50 years, and the total economic consequences of fishing losses.

INDIRECT CONSEQUENCES FOR FISHERIES AND SOCIETIES

Beyond their direct commercial value, many calcifying species are located at the bottom or middle of the marine food web; therefore, the effects of ocean acidification will likely be transmitted throughout ecosystems by predator-prey relationships (Figure 4; Doney et al. 2009). Nearly all commercially harvested

ECONOMIC IMPACTS OF OCEAN ACIDIFICATION ON LOCAL ECONOMIES

Complicating the estimation of ocean acidification's broader economic effects is the difficulty in quantifying indirect links among marine ecosystems and regional economies. New Bedford, Massachusetts, is an example of a city that could be disproportionately affected by economic losses brought on by ocean acidification (Cooley and Doney, submitted). New Bedford has historically relied on fishing income and currently hosts a large scallop fleet. In 2006, New Bedford had the largest commercial fishing revenues of any single city, about $280 million in primary sales, almost all from shellfish. This region already has little economic resilience; 20% of its population fell below the poverty line in 1999, approximately twice the statewide (9%) and nationwide (11%) rates that year. In addition, the income gap separating the highest- and lowest-income families is growing at the sixth fastest rate nationwide. Fishery losses in a city like New Bedford could continue to alter its economy and demographics and further accelerate the income gap's development.

wild finfish species prey to some extent on shellfish and crustaceans or their predators. Depletion of calcifying prey would alter or remove traditional food sources and intensify competition among predators for remaining prey species. This indirect pressure would likely reduce harvests of commercially important predators at the same time ocean acidification would directly pressure populations via metabolic or reproductive stress. The overall impact of losing calcifiers on predator numbers is not well known, but the total ecosystem impact of ocean acidification will certainly depend on whether alternative prey species are available and whether predators can switch to prey species that are not affected by acidification.

Coral reef damage associated with ocean acidification will also indirectly pressure marine ecosystems by disrupting the feeding and reproduction of numerous reef-dependent species. Declines in commercially and/or ecologically important species could follow as a result of decreased recruitment or increased success of competitors. In addition to creating unique ecosystems, reefs generate income and economic development from fishing and recreational diving.

If losses of plankton and juvenile shellfish alter marine food webs and losses of coral reefs eliminate habitat, entire ecosystems can shift into entirely new configurations after a sudden disturbance pushes these stressed communities past an ecological "tipping point." This progression is well understood in coral reef ecosystems that have been chronically damaged by temperature or pathogens; ocean acidification is expected to cause similar harm. Continuously stressed reefs become less ecologically resilient, meaning that they are less able to return to a stable, diverse coral community after a disturbance like a storm. Reefs damaged by such short-term events often then become dominated by macroalgae, and species diversity decreases (Hoegh-Guldberg et al. 2007). Herbivores, which tend to be less commercially desirable than predatory reef species, populate the reef. Perturbed ecosystems like these damaged reefs have lower biodiversity, are more susceptible to further injury, and provide fewer ecological services for humans. The mechanisms and outcomes of ecosystem shifts in non-coral reef communities (e.g., estuaries or coastal habitats populated by carbonate-forming organisms) are not as well understood, but non-coral communities may also undergo similar major shifts if plankton and juvenile shellfish losses are significant.

Projecting the economic consequences of ocean acidification's impact on entire ecosystems is difficult because biological responses are not known for most species. We need to understand how finfish populations will respond in the future to possible larval damage, shifts in prey species and distributions, and coral reef habitat loss. Humans play an integral role in shaping marine ecosystems through commercial fishing methods and harvest levels, but the long-term value of these ecosystems depends on more than just the quantity of fish caught in each season. Degraded marine resources affect humans through a variety of environmental connections. Coral loss will expose low-lying coastline communities and diverse mangrove ecosystems to storm and wave damage, increasing the potential for economic and social disruption following severe weather events. Many coastal and island societies in the developing world depend heavily on marine fisheries and tourism, and they stand to suffer the most economically from the consequences of ocean acidification.

IMPLICATIONS FOR U.S. POLICY AND MANAGEMENT

Until ocean acidification can be mitigated through a global reorganization of the energy and transportation infrastructure, initial responses must target local and regional scales. Action items that would work to maintain sustainable marine resources include: 1) updating fishery management plans to anticipate acidification; 2) adopting ecosystem-based management plans; 3) identifying ecologically resilient areas; and 4) planning for the social and economic consequences of ocean acidification. These efforts do not require large amounts of capital and can be tailored regionally.

Research into ocean acidification's impacts on all life stages (larval, juvenile, adult) of vulnerable marine life is also essential and will allow fisheries to be managed holistically by incorporating species interactions, predator-prey relationships, and the effects of changing ocean chemistry. Fishery management models that include acidification and climate change parameters will help determine appropriate future harvest levels for many fisheries. The likelihood that complex secondary ecological effects will follow species-specific responses emphasizes the need for ecosystem-based management. Ecosystem-scale planning will be particularly useful in areas where fisheries are dominated by predatory finfish (e.g., U.S. Pacific regions). These areas will be particularly vulnerable to changes in keystone/prey species and benthic habitat degradation, which could multiply the net negative effects of acidification.

Implementation of ecosystem-based fishery management and conservation of non-commercial species will allow greater numbers of species to survive changes in ocean chemistry and the ensuing ecological shifts that are likely to occur. A reduction in fishing pressure and preventable environmental stressors (such as local pollution) should begin before ocean acidification's effects on marine resources become obvious. The consequences of a precautionary approach to fishery management could decrease revenues in the short term, but may in fact result in greater fish stocks and higher revenues over the long term. If fisheries are to be sustainable in the face of climate change, then fishery management plans must include indirect impacts on non-commercial prey species and vulnerable benthic habitats.

Finally, changes in fishery management methods in anticipation of ocean acidification can be implemented in a way that balances ecosystem and social objectives by decreasing some catches and increasing others. Catch reductions may require temporary, regional, or permanent fishery closures in some areas. To maintain economic well-being in marine-resource-dependent communities during such a transition, managers can buy back fishing licenses and gear and provide job training. Increasing fishery capacity might involve encouraging multi-species fishing, developing new markets, minimizing waste, increasing aquaculture, or supporting research to select for species or strains that are less sensitive to altered seawater chemistry (Charles 2007). Mitigating the local economic effects of such a change will require temporary economic support to displaced individuals through re-education and job transitions.

A GLOBAL CHANGE WITH HUMAN CONSEQUENCES

Ocean acidification is a worldwide problem that is poised to affect multiple levels of society through our relationships with the marine environment. Dramatic declines in calcifying organisms and the commercially important species that feed on them are likely to accompany acidification, with substantial direct ecological and economic losses. Less clear are the indirect economic and social consequences of ocean acidification's effects on food webs and marine habitats. Middlemen, retailers, and consumers are all likely to experience secondary losses; the ways in which these groups experience and respond to ocean acidification will partly dictate the total economic and social costs to humans.

Policy changes designed to support marine conservation efforts in the face of ocean acidification must be initiated as soon as possible. Because of time lags in Earth's carbon system, the CO_2 that has already been released will continue to alter ocean chemistry throughout the foreseeable future. Earth has been slow to recover from past perturbations in the carbon system, and the biological changes associated with present-day ocean acidification will become more and more apparent over the coming decades. Economic effects of changing seawater chemistry will compound over time, beginning with losses of single species and culminating in entire ecosystem shifts. Reducing CO_2 emissions over the next few decades, despite the possibility of small up-front costs, could provide noticeable economic benefits over the next several generations.

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RESOURCES

National Marine Fisheries Service commercial fishing statistics: **http://www.st.nmfs.noaa.gov/st1/index.html**

PHOTO CREDITS

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Figure 2: Courtesy of Dr. John Guinotte

Figure 3: Courtesy of NOAA's Undersea Research Program/ Office of Oceanic and Atmospheric Research

Figure 4: Courtesy of Arctic Climate Impacts Assessment (ACIA), *Impacts of a Warming Arctic: Arctic Climate Impact Assessment*. Cambridge University Press, 2007.

Table 2: Adapted from Fabry et al. 2008

ˈOUSE COMMITTEE REPORˈ

(7)
Date Referred to Committee: January 21, 2011 **FURTHER REFERRALS: Resources**

Date of Committee Action: 2/23/12

The HOUSE SPECIAL COMMITTEE ON FISHERIES considered: **HJR 10**

HOUSE JOINT RESOLUTION NO. 10
Supporting expanded research concerning the detrimental effects of ocean acidification.
HJR 10-OCEAN ACIDIFICATION RESEARCH

Recommends it be replaced with [ ] HCS *or* [ ] CS *for* ________________(________)
For Senate Bills with new title: [ ] Technical Title [ ] New Title: HCR_______ **[ ] Same Title [ ] New Title**

[ ] attach amendments
[ ] add new referral to ___________Committee
[ ] Letter of Intent__________Committee

List of Abbrev for Depts.:
ADM
CED
COR
CRT
EED
DEC
DFG
GOV
DHS
LWF
LAW
LEG
MVA
DNR
DPS
REV
DOT
UA

***NEW* FISCAL NOTES**
*FN# is assigned by Chief Clerk's Office

*FN#	List by Dept(s):	Fiscal	Indet.	Zero
1	LEG			✓

***PREVIOUS* FISCAL NOTES**

FN#	List by Dept(s):	Fiscal	Indet.	Zero

Signing with recommendations	Printed Last Name	DP	DNP	NR	AM
[signature]	Pruitt			X	
[signature]	[illegible]				X
[signature]	HERRON			X	
[signature]	AUSTERMAN	X			
Robert J. Miller	MILLER	X			
Chair: [signature]	THOMPSON	X			
Chair:					