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SeaWeb

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# OceanUpdate

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## Ocean's Least Productive Waters are Expanding

The least productive waters in the ocean are expanding, at average rates between approximately one percent and four percent a year, according to a new paper in the journal *Geophysical Research Letters.*

The paper's authors, Jeffrey Polovina and Evan Howell of NOAA's Pacific Islands Fisheries Research Center in Honolulu, and Melanie Abecassis of the University of Hawaii, used data from NASA's Sea-viewing Wide Field-of-View Sensor (SeaWiFS) satellites to compile a decade-long series of estimates of surface chlorophyll. In particular, they examined the ocean's subtropical gyres, the largest ecosystems in each of the major ocean basins, which occupy approximately 40 percent of Earth's surface area. The biological production of these so-called oligotrophic ecosystems is so low that researchers have called them "biological deserts." Because of the gyres' size, even modest changes in their area can result in significant impacts on the distribution of chlorophyll throughout the global ocean.

Polovina and colleagues have found that the gyres' area has indeed grown. In the North and South Atlantic and the North and South Pacific, outside the equatorial zone, the areas of low-chlorophyll waters have expanded at average annual rates between 0.8 and 4.3 percent, and have replaced approximately 310,000 square miles (or 800,000 square kilometers) of higher surface chlorophyll habitat. In total, since 1998, these lower-chlorophyll areas have expanded by about 15 percent, or 2.5 million square miles (6.6 million square kilometers). Some regional differences exist: For example, although the North Atlantic's gyre is the smallest of the four, it has expanded more than the others, by 56 percent.

The authors note that the expansion of these areas was concurrent with "statistically significant" increases in the gyres' subtropical sea surface temperatures in each of the four oceans. The observations are, they continue, "consistent with the hypothesis that as the subtropical gyres become warmer, they become more stratified and the oligotrophic gyres expand." This suggests that productivity of surface ocean waters will continue to decline as global warming persists and increases.

**Source:** Polovina, J.J., *et al.* 2008. Ocean's least productive waters are expanding. *Geophysical Research Letters* **35(3)**, L03618, doi:10.1029/2007GL031745.

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## Impact of Salmon Aquaculture on Wild Salmon Populations

Since the late 1980s, wild salmon catch and abundance have declined dramatically in the North Atlantic and in the northeastern Pacific south of Alaska. At the same time, these areas have also seen an increase in salmon aquaculture production. Although previous studies have demonstrated negative impacts of aquaculture on wild salmonid populations, researchers had not been able to translate that information into predictions of changes in future survival and abundance in wild salmon. A new study in the journal *PLoS Biology* seeks to do just that.

The study, by Jennifer Ford and the late Ransom Myers of Dalhousie University in Nova Scotia, compares marine survival of salmonids in coastal areas with salmon farming to those in adjacent areas without such farms in Scotland, Ireland, Atlantic Canada and Pacific Canada. The researchers estimate changes in marine survival concurrent with the growth of salmon aquaculture.

They found that "all estimates of the effect of aquaculture on survival or returns were negative," and that the survival and annual returns of each generation of many stocks were reduced by more than 50 percent. In general, they found that Atlantic salmon populations were depressed more than Pacific salmon populations, particularly off Atlantic Canada. They also concluded that Irish sea trout were very strongly affected. In British Columbia, only pink salmon showed significant declines correlated with salmon aquaculture.

Ford and Myers write that, beyond the existence of aquaculture, the control and exposed areas do not differ significantly from each other. For example, they write, no evidence exists that the salmon farms in question have been established only in areas where wild stocks have already collapsed, nor that they are in areas where habitat is more disturbed by human activities. Nor, they say, is it likely that the results are due to any climate trend; although exposed populations are to the south of control populations in three out of five areas, latitude differences "are small."

Atlantic salmon populations appear to suffer from higher impacts than Pacific salmon species in British Columbian waters. The authors posit that one reason for this may be because farmed fish are also Atlantic salmon, and so wild populations of Atlantic salmon exposed to escapees from fish farms may be more susceptible to genetic effects from interbreeding, disease and other impacts. The declines in Irish sea trout cannot be explained by interbreeding, but the researchers suggest it may be a consequence of them spending long periods in coastal areas near salmon farms where they could be exposed to disease and parasites.

They conclude by noting that the time period in which they are estimating impacts includes the establishment of the aquaculture industry was established in each region. Although they state that better management should decrease the impact per metric tonne of farmed salmon, they question whether such improvements would be able to keep pace with the overall growth of the salmon farming industry.

**Source:** Ford, J.S., and R.A. Myers. 2008. A global assessment of salmon aquaculture impacts on wild salmonids. *PLoS Biology* **6**(2): e33. doi:10.1371/journal.pbio.0060033

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## How Will Increased Atmospheric $CO_2$ Affect Southern Ocean Plankton Communities?

The near-freezing waters of the Southern Ocean have long been recognized to act as a significant "carbon sink," helping reduce levels of carbon dioxide ($CO_2$) in the atmosphere. However, the prevailing assumption has been that, because $CO_2$ solubility is highest in cold water, increased temperatures would reduce the ability of the Southern Ocean to dissolve $CO_2$, resulting in a positive feedback loop: less $CO_2$ uptake by the ocean, leading to greater $CO_2$ levels in the atmosphere and causing greater temperature increases.

The one caveat to that scenario has been that this effect could be significantly moderated, or even negated, if rising $CO_2$ levels led to changes in the Southern Ocean's biological "pump"—specifically, if they would prompt increases in carbon-consuming planktonic organisms. A new study in the journal *Geophysical Research Letters* provides support for this view.

Philippe D. Tortell of the University of British Columbia and colleagues collected 35 surface water samples in the Ross Sea region of Antarctica and examined the composition of phytoplankton assemblages that they contained. They then conducted $CO_2$ manipulation experiments with some of the water samples, bubbling air with three different concentrations of $CO_2$ to ascertain the planktons' response.

In general, they found that all observed phytoplankton assemblages showed evidence of decreased carbon uptake when $CO_2$ levels were low, and most species increased their carbon uptake when $CO_2$ levels were high. They also noted that high $CO_2$ levels appeared to benefit some species at the expense of others. Such species are particularly efficient at fixing carbon, and often bloom in large numbers; as a result, when they die and sink to the bottom, they introduce large amounts of carbon into the sediment.

In other words, greater $CO_2$ levels could lead to greater productivity among Southern Ocean phytoplankton species that are especially effective at using $CO_2$ to produce food and ensuring its retention in the ocean. The greater the increase in surface-level $CO_2$, the greater the phytoplankton, which creates a negative feedback that could serve to mitigate some of the increase in atmospheric carbon dioxide.

**Source:** Tortell, P.D., *et al.* 2008. $CO_2$ sensitivity of Southern Ocean phytoplankton. *Geophysical research Letters* **35:** L04605. doi:10.1029/2007GL032583.

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## Study Provides New Information on Antarctic Ice Loss

One of the widespread public assumptions about global climate change is that increased temperatures will ultimately lead to a melting of the Antarctic ice sheet. However, although the 1995 collapse of the Larsen A Ice Shelf and the 2002 collapse of the neighboring Larsen B Ice Shelf added to the evidence that warming temperatures were affecting the more northerly reaches of the Antarctic Peninsula, the impacts of climate change on ice shelves and glaciers on the fringes of the Antarctic mainland remain uncertain. Indeed, because warming leads to greater precipitation, large parts of the Antarctic ice sheet are expected to increase in mass, at least initially.

Most of the data concerning ice loss in the polar regions have been derived from direct visual sensing from satellites and aircraft. But a recent study by Jianli Chen of the Center of Space Research of the University of Texas and colleagues in the journal *Earth and Planetary Science Letters* used a different approach in an attempt to provide greater clarity. The study compiled data from the Gravity Recovery and Climate Experiment (GRACE) Mission, which began in 2002. As part of the GRACE program, two identical spacecraft approximately 150 miles apart and in a polar orbit 300 miles above the Earth are mapping variations in the planet's gravitational field, including changes due to surface and deep currents in the ocean, variations of mass within the Earth and exchanges of water between ice sheets or glaciers and the ocean.

Chen and colleagues used GRACE data to examine possible ice loss rates at six points along the coast of Antarctica from January 2003 through September 2006. The authors then matched this data with ice-loss models.

Results were generally consistent with previous observations, although in some cases suggested a greater loss rate or smaller rate of mass increase than had previously been thought to be the case. In the coastal areas of the Amundsen Sea, for example, average ice loss rates were calculated to be about 20 cubic miles (81 cubic kilometers) a year. In the northern Antarctic Peninsula, the estimate is approximately seven cubic miles (28 cubic kilometers) a year. The estimate for the Amundsen Sea is consistent with earlier figured derived from GRACE data, while the new study provides the first such evidence for the northern Peninsula region. For Enderby Land in East Antarctica, the authors estimate a mass increase of about five cubic miles (21 cubic kilometers), which is much smaller than a previous estimate of about 20 cubic miles (80 cubic kilometers). The discrepancy in the Enderby Land figures, say the authors, can be attributed to improvements in data and their measurement over a longer time period.

The authors do not attempt to infer any increase or decrease in rates of change as a result of their study. However, they conclude that use of GRACE data, coupled with improvements in modeling, "will continue to improve understanding of global ice mass balance and related climate change."

**Source:** Chen, J.L., *et al.* 2008. Antarctic regional ice loss rates from GRACE. *Earth and Planetary Sciences Letters* **266:** 140-148.

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## Sea Lions Show Effects of Chronic Exposure to Domoic Acid

Harmful algal blooms are increasing in extent, frequency and type around the world, likely the result of a variety of factors including oceanographic regime shifts, overfishing, movement and discharge of ballast water, eutrophication and global climate change. As they increase, it is likely that so too will their impacts on marine fauna and human health.

For at least the past decade, blooms of the diatom genus *Pseudo-nitzschia* have apparently been increasing along the California coast, as have health impacts on marine mammals and humans from the potent neurotoxin the diatom produces, domoic acid. Domoic acid causes amnesic shellfish poisoning in humans, a condition first recognized in Canada in 1987. More recently, it has been associated with neurological effects in sea lions and seabirds off California.

In a paper in the journal *Proceedings of the Royal Society B*, Tracey Goldstein of the Marine Mammal Center in Sausalito, Calif., and colleagues detail the results of a study in which a total of 2,963 sea lions were admitted to the center for treatment after being found stranded along the California coast between 1998 and 2006. Of those, 715 showed neurological signs as a result of exposure to domoic acid. The majority (551) showed signs of acute exposure, which the researchers identified as "characterized by clinical signs that included ataxia [almost complete lack of muscle control], head weaving, seizures or coma which varied in severity but were continuous during the period of toxicosis, lasting about one week followed by recovery, if treated, or death." Most of these cases were found in clusters, signifying that a *Pseudo-nitzschia* bloom had affected the animals.

However, 164 sea lions showed hitherto unrecorded chronic symptoms: They suffered seizures that were two weeks or more apart; underwent periods of extreme lethargy; and suffered vomiting, muscular twitching, and other abnormal behavior. The time between the first presentation of these symptoms and the animals' eventual death ranged from 25 days to almost five years.

The authors note that information on chronic exposure to domoic acid is sparse, but that the toxin has been shown to cross the placenta, as it has been observed in amniotic fluid, fetal urine and fetal gastric fluid. As a result, they speculate that adult females that survive acute exposure may be passing the toxin on to their offspring, and that this may be playing a factor in what appears to be an increasing number of cases of chronic domoic acid poisoning.

**Source:** Goldstein, T., *et al.* 2008. Novel symptomatology and changing epidemiology of domoic acid toxicosis in California sea lions *(Zalophus californianus)*: an increasing risk to marine mammal health. *Proceedings of the Royal Society B* **275:** 267-276.

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## Economic Development May Decrease Environmental Quality of the Ocean

According to some economic theorists, environmental quality is a "luxury good," and therefore only affluent societies are willing and able to invest in environmental protection. This notion is shown in the Environmental Kuznets Curve (EKC), a graph of Simon Kuznets's hypothesis that says environmental problems escalate in the early stages of economic development, but then eventually reach a tipping point, after which further economic growth leads to improvements in environmental quality.

In a recent paper in the journal *Conservation Biology*, Rebecca Clausen and Richard York of the University of Oregon decided to test this hypothesis in relation to marine environments, and found it lacking.

Clausen and York conducted time-series analyses of the fisheries catch of 102 nations from 1960 to 2003, focusing on the catches' Marine Trophic Level (MTL), or at what level species appear in the food chain. They argue this provides a more complete picture of marine ecosystem health than simply the overall size of the catch. They found that, in direct contradiction of the EKC hypothesis, "nations' MTLs declined with increased economic growth, increased urbanization, and increased population size, in part because of associated increased catch."

They propose a number of explanations for why this should be so. They note, for example, that economic growth and modernization spur investment in new fishing technologies that not only influence the scale of harvest but also qualitatively alter how fish are caught. Enlarged fleets and improved technology enable fish to be targeted with greater accuracy and faster techniques. Second, the effect of the direct catch is amplified because intensification of production not only increases extraction from marine sources, it also contributes "excessive waste" (in the form of, for example, atmospheric pollution and plastic debris) to marine environments. Third, urbanization has drastically altered coastal marine habitat.

They conclude that, in addition to the overfishing, "continued economic growth, urbanization, and population increase will degrade global marine biodiversity."

**Source:** Clausen, R., and R. York. 2008. Economic growth and marine biodiversity: Influence of human social structure on decline of marine trophic levels. *Conservation Biology doi:* 10.1111/j.1523-1739.2007.00851.x

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## About Ocean **Update**

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