THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

CITATION

Mix, A.C. 2017. Follow the money. *Oceanography* 30(2):7–9, https://doi.org/10.5670/oceanog.2017.202.

DOI

https://doi.org/10.5670/oceanog.2017.202

Follow the Money

The White House budget proposal for FY2018 (OMB, 2017) includes substantial cuts to scientific research programs. Whether Congress enacts those proposals remains to be seen, but even if current funding levels remain intact, ocean (and other) scientists already believe that research funding is tight. Are those perceptions about tight funding really true, or are we are imagining a rosy past that didn't really exist? Let's see what the data say.

This column builds on earlier efforts in the "Sea Change" report (NRC, 2015), which considered US National Science Foundation (NSF) Ocean Sciences Division (OCE) funding between 2000 and 2014 (with projections from 2015 to 2020). I also examine a longer data set starting in 1970[1]. This column is limited to NSF, which deserves credit for transparency, as all of their data are publicly available. I hope to look at other US agencies and foreign governments in future columns.

My starting point was dollars spent on basic research by NSF-OCE (blue symbols in Figure 1a, historical solid, projections open). Until recently, the numbers generally rise through time. To correct for inflation, I calculated 2016-equivalent dollars from the US Consumer Price Index (red symbols in Figure 1a). Those inflation-corrected numbers correspond with our gut feeling that times are tight: the purchasing power for ocean sciences research peaked in 2003–2004, and with a few bumps has been declining for the past 12 years.

Without question, budgets are far below what they could have been had they tracked a fixed percentage of the US Gross Domestic Product (GDP). In Figure 1a, the dashed lines (blue is constant dollars, red is inflation corrected) model potential NSF-OCE funding as 0.0026% of GDP (the empirical average percentage between 1970 and 2016).

The maximum purchasing power for NSF-OCE occurred in the early 1970s, during the International Decade of Ocean Exploration (IDOE). From that anomalously high peak, NSF-OCE funding fell by the early 1980s to near the constant fraction of GDP lines. I was a graduate student then and recall hearing the grumblings about tight budgets and proposal rejections.

A few years later, optimists dreamed that science research would share in a "peace dividend" following the collapse of the former Soviet Union in 1991 and the end of the Cold War. Sadly, that windfall never happened for NSF-OCE, but funding generally tracked GDP growth until the mid-1990s.

When control of Congress changed in the mid-1990s, the so-called "Gingrich Revolution" and the "Contract for America" led to a new era of funding cuts. Even as economic growth led to increased federal revenue (https://www.whitehouse.gov/omb/budget/Historicals), funding for ocean science fell below the percentage of GDP model, and in inflation-corrected terms actually declined slightly. By 1999 this reduction of funding was seen as a crisis. President Clinton's chief of staff John Podesta said the cuts to science were "threatening the potential progress of innovation in America" (http://www.nature.com/nature/journal/v401/n6749/full/401103a0.html).

Proposals to double the NSF budget over a five-year period never formally passed as legislation (https://www.aip.org/fyi/2002/congress-passes-bill-authorizing-doubling-nsf-budget). Nevertheless, Congress found ways to invest in science between 2000 and 2003,

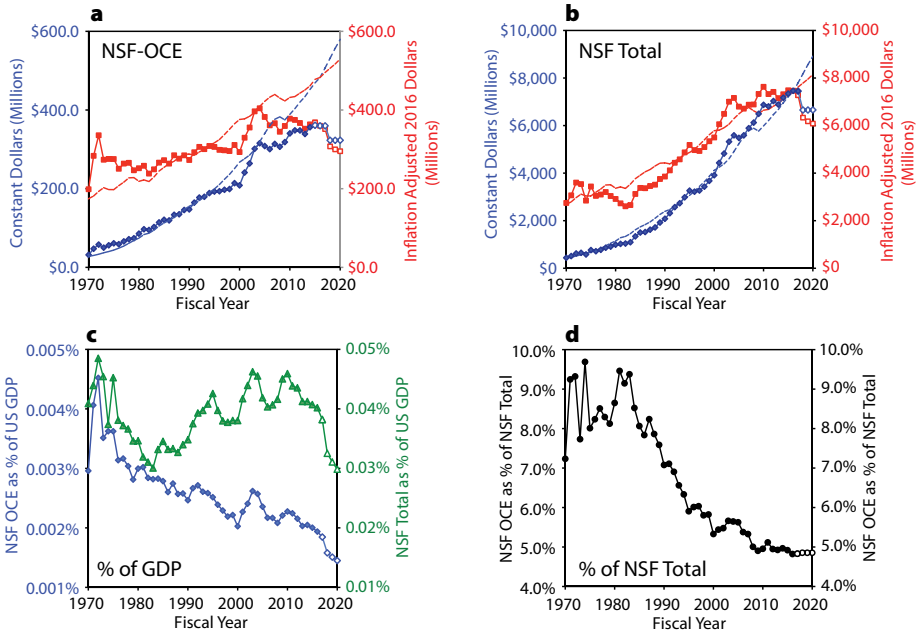


FIGURE 1. (a) History of NSF Ocean Sciences Division funding in constant dollars (blue symbols) and inflation corrected values (2016-equivalent dollars, red symbols), along with hypothetical budgets as 0.0026% of US GDP (constant dollars, blue dashed line; 2016-equivalent dollars, red dashed line). (b) As in panel (a) but for total NSF research funding in all fields (dashed lines are 0.040% of US GDP). (c) NSF OCE funding (blue, left axis) and NSF Total funding (green, right axis) as a varying % of US GDP. (d) NSF OCE as a percent of total NSF research funding.

and the NSF-OCE budget briefly grew faster than inflation for the first time since the early 1970s. Programs were launched with great optimism. However, the actual budget increases just got NSF-OCE funding levels out of a hole and back up the level that tracked GDP growth.

Following the September 11, 2001, terrorist attacks, a growing percentage of federal funds were shifted to defense and homeland security. Since 2004, inflation-corrected purchasing power for ocean sciences has declined steadily. If the OMB 2018 budget is enacted, NSF-OCE will have been reduced to the purchasing power it had in 1972 and 1992.

NSF details the implications of the White House budget here: https://www.nsf.gov/about/budget/fy2018/index.jsp; the proposed cut for NSF-OCE is about 10.2% (9.8% cut in disciplinary and interdisciplinary science). In the absence of reallocations of funding priorities within NSF, if the OMB 2018 budget becomes law, ocean infrastructure purchasing power will be up about 20% relative to 2003 (due to cost inflation of fixed facilities initiated when budgets were rising), but science investigator funding (the normal proposals we all write to do our work) will be down 49%. We will have lost nearly ***half*** the NSF science program in oceanography over a 15-year period[2].

Is this true of NSF as a whole? Yes and no.

In Figure 1b, the red and blue symbols are as before, but now for the total NSF budget rather than just for OCE science. As before, the dashed curves are dollar amounts for a constant fraction of GDP (here 0.04%, the average from 1970 to 2016). Figure 1b makes it clear that until now, total NSF funding has more or less tracked GDP growth since 1970. The proposed cuts in the OMB 2018 budget are not the first time NSF has seen cuts, but they are severe and abrupt relative to past history.

So why did NSF-OCE funding not keep up with the overall NSF budget? In Figure 1c, the blue curve is the NSF-OCE funding as a percentage of GDP. In the 1970s, NSF-OCE was allocated about 0.004% of GDP. That percentage dropped precipitously in the late 1970s, is now less than 0.002% of GDP, and is projected to fall further to about 0.0015%. In contrast, total NSF funding (the green curve) has oscillated but overall has stayed relatively constant as a fraction of GDP, recovering after a dip during the Carter and Reagan Administrations. The proposed FY2018 budget imposes on NSF a drop relative to GDP that is equivalent to those of the Reagan years.

To make this even clearer, Figure 1d shows what happened to OCE within NSF. The percentage of NSF funds dedicated to ocean sciences in the 1970s and early 1980s ranged between about 8% and 9% of the total NSF effort. The sea change for ocean sciences occurred even earlier than the visible loss of dollars in the 1990s. Ocean sciences appears to have dropped in priority at NSF (i.e., as a percentage of NSF's budget) starting in the mid-1980s, when NSF changed course to emphasize investment in programs the agency considered most directly related to economic competitiveness such as engineering and computer science (Bloch, 1985). Since that time, NSF has been gradually reducing its fractional commitment to ocean sciences. OCE is now under 5% of NSF's overall effort.

Readers of *Oceanography* almost certainly share my belief that ocean science is needed now more than ever, both in the United States and globally. The ocean remains the least explored part of

[1] Data reported here are for funds committed by the National Science Foundation Ocean Sciences Division (NSF-OCE). The data source for the interval 2000–2014 comes from NSF as part of the "Sea Change" report (NRC, 2015). Older data are gleaned from tables in the National Science Board Science and Engineering Indicators. Actual values from 2015 to 2017 are from the federal record. Projections are based on the White House proposed budget for FY2018. The numbers here reflect science operations and activities within NSF-OCE; they exclude major infrastructure projects (so called MREFC funds) such as ship construction and the one-time, 2008 funds associated with ARRA (the American Recovery and Reinvestment Act). Some additional ocean sciences research occurs in other divisions, for example in NSF's Office of Polar Programs (OPP), and those funds are not included here.

A caveat in this analysis is that alternate databases on federal programs exist by subject area (https://ncsesdata.nsf.gov/webcaspar), and in some cases give different values. Discrepancies appears to reflect the fact that fields specified in the ncsesdata product do not conform with NSF divisions, so a judgment must have been made about how to translate NSF program data into ncsesdata categories. Inspection of the ncsesdata database reveals large and implausible oscillations in division budgets on the order of $100 million; for example, in a single year (1991) the uncorrected oceanography budgets appear to shift down by $100 million while at the same time the combination of geology and environmental sciences budgets shift up by $100 million. The opposite shift occurs in 1996. Because of these discrepancies, the data provided directly by NSF-OCE was used, gleaned mostly from biennial Science and Engineering Indicators reports. Categorizing these values correctly involved some decisions to avoid the problem of funds jumping between pigeonholes. NSF staff kindly checked the estimates I made and agreed that they were reasonable. It should be noted, however, that older values in the NSF database are not as complete or detailed as more recent values, so some errors may remain. It may no longer be possible to check the details in the older data.

Inflation corrections were based on the US Consumer Price Index (https://inflationdata.com/Inflation/Consumer_Price_Index). Data on US Gross Domestic Product from 1970 to 2016 came from the US Bureau of Economic Analysis (https://www.bea.gov/national/index.htm). Projections from 2017 to 2020 are from the International Monetary Fund IMF Projection (https://knoema.com/qhswwkc/us-gdp-growth-forecast-2015-2019-and-up-to-2060-data-and-charts).

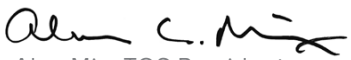
There was no attempt here to evaluate dollars available per scientist requesting funds. Anecdotally, however, it appears that the pool of scientists working in oceanography has grown substantially over the past several decades. For example, TOS was founded in 1978 with a few hundred members, and has grown by a factor of 10. Similarly, membership in the American Geophysical Union (AGU) in 1980 was about 13,000, and now is over 60,000 (of course, not all AGU members are ocean scientists). If this population growth in ocean sciences is correct, it implies less dollars of funding per scientist even if the amount of funding is stable or increasing, depending on the relative rates of change in funding and population of scientists.

[2] Calculation is as follows: in FY 2003, the NSF-OCE science budget was $301.47 million, and of that $114.69 million was for infrastructure support, and $186.77 million was for science and related activities (NRC, 2015). Translated into inflation corrected 2016-equivalent dollars, these values would be $369.66, $150.91, and $245.75 million, respectively. The values proposed in the FY2018 White House budget are $323.02, $190.77, and $132.25 million (constant dollars) or $307.49, $181.60, and $125.89 million (in 2016-equivalent dollars). Thus, in terms of purchasing power, the fractional changes from 2003 to the proposed FY2018 are a loss of 23% (total NSF-OCE) with a rise of 20% for infrastructure support, and a loss of 49% in infrastructure and related activities. For comparison, the change in total NSF budget over the same period (in 2016-equivalent dollars) is a loss of 10% in purchasing power, almost entirely due to the cuts proposed for 2018.

planet Earth. The benefits of ocean science are countless, but include sustaining the health of our planet and all its inhabitants, providing a sound basis for resource management, inspiring innovations that fuel economic growth (e.g., the emerging "blue" economy; http://www.oecd.org/futures/oceaneconomy.htm), and informing national and international security. Oceanography is essential.

To deliver on the promises of ocean sciences, long-term disinvestment in ocean research in the United States must stop. We can't just wish for that to happen. We need a positive vision of the future. We need to retain promising young ocean scientists in the field. We need diverse views. Strategic visioning efforts such as "Sea Change" (NRC, 2015) are a good start, but more coordination and a broader implementation plan are needed to justify funding.

TOS serves as a great pool of research talent and intellectual energy for the ocean sciences both in the United States and around the world. TOS is ready to help to facilitate the conversation to build a new generation of ocean sciences with new strategic investments from governments, private sector businesses, and an engaged public. I will discuss some ideas about how to do that in future columns, and welcome your input.



Alan Mix, TOS President

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Oceanography https://tos.org/oceanography

Oceanography (ISSN 1042-8275) is published by The Oceanography Society, PO Box 1931, Rockville, MD, 20849-1931 USA.