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Contribution to the Symposium: '*Ecosystem Studies of Subarctic and Arctic Seas*'

Food for Thought

Mechanisms for science to shape US living marine resource conservation policy

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National Oceanic and Atmospheric Administration Fisheries are responsible for the stewardship of the US living marine resources and their habitat and for providing productive and sustainable fisheries, safe sources of seafood, the recovery and conservation of protected resources, and healthy ecosystems to the nation. Their approach to conservation requires, by legislative mandates, that management be informed by science. It has evolved into a four-step approach to providing this advice: (i) the national framework for conservation science, (ii) region specific implementation, (iii) development of unbiased, scientific advice as required by the framework, and (iv) scientists acting, as appropriate, as advocates and science communicators. This approach has been a conservation success where, e.g. 92% of known managed fish stocks are no longer being overfished and 84% of known stocks are at healthy levels, with the latter including 43 stocks rebuilt from depleted levels. In a changing marine climate, it is all the more important that marine conservation decisions be driven by science.

Keywords: advocacy, fishery management, Magnuson–Stevens Act, marine conservation, marine mammals.

Introduction

Conservation of living marine resources (LMRs) is a major issue in the United States because of the enormous impact these have on marine ecosystems as well as on the economies of coastal communities and the Nation. The National Oceanic and Atmospheric Administration (NOAA), a bureau of the US Department of Commerce (Figure 1) is responsible to the American people for fulfilling this task. This responsibility is further delegated to NOAA Fisheries, one of the five line offices within NOAA. This office is committed to a four-fold mission to (i) ensure productive and sustainable fisheries, (ii) provide safe seafood, (iii) recover and conserve protected resources, and (iv) maintain healthy ecosystems and resilient coastal communities. American taxpayers entrust the nearly 3000 NOAA Fisheries employees with ca. $945 million annually to support these missions, which, in return, support 1.6 million jobs and $207.6 billion in sales (NMFS, 2017).

The US government approach to marine conservation requires, by legislative mandates, that management be informed by science. In so far as US marine conservation is effective, it is largely because of a four-step approach that has evolved from these mandates:

(i) Federal legislative and policy drivers provide a national framework for conservation science.

(ii) This framework is then implemented to meet regional needs.

(iii) NOAA scientists and their partners develop unbiased, scientific advice as required by the framework.

(iv) NOAA scientists act, as appropriate, as advocates and science communicators.

Ultimately, these four steps are key to maintaining healthy marine ecosystems and resilient coastal communities.

The power of this approach is clear from the conservation successes of the United States. Of the more than 500 commercially and recreationally harvested fish species, 91% of stocks with known status are not being overfished and 84% are at healthy levels. NOAA also protects 117 marine mammal stocks and 157 species listed under the

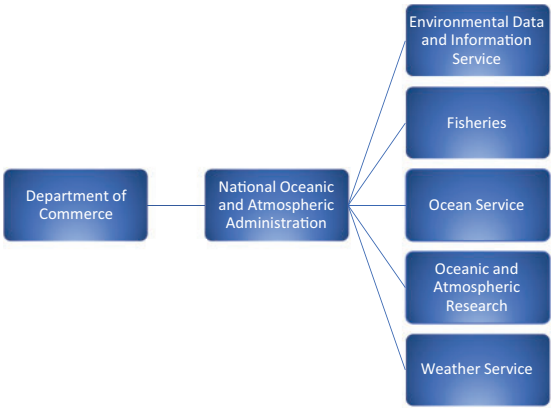

Figure 1. Simple organizational chart of the NOAA including its parent Department of Commerce and its five line offices (including NOAA Fisheries).

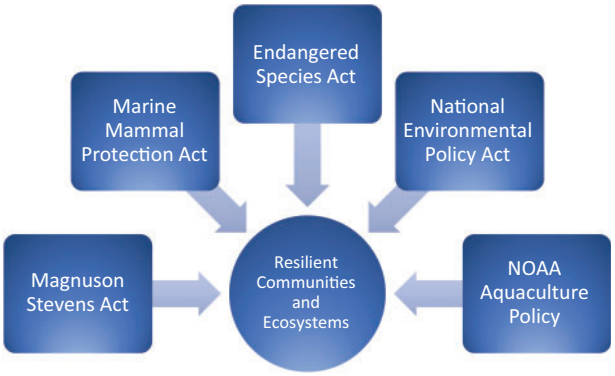

Figure 2. The key US congressional mandates and federal policies supporting US marine conservation science, which include the Magnuson–Stevens Act, the MMPA, the ESA, the NEPA, and NOAA's Marine Aquaculture Policy.

Endangered Species Act [ESA (https://www.fisheries.noaa.gov/topic/laws-policies#endangered-species-act)] as endangered/threatened species, most of which are stable or improving in status.

In this article, I will explore in more detail the elements of this four-step approach. I will also provide examples of specific successes. The materials here are drawn from an invited presentation made at the Ecosystem Studies of Subarctic and Arctic Seas (ESSAS) Open Science meeting held in Tromsø, Norway 11–15 June 2017. As with the ESSAS presentation, this paper will not evaluate the success or failures of US management of LMRs, but instead will focus on how science is provided to the managers.

US structural approaches to marine conservation

The US approach to marine conservation has an overarching framework which provides structure for both the science and management of LMRs. The four key legislative mandates (Figure 2) all call for science-based decisions made using best scientific information available (BSIA). Details on each mandate are available from the NOAA Fisheries. For the sake of brevity, I will focus here on one which is illustrative of the others—the Magnuson–Stevens Fishery Conservation and Management Act [MSA (https://www.fisheries.noaa.gov/topic/laws-policies#magnuson-stevens-act)].

The MSA is the primary law governing marine fisheries management in US federal waters. First passed in 1976, the MSA fosters long-term biological and economic sustainability of US marine fisheries out to 200 nautical miles from shore. Key objectives of the Act are to:

(i) prevent overfishing,
(ii) rebuild overfished stocks,
(iii) increase long-term economic and social benefits, and
(iv) ensure a safe and sustainable supply of seafood.

Prior to the MSA, US waters beyond 12 nautical miles were international waters and were fished by fleets from other countries. The 1976 law extended US jurisdiction to 200 nautical miles and established fisheries governance that focussed on eight regional fishery management councils (councils) with representation from the coastal states and fishery stakeholders. The councils' primary responsibility is development of fishery management plans (FMPs) and to make recommendations regarding regulations that implement Federal management in a given region. When reviewing FMPs, FMP amendments, and regulations, the US Secretary of Commerce (as required by the MSA) ensures that they comply with a number of conservation and management requirements, including the 10 National Standards (NSs) (https://www.fisheries.noaa.gov/topic/laws-policies#magnuson-stevens-act)—principles that must be followed to ensure sustainable and responsible fishery management. NS2 requires that "Conservation and management measures shall be based upon the best scientific information available" (https://www.st.nmfs.noaa.gov/science-quality-assurance/national-standards/ns2_revisions). A key element of policies under NS2 is the determination of BSIA, which allows for the use of science from both governmental and non-governmental sources. The criteria to consider when evaluating BSIA are "relevance, inclusiveness, objectivity, transparency and openness, timeliness, verification and validation, and peer review, as appropriate." Of particular interest to the scientific community is the peer-review process, which ensures that the inclusiveness, quality, and credibility of scientific information and scientific methods meet the standards of the scientific and technical community. Peer review helps ensure objectivity, reliability, and integrity of scientific information.

The US Secretary of Commerce, working with each fishery management council (https://www.fisheries.noaa.gov/insight/fisheries-management-united-states), has established a peer-review process which evaluates the scientific information used for conservation and management of the fishery. The Secretary of Commerce publicly identifies the MSA peer-review process in the Federal Register (The Federal Register is the official journal of the federal government of the United States that contains government agency rules, proposed rules, and public notices.) along with a brief description of the process. Detailed information on the review processes are made publicly available on each council's website, with each council's Scientific and Statistical Committee playing a pivotal role in the provision of scientific advice (as well as advice on setting each managed stock's acceptable biological catch).

The policies established under NS2 provide clear guidance for how science is introduced, vetted, and used in the management of fish stocks included in regional FMPs. The result is that under the MSA, US fisheries management is a transparent and robust

process of science, management, innovation, and collaboration with the fishing industry. For most stocks, a scientific analysis of the abundance and composition of the stock (a "stock assessment") is conducted and used to determine if the stock is subject to overfishing or is overfished. Using this scientific data, councils set annual catch limits, and if they are exceeded in a fishing year, predetermined accountability measures provide the mechanisms to mitigate the effects of the overfishing. Since 2011, US domestic fisheries have had measures in place to meet the new requirements, and today, 91% of fisheries are maintaining harvest levels at or below agreed-upon annual catch limits.

NOAA's other legislative drivers for marine conservation (https://www.fisheries.noaa.gov/topic/laws-policies) [i.e. National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), ESA] provide similar frameworks for introducing science into management. These other acts also charge NOAA with conducting scientific evaluations of management actions, but only the MSA sets up a regional governance structure based on regional councils comprised of stakeholders with responsibility for providing sound management advice to regional managers.

Regional implementation of the national framework

Given the broad diversity of regional conservations issues (Figure 3), it would be inappropriate to attempt to provide a single "national" response. NOAA Fisheries is effective because it treats these as regional issues within a national framework. The eight fishery management council regional fisheries vary markedly. The North Pacific (Alaska) region is dominated by large commercial fisheries, including some of the largest commercial groundfish and salmon fisheries in the world, with landed value in 2015 of $1.7 billion (NMFS, 2017). In contrast, Gulf of Mexico region fisheries are largely recreational, with the value of commercial fisheries being <$0.2 billion in 2015, most of which is from shellfish (NMFS, 2017).

To provide the science and management for these regional interests, NOAA Fisheries has 1400 scientists in six regional science centres (with ca. 25 labs), and each science centre is linked to a companion (but physically separate) regional management office. Science centres are led by science centre directors (who are scientists) who report to headquarters via the NOAA Fisheries Chief Science Advisor and not to the lead regional manager/administrator. The regional knowledge and local contacts allow NOAA Fisheries to provide tailored advice for regional problems (while still providing for cross-regional communication of science and management solutions through headquarters offices). Each of the regional science centres also provides their own unique international connections (e.g. the Northeast Centre interacts most frequently with Europe, while the Southeast Centre maintains strong ties with Caribbean and Gulf of Mexico interests.) The headquarters Office of Science and Technology supports national-level bilateral scientific agreements with a variety of nations and scientific organizations.

An additional strength of the NOAA Fisheries approach is that the overall scientific portfolio is directed by a single national Chief Science Advisor and Science Board. The Board consists of the directors of the six regional science centres, the director of the national Office of Science and Technology, and the three national-level senior scientists (stock assessment, ecosystems, and economics). In this capacity, the Chief Science Advisor acts as a chief executive, and the Science Board acts as a board of directors to manage and coordinate the regional science portfolios with the national framework.

Each science centre, though regionally focussed, is staffed to provide scientific support on all of NOAA Fisheries' legislative mandates. Most of the scientific advice utilized by NOAA Fisheries managers is produced by the NOAA Fisheries science centres. However, additional direct scientific support is also provided by NOAA's partners (e.g. academic cooperators). This is particularly important role for NOAA's Cooperative Institutes (http://ci.noaa.gov/) and Cooperative Science Centers (http://www.noaa.gov/office-education/epp-msi/csc), both of which represent consortia of universities and research institutes. Finally, the administrative framework for presentation of BSIA to NOAA managers provides opportunities for other scientists to provide scientific advice, particularly with respect to stock assessments.

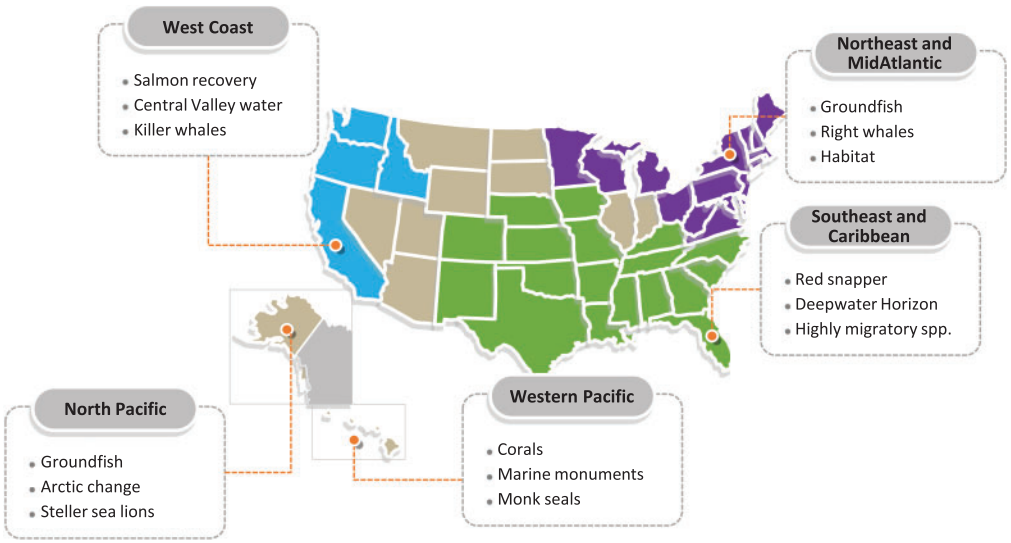

Figure 3. Selected NOAA Fisheries marine conservation issues by NOAA Fisheries region, ca 2017.

Ensuring quality science and scientists

Conservation places a heavy responsibility upon NOAA scientists to provide the best possible science. Because of NOAA Fisheries' regulatory role, decisions are frequently made that are the subject of considerable controversy. NOAA is the most-frequently litigated Federal agency, largely because of its regulatory role.

With the legislative drivers and supporting policies in place, it has been difficult for adversaries of NOAA's regulatory decisions to contest the use of science-based management. However, the need to discredit the science to win a lawsuit has led to attacks on the quality of science and on NOAA scientists.

Concerns also exist that science may be manipulated to meet political exigencies or that scientists may be prohibited from expressing their scientific opinions if they conflict with agency policy. This was part of the reason that NOAA Fisheries decided ca. 1999 to separate administration of the science centres from the regulators in the regional management offices, thereby eliminating potential conflicts of interest between science and management at the regional level.

All of this has led to the need for strong procedures and policies within NOAA that ensure the continued provision of high quality, unbiased scientific advice including:

(i) a NOAA Fisheries Science Quality Assurance Process (SQAP) involving independent peer review of science at all levels, and

(ii) a NOAA Scientific Integrity Policy designed to guide (and protect) scientists in the ways they express their scientific advice.

NOAA Fisheries has developed a SQAP that provides high-quality science as well as prohibits tampering with results. This has produced the most comprehensive scientific review process in NOAA (Figure 4). The NOAA Fisheries SQAP has four levels of review:

(i) internal review of individual scientist's fundamental research communications (http://www.nmfs.noaa.gov/op/pds/documents/04/04-113.pdf), which is aligned with NOAA's policy on review of research communications, and the US Government Information Quality Act;

(ii) peer review of individual stock assessments (https://www.st.nmfs.noaa.gov/science-quality-assurance/MSA-peer-review-processes/index), which aligns with the US Government's Office of Management and Budget's Peer Review Standards (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf);

(iii) annual reviews of each science centre's research portfolios (https://www.st.nmfs.noaa.gov/science-program-review/index); and

(iv) NOAA Scientific Advisory Board and National Academy of Sciences (NASs) reviews of cross-cutting, national level topics.

Figure 4. The four elements of NOAA Fisheries Science Quality Assurance Process, including both internal and external [e.g. NAS] review (https://www.st.nmfs.noaa.gov/science-quality-assurance/indexs).

NOAA Fisheries employs these nested levels of review for assurance that it is doing the right science, doing it properly, and then applying it appropriately in the management realm.

All science destined for public dissemination, whether in peer-reviewed journals or simply as part of a fish stock assessment, is required by NOAA Fisheries to be reviewed as a fundamental research communication. However, in the case of fish and marine mammal stock assessments, a second level of review which focuses on the assessment itself is also required. These are performed through the NS2 peer-review process for fish (see following discussion) and the scientific review groups established under the MMPA for marine mammals. In the case of science with significant impacts (e.g. the implementation of a new national protocol for measuring recreational fishery catches), NOAA Fisheries may also ask for a higher-level review, which can be accomplished through groups such as the NASs. Because all of these reviews focus on single topics or manuscripts, they miss potential improvements of larger science portfolios within the agency's individual science centres. Annual external reviews of the quality of each centre's portfolio were implemented beginning in 2012, such that all centres are reviewed each year on the same topic (e.g. in 2017, all centres' economics and social science programmes were reviewed).

The importance of these four levels of review has been especially important with the US Congress, where representatives and senators have called for numerous investigations of NOAA science by the NAS and investigative arms of the Federal government (e.g. the US Government Accountability Office, and the Department of Commerce's Inspector General). Without exception, all have found the science to be sound.

A separate but equal element of NOAA science policies is the NOAA Scientific Integrity Policy. This policy provides a valuable complement to the review programme because it provides clear guidelines on how NOAA scientists can talk about their science. Basically, a NOAA scientist is free to (and is expected to) publish and speak about all of his/her scientific results. At times, these results may be inconsistent or appear to be inconsistent with NOAA Fisheries policy. The Policy provides guidance to NOAA scientists in how to do this in an appropriate way (e.g. by providing a disclaimer that the article represents the opinion of the author(s) and not NOAA Fisheries).

The role of advocacy for government scientists

The reality is that successful conservation science, as defined by the Agency's mandates, is actually accomplished through the work of individual scientists and managers. It should go without saying that government scientists must be viewed as the vendors of unbiased, neutral science. That is the reason for many of the oversight activities that NOAA has instituted to ensure sound scientific advice. Nonetheless, there remains a role for government scientists to act as advocates for conservation. Scientists should be

committed to not only owning their science, but to getting others to also own it.

Important conservation issues demand this, because scientists are frequently in the position of changing a culture through what amounts to "disruptive science". Here are two quick examples (one small and one large) where scientists acting as advocates have provided the vision necessary to achieve major conservation successes.

The first example is conservation of the vaquita (*Phocoena sinus*). This may presently be the world's rarest marine mammal, which is on the edge of extinction. The 2016 Joint Mexico–United States survey of the population (endemic to the Gulf of California) found < 30 animals remaining, which appears to be a decrease of 50% since the 2015 survey (Morrell, 2017). This porpoise is often caught and drowned in gillnets used by illegal fishing operations in marine protected areas within the Gulf. If not for the efforts of a small group of Mexican and United States scientists who have repeatedly raised the alarm that the population is precipitously declining and that the illegal bycatch needs to be addressed, it is likely that the species would go the way of the baiji or Chinese river dolphin (*Lipotes vexillifer*), which is now considered functionally extinct (Turvey *et al.*, 2007). The same US scientists worked with Chinese scientists to raise alarm over the status of baiji, but their efforts came too late. By 2007, there was sufficient notice of the baiji's imperilled status for the conservation community to fund a new survey, but no animals were found over a 6-week survey. These same US scientists learned from the baiji work that they needed to raise the alarm with the Mexican and US governments and to also communicate this information to the public through lay literature if the declining vaquita population was to be saved. As such, they have worked cooperatively over the past decade to monitor population status and have also worked with the two governments and the conservation community to address the illegal fishery. At present, there is hope that the remaining vaquita can be taken into captivity, while their habitat issues (i.e. illegal fishing) are dealt with by the Mexican government (Goldfarb, 2017).

A second example of how a scientist advocate can move conservation forward is the adoption of a formal policy supporting ecosystem-based fishery management (EBFM) by the US government (https://www.st.nmfs.noaa.gov/ecosystems/ebfm/creating-an-ebfm-management-policy). NOAA Fisheries has worked for almost two decades to adopt an EBFM to maintain ecosystems in a healthy, productive, and resilient condition so that they can provide the services that humans want and need (EPAP, 1998; Hilborn, 2004; Pikitch *et al.*, 2004). During this time, fisheries science centres and their academic partners have made significant progress in understanding the scientific underpinnings of EBFM. With this said, NOAA has made little progress adopting a comprehensive, national programme of EBFM until it created a position of Senior Scientist for Ecosystems in 2012. Operationalizing EBFM nationally became a major responsibility of this new Senior Scientist, and having a senior leader focussed on national ecosystem issues resulted in the rapid progress made on producing an actual written policy. NOAA Fisheries has now adopted both an EBFM policy and a roadmap for implementing the policy, largely because of the herculean efforts of dedicated Agency staff (https://www.st.nmfs.noaa.gov/ecosystems/ebfm/creating-an-ebfm-management-policy). The US National Ocean Council has held up this effort as an example for other federal agencies seeking to adopt ecosystem-based management (EBM).

Similar progress has been made under the Senior Scientist for Stock Assessments in the development of the "Next Generation Stock Assessment Improvement Plan" and in the development of national policies for the prioritization of stock assessments. Tasking senior leadership with the responsibility of implementing national policies seems to be a good example of how advocacy can achieve positive results in government.

Scientists as communicators

It has taken more than a passion for conservation science to make these scientists effective advocates. To move conservation forward, they must also communicate with stakeholders and partners, especially with non-scientists. Scientists are accustomed to identifying the quality (precision) of the science they provide. But, we should pay equal attention to whether the information we are providing is what the managers, partners, and stakeholders really need (accuracy or the "right science").

Doing the latter is problematic, particularly because scientists often have a hard time engaging non-scientists in effective dialogue to identify scientific questions and needs. Although scientists may have an unclear vision of what their partners and stakeholders need in the way of scientific advice, the latter often do not know either. As such, it is important to pursue strategies for providing advice that begin by initiating this dialogue.

Engagement with stakeholders is a key element of integrated ecosystem assessments as defined both by ICES (as a specific action area) and by NOAA (https://www.integratedecosystemassessment.noaa.gov; Figure 5, see in particular Step 1: Define EBM Goals and Strategies.). Jointly defining goals and targets with a suite of interested parties and stakeholders greatly improves the likelihood that the process will provide useful advice. Similarly, NOAA Fisheries' strategy for providing scientific advice to managers dealing with climate change has been initiated through a similar joint conversation (Figure 6). There the explicit "end game" is climate informed reference points produced through

Figure 5. Conceptual model for NOAA's approach to integrated ecosystem assessments. The process begins with the definition of EBM goals and targets and continues through the evaluation of management strategies (https://www.integratedecosystemassessment.noaa.gov/).

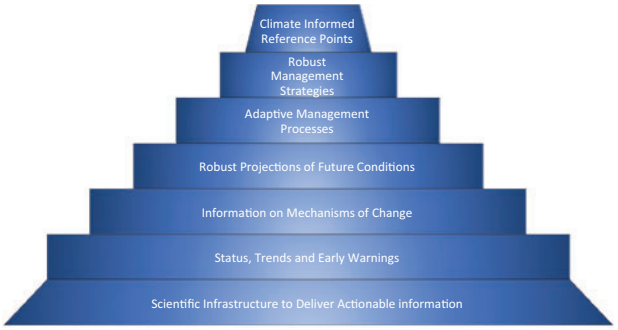

Figure 6. Hierarchy of elements comprising NOAA Fisheries Climate Science Strategy (https://www.st.nmfs.noaa.gov/ecosystems/climate/national-climate-strategy).

management strategies driven by managers, but supported by Agency scientists.

Conclusion

The successes that NOAA Fisheries has had in providing science for conservation are based on a combination of:

(i) legislative mandates and NOAA policies focussed on science,

(ii) regional implementation of the mandates and policies,

(iii) science quality assurance, and

(iv) individual scientists acting as advocates and communicators.

Using this rubric, NOAA has addressed a multitude of conservation issues over the past two decades where scientific advice has driven the process:

(i) ending overfishing for most US fish stocks;

(ii) rebuilding 41 formerly overfished fish stocks to healthy levels;

(iii) reducing the incidental mortality of marine mammal species from anthropogenic sources through application of formal and informal take reduction processes;

(iv) developing and implementing a transparent and effective process for providing the scientific advice to facilitate the listing, delisting, and downlisting of species under the ESA;

(v) making climate change impacts an explicit consideration in NOAA Fisheries decision making; and

(vi) implementing EBFM.

These have all been major conservation issues—all driven by scientific advice—all with a potential for major conflicts. Most have been successes (though some are still works in progress). Many of these have had significant economic and social impacts and several have resulted in litigation. In almost every case where science has been called into question, NOAA Fisheries and its sound science has prevailed.

Acknowledgements

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