Japan (I): On the Threshold of an Age of Big Science?

Japan is the first major nation outside the European tradition to become "industrialized" and "modernized." Rising from feudalism barely a century ago, and again from the ashes of defeat in World War II, the Japanese have rebuilt their country and have achieved a widely touted "economic miracle." The Japanese economy has been expanding by more than 10 percent a year, on the average, for the past decade, and Japan's gross national product has now become the world's third largest, behind only the United States and Russia. Two years ago *Fortune* magazine credited Japan with achieving "the highest average real growth rate ever scored over so long a period by any great nation anywhere."

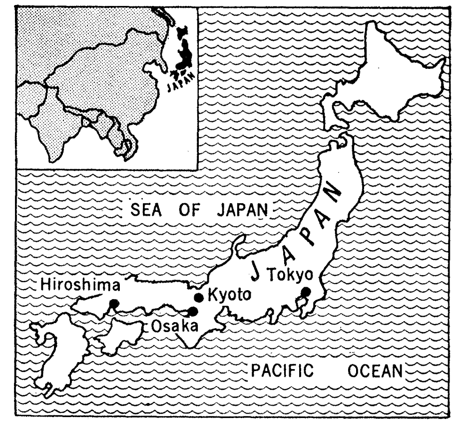
Where it will all end nobody knows, but some of the most astute American analysts are predicting that Japan could rival the superpowers. Edwin O. Reischauer, Harvard professor, former ambassador to Japan, and one of the leading American authorities on the Far East, stated in a television documentary last April: "In the history of nations, there sometimes occurs a stage which later generations look back to as a Golden Age. It's a time when a nation exerts an influence on its neighbors and on the future far out of proportion to its actual size or wealth. Japan may be entering such a Golden Age right now." Herman Kahn, head of the Hudson Institute and a leading futurologist, is even more exuberant. "It would not be surprising," Kahn says, "if the 21st century turned out to be the Japanese century."

Whether such predictions come true or not may well depend on how Japan develops its scientific and technological capabilities. Japanese science planners, at any rate, are convinced that Japan must greatly strengthen its research establishment if it is to play a world leadership role in the years ahead. One of the persistent refrains I encountered in recent interviews with Japanese government, university, and industrial scientists was concern over whether Japan, now that it has so spectacularly pulled abreast of the West in many respects, is ready to make the next great surge toward the head of the class.

In the flush of enthusiasm over Japan's tremendous progress it is easy to overlook glaring contradictions in the record of advance. Japan's economy is booming, yet per capita income is low. Industry is turning out some of the world's most sophisticated technical products, yet two-thirds of Tokyo is without sewers. Japan has the world's finest railroad system, yet its highway network is hopelessly deficient. A standing joke is that Japan has barely enough paved road to park all its cars, so it ends up parking them all, bumper to bumper on the main thoroughfares, every rush hour.

The development of science and technology shows a similar uneven quality. Japan has unquestionably made great strides since World War II. Expenditures for research and development have been increasing even more rapidly than the soaring gross national product; new laboratory facilities have been built; the technical manpower pool has been greatly enlarged (it's now probably the third largest in the world, behind only the United States and Russia); and Japan's high-technology products have swept over world markets. But further progress is being threatened by a number of formidable, fundamental problems.

Philip M. Boffey, a member of the News and Comment staff, recently spent a month in Japan. In this first article, he discusses the relative strength of the Japanese research establishment and Japan's initial ventures into the areas of "big science." Subsequent articles will discuss university and industrial research and some general problems faced by Japanese science.



These include a case of financial malnutrition (despite recent boosts in spending) that makes the present budgetary laments of American scientists sound like the cries of a spoiled brat; a siege of student unrest that is much more disruptive than our own campus disturbances; a relatively rigid organizational structure that inhibits mobility of researchers and discourages cooperative research efforts; a language barrier that deprives Japanese science of potentially fruitful contact with foreigners; and a seemingly deep feeling of distrust that alienates much of the academic science community from the national government. There are even some Japanese leaders who question whether their race has the innate ability to perform "creative" science.

At the outset, it must be acknowledged that any attempt to assess Japanese science is fraught with perils. To begin with, there is the inherent difficulty of trying to assess the scientific capability of a nation when reliable measures of such capability do not exist. Then there are the problems of operating in any unfamiliar territory—problems of knowing who is wise and who is not, who is objective and who has an axe to grind. These are compounded by the language barrier. I neither speak nor read Japanese, and while almost all Japanese study English as a second language in school, relatively few are fluent enough to express complicated ideas in English. Many an interview ended in linguistic impasse, with the interviewee grasping the question, formulating the answer, and then expressing regret that he could not put his thoughts into English.

The peculiar (to a Westerner) Japanese customs are an equally formidable barrier. The Japanese have the reputation for being excessively polite, for telling a foreigner what they think he wants to hear, and for being excessively self-critical—all of which compounds the difficulty of knowing how sound an appraisal one is receiving. Moreover, personal relationships are often crucial in Japan, and a Japanese leader is much less apt to speak frankly to a journalist he doesn't know than would a comparable official in the United States. You can seldom rush in, conduct your business quickly, and then rush out as you would with a busy American official. One day I went to see one of Japan's most eminent statesmen of science, armed with a crucial letter of introduction from one of his closest friends in America. I was received graciously, had some tea, and chatted amiably, but every time I tried to ask a substantive question, it was ignored or turned away. Two hours later I still had not a shred of substantive information, and I left feeling the interview was a complete disaster. But I was assured by an American scientist, a veteran of many years' dealings with the Japanese, that the interview had been a stunning success, for the eminent man had personally got on the phone and opened numerous doors for me, and he had agreed to see me again. Later, when I returned, this Japanese scientist gave me one of the best interviews of my visit.

6th Ranking Science Power

In comparison with other advanced nations, it must be said, the Japanese research and development effort remains relatively small. Though Japan has the world's third largest economy, it ranks no better than sixth in terms of various indices related to expenditures for research and development—well behind the United States and Russia, and also behind Britain, France, and Germany. Japan's expenditures for R&D in 1968, according to unofficial preliminary estimates, totaled roughly $2.1 billion. This represented a very sizable 27 percent increase over the previous year but was still less than one-tenth the comparable figure in the United States. However, at the present rate of expansion, some analysts predict that Japan will sweep past Britain, France, and West Germany to become indisputably the third-ranking "scientific power" in the world during the next decade.

The Japanese research system differs markedly from the American in several respects. The most notable is the relatively small role played by the national government and the correspondingly large role played by the private sector. The Japanese government has recently been financing only about 30 percent of the nation's total R&D spending, with the great bulk of the remaining 70 percent being paid for by private industry. In the United States, and in most other advanced nations, the percentages are reversed, with the national government playing the lead role.

The Japanese government's R&D funds are distributed through at least 11 ministries, with the Ministry of Education (which supports the bulk of university research), the Ministry of International Trade and Industry, the Ministry of Agriculture, Forestry, and Fisheries, and the Science and Technology Agency playing the major roles. Medical research, in sharp contrast to the situation in this country, is very heavily supported by private universities. Also in contrast to the American situation, there are few private foundations that support research in Japan.

One consequence of the relatively low level of government support in Japan is that the government has had relatively less control over the directions taken by the nation's research establishment than would otherwise have been possible. Another consequence is that the research community has been denied the governmental largesse that has primed the way for scientific advance in other nations. Yoshio Tomanaga, head of the Agency for Industrial Science and Technology, told *Science* the low level of government support is a "fundamental weakness" in Japanese science that must be—and, in fact is being—rectified.

The research facilities in Japan at their best are fully equal to those found anywhere in the world. I asked Donald S. Rodbell, General Electric's scientific representative in Japan, what he thought of three leading laboratories, one industrial, one academic, and one governmental. He gave all of them high marks. He said the Central Research Laboratory of Hitachi, Ltd., the big electrical manufacturer, has "about the same quality of equipment and same level of competence" as GE's own research and development center in Schenectady, N.Y., which is high praise indeed, since GE's labs are reputed to be as good as any in American industry. Rodbell also called the Institute for Solid State Physics, which is attached to the University of Tokyo, "comparable with the best in the world," and he said the government's Electrotechnical Laboratory is "equal to anything in the U.S."

American scientists who have visited Japanese academic laboratories during the past decade under National Science Foundation auspices have submitted mixed reports. Some have commented on "severe overcrowding" and "dreary dinginess," others have waxed ecstatic over "modern well-equipped laboratories" stuffed to overflowing with an "abundance of large expensive instruments." Japan has yet to win a Nobel Prize for experimental work, a fact which some observers attribute to the relatively impoverished condition of Japan's laboratories for many decades. But in general, according to Takashi Mukaibo, special assistant to the president at the University of Tokyo and a former Japanese science attaché to the United States, the best Japanese university labs are now equipped as well as the best in this country. Their operating budgets, however, are still considerably lower, and the second-rank laboratories are said to be poorly equipped in comparison with those in this country.

Measures of Achievement

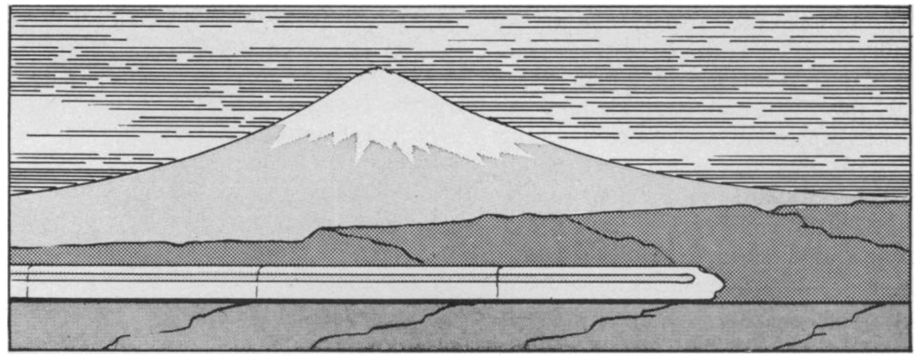
How good is Japanese science? Here the guideposts are very hard to interpret. If one considers the Nobel Prize as the supreme measure of scientific achievement, then Japan does not stack up very well. The nation has had only two Nobel laureates—Hideki Yukawa and Shinichiro Tomanaga, both theoretical physicists—compared with more than 70 for the United States, more than 40 for Britain, more than 20 for France, and more than 40 for the two Germanys combined. But Japan has unquestionably made substantial contributions in a number of disciplines. Various surveys taken over the past decade have shown that Japan ranked fourth in number of papers published in the world's physics journals, third in chemistry publications and first in papers relating to rice.

But perhaps the most reliable guide is a "self-evaluation" published in the English-language magazine *Technical Japan*. Based on answers to a questionnaire sent to various Japanese science institutes and societies, the survey concluded that Japan excels in subjects where the object of research is either peculiar to or abundant in Japan, such as volcanoes, encephalitis, rice blight, and astronomy; in subjects related to state-run enterprises, such as train operation, magnetometry, and microwave research; in subjects related to industries peculiar to Japan, such as silkworm genetics and zymogenic microorganisms; and in studies related to Japanese industries which compete in international markets, such as shipbuilding, textiles, and vitamin synthesis. On the debit side, the survey concluded that, while Japan is strong in relatively narrow spheres, it is weak in studies that are affected by the general scientific level in Japan, in studies where relations between theory and practice are important, and in research requiring large facilities and equipment.

The Japanese have particularly lagged in areas of "big science" that require substantial financing and strong leadership from the national government.

Defense Science Harassed

Defense research, according to one Western analyst, is in especially "sorry shape," partly because the Japanese for many years after the war were not permitted to engage in military research and partly because even today there is strong revulsion against military activities in many segments of the academic and scientific communities, as well as in the public at large. Defense science has been hampered by inadequate funding (the Japanese government's budget for the fiscal year ending 31 March 1970 included only $25.3 million for defense research, an increase of about 5 percent from the previous year) and by harassment from left-wing students and scientists. The influential Japan Physical Society, according to press reports, asked all its members connected with the Japan Defense Agency to refrain from participating in the society's annual meeting last October; and on at least three other occasions defense scientists have been forced to withdraw papers from professional meetings. Similarly, officers from the Japan Self-Defense Force have been denied the opportunity to study at many leading graduate schools. Some universities have publicly stated that they will not accept military officers; others have simply flunked them out. All 20 defense officers at graduate schools of national and public universities failed to pass examinations for the master of arts in 1968, while 23 of 24 self-defense officers and engineers who took graduate school entrance examinations in early 1969 failed to pass. Since these were all supposedly elite officers, defense officials publicly charged that the universities were trying to avoid campus trouble by flunking all military personnel. Japanese defense officials have also privately admitted to American colleagues that they have difficulty getting scientists to perform defense research.



The volume of defense research is apt to increase in the future, however, in line with pressures for Japan to rearm more extensively. The Japan Defense Agency has announced that its 1972–76 buildup program will include about $417 million for research and development, with major emphasis on missiles, information collection, and aircraft.

Space research has also been carried out on a relative shoestring budget. "Their whole space budget would barely pay for the paint on one of our nose cones," snorts one American aerospace representative stationed in Tokyo. "You could cram all the qualified space scientists in Japan into this room," another Western analyst told this reporter. In the past 10 years the Japanese government has spent roughly $100 million on space R & D. That's only about half the cost of a single U.S. Saturn 5 rocket and a miniscule amount when compared with the more than $35 billion spent by the National Aeronautics and Space Administration over the same period.

The Japanese space program is especially interesting because it reflects many of the themes and conflicts that run through the entire Japanese research effort. The program has thus far been heavily influenced by the antimilitarist sentiments of a small group of university professors, by the lack of a strong government role, by a nationalistic desire to "go it alone," and by a drive for international recognition as a leading technological power.

The Japanese space effort is currently conducted by two somewhat competing factions—a university group that is seeking to orbit a scientific satellite; and a government program that plans to orbit satellites for such practical applications as communications, navigation, meteorological observation, and geodetic surveys. Cooperation between the two factions is said to be minimal—they even have separate launching facilities and widely different approaches to rocket development—though the university work is financed by the government through the Ministry of Education.

The "father" of Japanese space science is generally acknowledged to be Hideo Itokawa, former key figure at the University of Tokyo's Institute for Space and Aeronautical Science, who began experimenting with pencil-sized rockets and solid fuels in 1955. The government, preoccupied with rebuilding the economy, at first showed little interest in space, so Itokawa and his colleagues were enormously influential in determining the direction of the Japanese space program. In many ways, they *were* the program. They not only dominated basic research, but they also built their own bases (with government funds) and launched their own rockets. The analogous situation in this country would be if Harvard or M.I.T. performed the functions of the National Aeronautics and Space Administration.

Space Frustrations

Itokawa and his colleagues scored notable successes in the development of sounding rockets, and within a decade, they had reached the point where a serious effort could be made to launch a scientific satellite using only Japanese technology. The Japanese press and public figures confidently predicted that Japan would become the fourth nation —after Russia, the United States, and France—to orbit a satellite on its own. But the last few years have been marred by a series of frustrations. In early 1967, Itokawa, in the wake of two launching failures and allegations of sloppy financial management, resigned to go into private business. Then, militant Japanese fishermen, protesting that rocket launchings interfered with their fishing, brought the program to a halt for a long period. Last September, after the program was resumed, the Tokyo University scientists failed for the fourth successive time to launch a satellite.

All four failures were attributed to problems with booster ignition or booster separation, and there has been vigorous argument over whether the problems primarily reflect poor design, poor systems engineering, sloppy production or inadequate testing of components. But the fundamental problem has probably been inadequate funding. "I don't think the Japanese have made any more mistakes than we did in the early stages," says one American space analyst. "They've shown boldness and initiative and gone way out on a limb. But it's a cheap jack effort." One reason Japan lags, of course, is that all rocket research was forbidden for many years after World War II.

Guidance Problems

Japan is generally behind in the development of advanced guidance systems and of liquid fueled rockets—deficiencies which seem to stem partly from inadequate funding and partly from the antimilitarist views of the Tokyo University professors. Itokawa's group reportedly feared that the more maneuverable liquid-fueled rockets and advanced guidance systems might prove useful to military circles should they wish to develop long-range missiles with warheads. But the Japanese press has lately suggested that this "phobia" against developing guided rockets may be one reason for the university's repeated failures.

Although Itokawa's group dominated the Japanese space program for roughly a decade, the Japanese government became increasingly interested in space throughout the 1960's. By 1968, for the first time, the space budget for the government's Science and Technology Agency exceeded the budget for the University of Tokyo's space group. The agency, unlike the university, has been working on liquid- and solid-fueled hybrid rockets equipped with guidance systems. Various other government ministries are also working on applications satellites relevant to their areas of responsibility. In an effort to impose some order on this chaos, the government established a Space Activities Commission in 1968 and a new Space Development Corporation last October, which may ultimately develop into a Japanese NASA.

Japan has consistently sought to conquer space on its own and has turned down American offers to launch a Japanese satellite on an American rocket. But repeated failures and a realization that major investments would be necessary to achieve success led the Japanese last year to conclude a technical agreement with the United States which allows American aerospace firms to provide Japan with unclassified technology and equipment, including guidance control technology, up to the level of the Thor-Delta rocket. Some Japanese were not too happy about relying on American technical assistance, commenting that such reliance would render Japan's space capabilities "no better than those of Italy in the eyes of the world." But Japan has made it clear it still intends to "go it alone" as much as possible and will not simply buy American rockets or pay to have the United States launch Japanese satellites. The United States apparently agreed to supply the technical information to Japan partly from a feeling that Japan was going to develop a satellite launch capability anyway, and so the United States might as well try to influence the course of development, and partly from a desire to reduce an overwhelming trade deficit with Japan by letting American firms into the Japanese space market.

The outlook in Japan is for more and more space spending. The nation's space budget has jumped rapidly in recent years—from $15.6 million in 1967 to $20.4 million in 1968 to $25.6 million in 1969—and the trend is likely to continue upward. In the United States there are increasing doubts as to whether the space program has really been worth the tremendous sums it cost. The Japanese, however, believe space development will pay handsome political and economic dividends. In a long-range plan announced last October, the Space Activities Commission said that space achievements "provide a yardstick for measuring a country's general status as a national power."

Nuclear Advances

The only "big science" program in Japan that is supported at what Western analysts regard as a high enough level to be truly productive is the atomic energy program. The government's main budget for atomic energy R & D totaled $83.1 million this year, a hefty 44 percent increase over the previous year. Government funding for research in the universities and research spending by industry totaled additional tens of millions. The chief thrust of the program is toward the development of power reactors, but the program also includes research and development on nuclear fuel fabrication, the use of radioisotopes, and nuclear ships. The hull of Japan's first nuclear-powered ship, the *Mutsu*, was launched last June, and the 8350-ton vessel is scheduled for completion in 1972.

Japan has great incentive for developing its nuclear generating capacities, for the nation is heavily dependent on imported fuels to keep its industrial wheels turning. Nearly three-fourths of the country's energy needs are met by overseas energy sources, notably petroleum from the Middle East. The precariousness of Japan's position was brought home sharply during the 1967 Arab-Israeli war, when oil shipments were curtailed and Japan was left with only a meager 45 days' supply of oil. Japan seems to be as poorly supplied with uranium as it is with oil, but at least uranium can be stockpiled more easily.

Japan currently has two commercial nuclear power plants in operation, about four more under construction, and perhaps 15 others planned for starts by 1975. Atomic power is expected to be the nation's chief source of energy by the year 2000.

Japan got a relatively late start in developing nuclear power, partly because research involving nuclear energy was forbidden for many years after World War II. Thus Japan's initial effort has been to catch up with the West, and its first generation reactors have relied largely on importing foreign technology. But the Japanese are determined to develop an independent capability. The pattern seems to be that a utility will hire an American manufacturer as prime contractor for its first reactor with a Japanese firm as a key subcontractor, but for the second reactor of that size a Japanese firm will become the prime contractor. The government encourages domestic manufacture by granting favorable loans and subsidies to electric utilities that "buy Japanese" and by granting favorable loans to Japanese manufacturers.

The Japanese government has embarked on national projects to develop a fast breeder reactor, which would produce more nuclear fuel than it consumes, and an advanced converter reactor, which would use uranium more efficiently than a conventional reactor. Other major projects include research on fusion, on plutonium production, and on two processes for enriching uranium, namely the gas diffusion and centrifuge processes. The government's

Joint Atomic Energy Research Institute announced last year that it had succeeded, for the third time, in producing plutonium. And the Institute for Physical and Chemical Research announced last year that it had succeeded in producing enriched uranium through the gas diffusion method by using two different types of barriers—one a thin film of aluminum, the other a Teflon film—to separate the uranium-235 from the unwanted uranium-238. The concentrations achieved were somewhat less than the concentration needed for practical nuclear power generation and considerably less than the concentration needed for nuclear bombs, but the announcements caused quite a stir in Japan.

The fact that Japan seems on the way toward developing an independent nuclear capability and an independent rocket launching capability has raised fears that Japan, in the future, might decide to rearm itself with nuclear-tipped missiles. The pacifism and the "nuclear allergy" which have dominated Japanese politics since World War II are still running strong. Some Western diplomats, for example, believe any Japanese government that openly advocated nuclear armament today would be thrown out of office. But some industrial circles are said to be pushing for development of nuclear arms, and Prime Minister Eisaku Sato himself gave a speech to a business group in December which some Westerners have interpreted as expressing a personal preference for a nuclear-armed Japan. The Japanese have been reluctant to sign the nuclear nonproliferation treaty, partly from a desire not to place themselves at a disadvantage in developing the peaceful uses of nuclear power. But some circles in Japan have also opposed the treaty from a desire to keep open the option of developing nuclear armaments.

Though atomic energy is probably the most advanced of the "big sciences" in Japan, further progress is threatened by a number of problems. The most serious, perhaps, is a shortage of scientists and engineers in the atomic energy field. The deficit is expected to become acute in a year or two and to reach more than 10,000 by 1975. Other problems include tight budgets at some laboratories, a shortage of plutonium, overlapping responsibilities among some government facilities, and lukewarm support from industry for some of the government projects. Western analysts state that the nuclear ship was considerably delayed while waiting for industry support, and they predict that reactor development will be similarly delayed.

Japan's increasing commitment to "big science" projects may ultimately have profound effects on the nation's entire research establishment. Japanese commentators have suggested that one or more national projects would help alleviate the chronic shortage of research funds, would elevate the general standard of science and technology, and would enhance Japan's prestige as a technical power, thus increasing its political influence and aiding its foreign trade efforts. As one exuberant editorial writer expressed it, "Entry into the field of 'Big Science' will lay the foundations for the lucrative business of the future—the mammoth computers, electronics, the supersonic jets, and other technological marvels." For the past decade, while the United States and other advanced nations have invested in science primarily to enhance national defense or secure international prestige, the Japanese have performed the bulk of their R & D to spur economic growth. Japan has come on fast on this basis alone, but now the Japanese are seeking a broader rationale, something that possesses the "magical charm" needed to win government approval of massive research funding. If they find such a rationale, the impetus might well be enough to launch Japan on the way toward a "scientific miracle" as impressive as the "economic miracle" of the past decade.—PHILIP M. BOFFEY

Environmental Policy Act: Congress Passes a Landmark Measure—Maybe

Congress completed action just before Christmas on the National Environmental Policy Act of 1969, described by Senator Henry M. Jackson, chairman of the Senate Interior Committee, as "the most important and far-reaching conservation measure ever enacted." In part, the act amounts to no more than a statement of good intentions and whether it actually lives up to Senator Jackson's words will depend on how seriously it is taken by the Administration and the Congress itself. Its usefulness will depend also on the efforts of conservationists and others to make the issue of environmental quality weigh heavily enough politically to influence the day-to-day decisions of government administrators and practical politicians.

The act, which had strong backing in both the House and Senate and no significant opposition (final passage in each body was by voice vote), has two major features. The first consists of a declaration of policy that is made more meaningful by an "action-forcing" provision prescribing specific procedures to be followed by federal agencies as they develop policies and plans which would affect the environment. The second requires the President to submit to Congress an annual environmental quality report and to establish, as part of the Executive Office of the President, a high-level Council on Environmental Quality. Congress would hold hearings on the President's report, which the new council would have the task of preparing.

The Environmental Policy Act is loosely analogous to the Employment Act of 1946. That act prescribed full employment as a national goal and established the three-member Council of Economic Advisers, which, although virtually ignored during some periods, has been highly influential in the shaping of government economic policy during the 1960's.

The Environmental Policy Act calls on the government to seek environmental enhancement by "all practicable means, consistent with other essential considerations of national policy. The policy goals include having an environment supporting diversity and individual choice; attaining, to the maximum extent possible, the recycling of depletable resources; and—achieving a "balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities."

According to the act, each person "should enjoy a healthful environment" and has a "responsibility to contribute to the preservation and enhancement of the environment." As the Environmental Policy Act was first passed by the Senate, this provision had the ring of an environmental bill of rights—saying