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Between the Devil and the Deep Sea

C. K. Tseng, Mariculture, and the Politics of Science in Modern China

By Peter Neushul and Zuoyue Wang***

ABSTRACT

C. K. Tseng was a Chinese marine botanist trained in the United States before World War II who pioneered ocean farming and launched China as the world's largest producer of marine algae. After succeeding in supplying China with a new source of food and chemicals, Tseng survived inhuman treatment during the turbulent decade of the Cultural Revolution (1966–1976) and resumed his work in the late 1970s to help China's drive toward modernization. Tseng's experience exemplifies that of a generation of Chinese scientists who persisted in the effort of "Saving China via Science" despite hardships under the Nationalist rule and Maoist purges. It also reveals tensions between science and state and between nationalism and internationalism. Tseng's story explores two largely uncharted territories in the history of science: the history of marine botany and of modern science in China.

WHEN SYLVIA EARLE, THE FAMOUS AMERICAN deep-sea diver and marine biologist, visited China in June 1973, she looked forward not only to seeing a mysterious land still in the midst of great upheaval but also to the possibility of meeting a hero of hers. Earle specialized in phycology, the study of marine algae, and was familiar

* Department of History, University of California, Santa Barbara, California 93106.

** Department of History, California State Polytechnic University, Pomona, California 91768.

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With the exception of Tseng's, Chinese names in this essay are spelled according to the *pinyin* system and appear with family name first and given name last; sometimes the Wade-Giles spellings are given in parentheses. We have used "Tseng" rather than "Zeng Chengkui," as the name is rendered in *pinyin*, because Tseng, who is still alive, continues to use the traditional spelling in his English publications. None of the Chinese in this essay with the same last names are related to each other. Translations from Chinese to English are our own unless otherwise noted.

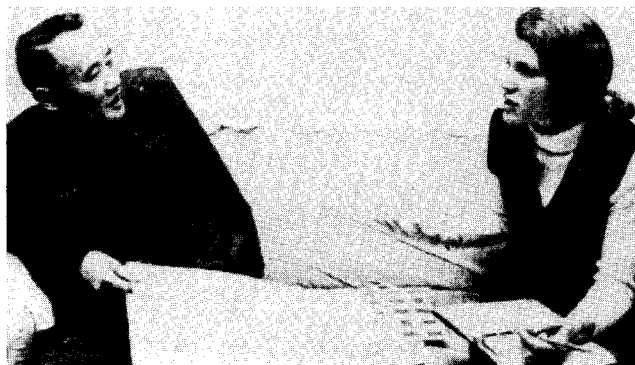


Figure 1. Sylvia Earle meets with C. K. Tseng at Jinan in June 1973. The meeting helped improve Tseng's political fortunes during the Cultural Revolution. (Courtesy Sylvia Earle.)

with the pioneering work of Cheng Kui Tseng of the Institute of Oceanology in Qingdao.¹ Tseng—"C. K." to his American friends—studied at the University of Michigan during the 1940s and returned to China after World War II; there he used a unique combination of basic and applied research to bring about a maricultural revolution. By the 1970s, China's mariculture industry employed thousands of marine farmers whose crops were an important source of food and raw materials for the chemical industry. Tseng distinguished himself during the 1950s as a world authority on marine algae but then "disappeared" during the Cultural Revolution. The Devil was loose in China during these turbulent years when Red Guards laid waste to the academic community, subjecting scholars to imprisonment and strenuous "re-education." Chinese scientists completely lost touch with their Western colleagues, many of whom looked on the unfolding events with great concern.²

Uncertain about Tseng's fate, Earle was thrilled to learn, upon her arrival, that he was still alive and that she could meet him in the city of Jinan. She was the first American scientist to speak with Tseng in more than a quarter century. The sixty-four-year-old marine biologist was surprisingly youthful looking and greeted her warmly. Tseng's English was excellent, and the two talked enthusiastically about their research and mutual friends in marine botany. (See Figure 1.) He questioned Earle closely about scientific advances and was surprised to hear that marine farming, or "mariculture," had made no major advances in the West. Tseng gave Earle a letter to friends in the United States, reassuring them that he was in good health and eager to receive copies of their scientific publications.³

Unbeknownst to Earle, her meeting with Tseng and the accompanying publicity helped

¹ Phycologists, or marine botanists, consider themselves "marine biologists" rather than "oceanographers." Marine biology traces its roots to the Phoenicians, Greeks, and Vikings but was firmly established during the sixteenth century when European countries started exploring the oceans and the nature of their biology. During the nineteenth century the field split into biological oceanographers, who studied life in the open ocean, and marine biologists, who studied life on the seashore. The two fields merged during the twentieth century and are now synonymous. See Herbert T. Webber and Harold V. Thurman, *Marine Biology*, 3rd ed. (New York: Harper Collins, 1991), pp. 4–6.

² During the Cultural Revolution radical Maoist students called themselves "Red Guards," while their counterparts among young workers took the name "rebels." In this essay we have used the terms interchangeably.

³ Telephone interview with Sylvia A. Earle by Peter Neushul and Zuoyue Wang, 3 Jan. 1995 (hereafter cited as **Earle interview**). See also Sylvia A. Earle, "A Western Botanist in Eastern China," *Plant Science Bulletin*, Mar. 1974, pp. 2–4; Earle, "A Report on Phycology in China—1973," *Phycologia*, 1973, 12:248; and Earle, "A Report on the State of Oceanography in China," *Oceans*, 1978, 11:28–31.

relieve political pressure on the scientist and marked the beginning of his resurrection as China's leading marine biologist. Branded a U.S. agent and spy, Tseng suffered a great deal at the height of the Cultural Revolution. For five months, as Zhu Kezhen (Ko-chen Chu), vice-president of the Chinese Academy of Sciences, recorded in his diary, "Tseng was put in solitary confinement in a small room, [often] forced to kneel on the floor all day long, and punished whenever he fell to the side." He was beaten by Mao Zedong's Red Guards, many of whom came from the ranks of laboratory workers and some of whom were graduate students at the Institute of Oceanology.⁴ Tseng's experience was not uncommon among Chinese scientists, who were frequently ill treated despite their scientific and technological contributions.

In recent years the causes of the Cultural Revolution and its impact on Chinese society have attracted the attention of many scholars, both in China and abroad. Yet we know little about the experience of Chinese scientists during that violent period or, for that matter, during the twentieth century more generally. Most literature on science in the People's Republic focuses on nuclear weapons makers and dissidents, overlooking the stories of the vast majority who labored to achieve concrete scientific and technological goals in an often-hostile political environment. Tseng's experience, both before and after the Communist revolution in 1949, offers a rare avenue whereby we can explore both the history of ocean farming and the politics of science in modern China. We will examine the social and political contexts of science within a succession of Chinese governments, from the Nationalists to the Communists. A particular focus is the social construction of science within the Maoist totalitarian regime, about which little is known, especially compared to the growing body of literature on science in the former Soviet Union and Nazi Germany.⁵

⁴ Zhu Kezhen, *Zhu Kezhen riji* [Zhu Kezhen's diaries], 5 vols., Vol. 5 (covering 1966–1974) (Beijing: Science Press, 1990) (hereafter cited as *Zhu, Zhu Kezhen riji*), entry for 6 June 1970, p. 457 (quotation); Earle interview; interviews with C. K. Tseng by Peter Neushul, Zuoyue Wang, and Lawrence Badash, Sept. 1994, Qingdao, China (hereafter cited as **Tseng interview, 1994, Qingdao**); and interview with Fei Xiugeng by P. Neushul, Wang, and Badash, Sept. 1994, Qingdao (hereafter cited as **Fei interview**). Little contemporary documentation about Chinese scientists survived the Cultural Revolution. Although we found a surprisingly large body of archival material on Tseng's career in China and the United States, our study of Chinese science during the Cultural Revolution is based largely on a series of interviews, with Tseng and others, and on a number of Chinese sources, including the diary of Zhu Kezhen, vice-president of the Chinese Academy of Sciences. The archival materials are in the C. K. Tseng Papers, Institute of Oceanology, Qingdao (hereafter cited as **Tseng Papers**). We draw on an interview with C. K. Tseng by Peter Neushul and Michael Neushul, Aug. 1986, Goleta, California (hereafter cited as **Tseng interview, 1986**); Tseng interview, 1994, Qingdao; interviews with Fei Xiugeng (**Fei interview**), Sun Guoyu (**Sun interview**), Zheng Bolin (**Zheng interview**), and Zhou Xiantong (**Zhou interview**) by P. Neushul, Wang, and Badash, Sept. 1994, Qingdao; and interview with Tseng by P. Neushul and Wang, Dec. 1994, Los Angeles (hereafter cited as **Tseng interview, 1994, Los Angeles**).

⁵ For a review of the literature on the Cultural Revolution see Xiuyuan Liu, "A Step toward Understanding Popular Violence in China's Cultural Revolution," *Pacific Affairs*, 1994, 67:533–563. Literature on nuclear weapons makers and dissidents includes H. Lyman Miller, *Science and Dissent in Post-Mao China: The Politics of Knowledge* (Seattle: Univ. Washington Press, 1996); Iris Chang, *Thread of the Silkworm* (New York: Basic, 1995) (the story of Qian Xuesen [H. S. Tsien], architect of the Chinese rocket program); and John Wilson Lewis and Xue Litai, *China Builds the Bomb* (Stanford: Stanford Univ. Press, 1988). On science in modern China more generally see James Reardon-Anderson, *The Study of Change: Chemistry in China, 1840–1949* (New York: Cambridge Univ. Press, 1991); Li Peishan, "Genetics in China: The Qingdao Symposium of 1956," *Isis*, 1988, 79:227–237; Richard P. Suttmeier, *Research and Revolution: Science Policy and Societal Change in China* (Lexington, Mass.: Lexington Books, 1974); and Stephen Salaff, "A Biography of Hua Lo-keng," *Isis*, 1972, 63:143–183. See also Sidney A. Gould, ed., *Sciences in Communist China* (Washington, D.C.: American Association for the Advancement of Science, 1961); and Leo A. Orleans, ed., *Science in Contemporary China* (Stanford, Calif.: Stanford Univ. Press, 1980), for American scientists' assessment of Chinese science in various fields. Recent works on science in the Soviet Union and Nazi Germany include Loren Graham, *The Ghost of the Executed Engineer: Technology and the Fall of the Soviet Union* (Cambridge, Mass.: Harvard Univ. Press, 1992); Graham, *What Have We Learned about Science and Technology from the Russian Experience?* (Stanford,

C. K. Tseng's story is one of intricate compromise. A patriot at heart, Tseng sought to strengthen China through science and technology despite the trials of war and political persecution. His vision of the role of science and technology in nation building led him to adopt a distinctive scientific style that emphasized the integration of basic and applied research. Recent scholarship has questioned whether there is any basis for maintaining this divide, with some even suggesting that "basic research" perhaps exists only as a rhetorical device used by scientists to win funding and prestige. For Tseng, however, "basic" and "applied" were distinct but connected approaches to scientific work that he used to plan his career and organize his research program. Tseng modified the traditional "assembly-line model" that depicts science flowing into technology, advocating developmental research as a means for furthering basic psychological science. Indeed, working the boundaries between science and technology was a strategy that served him well both in engineering a maricultural revolution and in adapting to the Communist Party's ideology of science—what Mao called "revolutionary utilitarianism." Tseng's research conformed to a Chinese science policy that overwhelmingly emphasized the need for science and technology to serve national defense and economic development, leaving little room for "pure science."⁶ His tactic of integration and adaptation did not, however, protect his research program during the Cultural Revolution, when a new radical Maoist ideology of "mass science" replaced the earlier instrumentalist view. In many ways, Tseng's colorful career, spanning much of the twentieth century, shows that the goal of strengthening the nation through science and technology has deep roots in modern Chinese history and is enjoying a comeback in the post-Cultural Revolution era.

SCIENCE AND NATIONALISM IN CHINA

Cheng Kui Tseng's early education typified that of many in China's first generation of scientists in modern times. He grew up around the turn of the century, during a period of great social and political upheaval. Two years after Tseng's birth in 1909, Sun Yat-sen led the revolution that overthrew the Qing dynasty and established the fragile nationalist Republic of China. In the following years fighting among rival warlords, economic crises, and foreign threats, especially from Japan, took their toll on the new government. Despite the security provided by a successful family shipping business and a sheltered upbringing, Tseng felt the impact of China's changing fortunes and, especially, the perpetual shadow of foreign domination. At an early age he witnessed the abject poverty of peasants in

Calif.: Stanford Univ. Press, 1998); Paul Josephson, *Totalitarian Science and Technology* (Atlantic Highlands, N.J.: Humanities Press, 1996); and Monika Renneberg and Mark Walker, eds., *Science, Technology, and National Socialism* (New York: Cambridge Univ. Press, 1994).

⁶ Mao Zedong, "Zai yan'an wenyi zuotanhui shang de jianghua" [A speech at the conference on literature in Yan'an], May 1942, in *Mao Zedong xuanji* [Selected works of Mao Zedong], 4 vols. (Beijing: People's Press, 1963), Vol. 3, pp. 849–880, on p. 866. See also Dong Guangbi, *Zhongguo jinxiandai kexuejishushi lungang* [Outline for a history of science and technology in modern and contemporary China] (Changsha: Hunan Educational Press, 1992). On the focus of science policy see Yao Shuping *et al.*, *Zhongguo kexueyuan* [Chinese Academy of Sciences], 3 vols., Vol. 1 (Beijing: Contemporary China Press, 1994) (hereafter cited as **Yao et al.**, *Zhongguo kexueyuan*); Suttmeier, *Research and Revolution*; and Zuoyue Wang, "Revolutionary Utilitarianism: Science and Political Ideology in China, 1949–1976," paper presented at a workshop on Science and Political Ideology, Union College, Schenectady, New York, Aug. 1997. On basic and applied science see, e.g., Chandra Mukerji, *A Fragile Power: Scientists and the State* (Princeton, N.J.: Princeton Univ. Press, 1989); Ronald Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880–1945," *Isis*, 1995, 86:194–221; and Daniel Sarewitz, *Frontiers of Illusion: Science, Technology, and the Politics of Progress* (Philadelphia: Temple Univ. Press, 1996).

Xiamen (Amoy), an island city on the East China coast. He took his countrymen's plight to heart, changing his name to "Ze-Nong"—which means "to benefit the peasants"—when he was in high school. Tseng was not alone in thinking this way. Many Chinese students chose to study agriculture, at home and abroad, to seek a means for solving China's recurring food crises. Tseng's parents, however, opposed his choice of the well-known agricultural school at Nanjing University because it was three hundred miles from home. As a compromise he attended Fujian (Fukien) Christian University, in Fuzhou (Foochow), fifty miles from Xiamen.⁷

The Chinese Nationalist movement of the 1920s led Tseng to take his first political stand: he participated in a student strike against Fujian Christian University after the administration refused to register with the new government. The strike failed, and Tseng was expelled at the end of the year. Undaunted, he went to Guangzhou, site of Sun Yat-sen's Nationalist Party headquarters, in hope of attending the new Sun Yat-sen University. He arrived too late to take the entrance examination and returned home to enroll at Xiamen University in 1927. There he studied botany with Zhong Xinxuan (Hsin-hsuan Chung) and Qian Chongshu (Chung-shu Chien), both of whom were educated in the United States. Zhong was particularly influential, as he was interested in marine algae and even started a collection of local species.⁸

It was Zhong's course on general phycology that inspired Tseng's interest in "agriculture in the sea," an idea that both aroused his intellectual curiosity and spoke to his desire to serve China's peasants. Tseng was employed as an assistant in the Department of Biological Sciences and began collecting marine algae for classes at the university, thus becoming China's first practicing marine phycologist. To his surprise, Tseng found that coastal residents not only harvested algae as food, animal feed, and fertilizer but also cultivated a species of the genus *Gloiopeltis* called "*chicai*" on littoral rocks divided up and owned by families in the community. The discovery led Tseng to expand his research project beyond a survey of Xiamen's economically important algae to include investigation of the cultivation, uses, and trading of *chicai*. He learned that the "marine farmers" were following an ancient tradition dating back to the Song dynasty at the turn of the last millennium. By scraping the rocks with knives and other tools several times a year they eliminated algal competitors and thereby encouraged the natural growth of *chicai*.⁹

⁷ C. K. Tseng, "My Research Life for the Past Sixty Three Years" (hereafter cited as Tseng, "My Research Life"), in *Selected Works of C. K. Tseng*, ed. Qin Wenshan, 2 vols. (Beijing: Ocean, 1994), Vol. 1, p. 1; and Fei Xiugeng and Zhou Baicheng, "Zeng Chengkui" [C. K. Tseng], in *Zhongguo xiandai kexuejia zhuanji* [Biographies of modern Chinese scientists], 6 vols. (Beijing: Science Press, 1994), Vol. 5, pp. 572–579.

⁸ On the student strike see Tseng interview, 1994, Qingdao; and William P. Fenn, *Christian Higher Education in Changing China, 1880–1950* (Grand Rapids, Mich.: Eerdmans, 1976). According to Fenn, the Fujian strike collapsed after the government indicated that it did not want to assume control of the university. The strike did, however, lead to Chinese leadership at Fujian. Zhong went to Harvard and Qian studied at the University of Illinois, the University of Chicago, and Harvard. See Chu-yuan Cheng, *Scientific and Engineering Manpower in Communist China, 1949–1963* (Washington, D.C.: National Science Foundation, 1965), pp. 406, 424; and "Qian Chongshu," in *Zhongguo kexuejia cidian* [Dictionary of Chinese scientists] (Jinan: Shandong Science and Technology Press, 1984), Vol. 3 (the modern period), pp. 354–356. Zhong's collection of marine algae is discussed in C. K. Tseng to N. L. Gardner, 18 Apr. 1932, N. L. Gardner Papers, C. K. Tseng Folder, Berkeley Herbarium, University of California, Berkeley (hereafter cited as **Gardner Papers**). His samples are still a part of the Berkeley herbarium collection.

⁹ Fei and Zhou, "Zeng Chengkui" (cit. n. 7), p. 572. For an introduction to phycology see Harold C. Bold and Michael J. Wynne, *Introduction to the Algae: Structure and Reproduction*, 2nd ed. (Englewood Cliffs, N.J.: Prentice-Hall, 1985). The use of marine algae was also common along the Pacific coast of North America, where Native Americans collected *Porphyra* and giant kelp as sources of food, medicine, fishing line, bottles, and for numerous other purposes. See Peter Neushul, "The History of California's Kelp Industry" (M.A. thesis, Univ. California, Santa Barbara, 1986).

In 1932, aided by a junior fellowship from the Rockefeller Foundation, Tseng went to graduate school at Lingnan University, another Christian school, in Guangzhou, where he worked with two American teachers, Floyd A. McClure and Franklin Metcalf. There he published his first scientific paper, on *chicai* and other economically important algae of Xiamen. Together with the eminent Chinese plant physiologist Tang Peisong, Tseng also studied the iodine content of laminariaceous algae on the China coast.¹⁰ These projects marked the beginning of his scientific career and his drive to develop more efficient methods of cultivating marine algae. Tseng would pursue these goals in the laboratory and in the ocean for the next half century.

A combination of intellectual interest and social concern shaped Tseng's approach to marine biology. He never viewed his scientific research as an ivory tower exercise, nor did he allow his maricultural agenda to supersede his interest in the disciplinary development of Chinese phycology. On the contrary, he recognized from the beginning that good science was the key to successful ocean farming. To this end he immersed himself in pure phycology, devoting the first years of his career to studying the taxonomy of marine algae. He explored the coast of China on numerous lengthy field trips, often traveling alone under difficult conditions. Unlike scientists interested in terrestrial agriculture, Tseng had no body of published information to work from. He did not even know the names of many of the marine algae, let alone anything about their reproductive cycles or growth rates. Reflecting on his taxonomic campaign, Tseng recalled realizing that "before I could do anything in my choice of seaweed cultivation, I should be familiar with their names."¹¹

Early in his career Tseng also exhibited a great ability to attract patronage for his work and a natural talent for tapping into the international scientific community. His research was supported by the China Foundation for the Promotion of Education and Culture, which administered funds returned by the United States from the Boxer Rebellion indemnity, and the Rockefeller Foundation.¹² To help identify the specimens he collected, Tseng corresponded with foreign scientists, including Kintaro Okamura of the Tokyo Imperial Fisheries Institute and William A. Setchell and Nathaniel L. Gardner of the University of California at Berkeley. Even these experts could not agree on the names of some Pacific algae. Tseng once sent specimens of *Gloiopeltis* both to Japan and to the United States for identification. Okamura identified the alga as *Gloiopeltis furcata*, whereas Gardner thought it was a new species. Although he eventually opted for Okamura's classification,

¹⁰ C. K. Tseng, "Gloiopeltis and Other Economic Seaweeds of Amoy, China," *Lingnan Science Journal*, 1993, 12:43–63; and Tseng and P. S. Tang, "On the Occurrence of Two Laminariaceous Plants on China Coast with a Note on Their Iodine Content," *ibid.*, 1936, 15:219–224. See also Tang, "Aspirations, Reality, and Circumstances: The Devious Trail of a Roaming Plant Physiologist," *Annual Review of Plant Physiology*, 1983, 34:1–19. The careers of McClure and Metcalf are described in William J. Haas, "Botany in Republican China: The Leading Role of Taxonomy," in *Science and Medicine in Twentieth-Century China: Research and Education*, ed. John Z. Bowers, J. William Hess, and Nathan Sivin (Ann Arbor: Center for Chinese Studies, Univ. Michigan, 1988), pp. 31–65.

¹¹ Tseng, "My Research Life," p. 2. See also Bo Ying, "Zeng Chengkui" [C. K. Tseng], in *Zhongguo xiandai shengwuxuejia zhuan* [Biographies of modern Chinese biologists], Vol. 1, ed. Tan Jiazhen (Changsha: Hunan Science and Technology Press, 1986), pp. 419–438.

¹² On research support for Tseng see *A Summary Report of the Activities of the China Foundation for the Promotion of Education and Culture from 1925 to 1945* (China Foundation, 1946). The Boxer uprising of 1900 was a Chinese nationalist revolt against foreign imperialism and Christian missionaries. An international force of British, French, Japanese, Russian, German, and American troops crushed the rebellion and took possession of Beijing. As part of the humiliating peace settlement, China was forced to pay a fine of 450 million taels (\$330 million), with interest accruing over thirty-nine years at 4 percent annually. The final total was 982,238,150 taels, over double the original amount. The U.S. and British governments mitigated the payments by using a portion of the money to finance scholarships for Chinese students. See Immanuel C. Y. Hsu, *The Rise of Modern China* (London: Oxford Univ. Press, 1975), pp. 470–498.

Tseng became increasingly appreciative of the intricacies of algal taxonomy and began to exchange specimens with Setchell and Gardner.¹³

In 1934 Tseng completed a thesis on the taxonomy of Xiamen's marine algae and earned a Master of Science degree at Lingnan. A year later he was employed as a lecturer in the Department of Biology at Shandong University in Qingdao. Tseng returned to Lingnan in 1938 as an associate professor in charge of the school's plant specimen collections. By 1940 the Lingnan herbarium had a representative collection of Chinese marine algae. At this juncture, with no further opportunities for studying phycology in China, Tseng decided to continue his taxonomic research in the United States.¹⁴

A CHINESE SCIENTIST IN AMERICA

Tseng's choice of the United States was not accidental. It reflected the extraordinary influence of American institutions in Chinese society in general and Chinese science in particular in the first half of the twentieth century. American missionaries reinforced this relationship by establishing a variety of educational institutions ranging from elementary schools to universities. Graduates of the missionary colleges naturally looked to the United States for advanced degrees, as many of their instructors were American scientists. American philanthropic enterprises also played a key role in the development of Chinese science. In the 1920s and 1930s the Rockefeller Foundation founded the Peking Union Medical College at a cost of \$33 million. Peking Union and other American-funded medical colleges trained generations of Chinese doctors and biomedical researchers. Although less well endowed, the China Foundation for the Promotion of Education and Culture was perhaps more influential because it funded scientific research on a broad basis and utilized an effective system for evaluating research proposals.¹⁵ Although Tseng's protest against Fujian Christian University in the 1920s reflected a nationalistic sensitivity toward missionary activities in China, he nonetheless believed strongly in the international scientific community and indeed relied on U.S. funds and communication with U.S. phycologists for much of his taxonomic research in China.

Geography also played a role, as Tseng wanted to work with phycologists who knew

¹³ For a request for specimen identification see Tseng to Gardner, 18 Apr. 1932, Gardner Papers. Sadly, the literature and samples sent by the Berkeley scientists did not always reach China, causing Gardner to remark, "It is unfortunate that these trying times in the world make it so difficult to carry on legitimate work between countries": Gardner to Tseng, 21 Feb. 1934, Gardner Papers. For brief biographies of leading phycologists of this century see David J. Garbary and Michael J. Wynne, eds., *Prominent Phycologists of the Twentieth Century* (Hantsport, Nova Scotia: Lancelot, 1996). There are no general histories of phycology. For a partial history of algal taxonomy see George F. Papenfuss, "Classification of the Algae," in *A Century of Progress in the Natural Sciences*, ed. Edward L. Kessel (San Francisco: California Academy of Sciences, 1955), pp. 115–225.

¹⁴ See Fei and Zhou, "Zeng Chengkui" (cit. n. 7); and Tseng, "My Research Life," pp. 2–3.

¹⁵ On the influence of American institutions on Chinese science see, e.g., Li Peishan, "The Introduction of American Science and Technology to China before 1949 and Its Impact," in *United States and the Asia-Pacific Region in the Twentieth Century*, ed. Shi Xian-rong and Mei Ren-yi, (Beijing: Modern Press, 1993), pp. 603–618. Advocates of the U.S. model did not always succeed in China, however. See Peter Buck, *American Science and Modern China, 1876–1936* (Cambridge: Cambridge Univ. Press, 1980); and Randall E. Stross, *Stubborn Earth: American Agriculturalists on Chinese Soil, 1898–1937* (Berkeley: Univ. California Press, 1986). On missionary educational institutions see Fenn, *Christian Higher Education in Changing China* (cit. n. 8); and China Educational Commission, *Christian Education in China: A Study Made by an Educational Commission Representing the Mission Boards and Societies Conducting Work in China* (New York: Committee of Reference and Counsel of the Foreign Missions Conference of North America, 1922). On the training of Chinese doctors and researchers see Bowers et al., eds., *Science and Medicine in Twentieth-Century China* (cit. n. 10); and Dong, *Zhongguo jinxindai kexuejishushi lungang* (cit. n. 6), p. 89. For a description of the foundation's activities see *Summary Report of the Activities of the China Foundation* (cit. n. 12).

the marine algae of the Pacific. His first choice was Gardner, who, together with Setchell, had built the Berkeley herbarium into the premier center for the identification of Pacific marine algae, cataloguing more than 670 species and infraspecific taxa in at least 110 genera, forty of which they defined as new. "I hope you may be interested in an unknown student of yours in the Far East," Tseng wrote Gardner in 1932, "who is eager to study, especially under you, and who hopes to carry on his phycological studies with your help." Tseng also described his work on *Gloiopeltis furcata*, a marine alga of "great commercial value" in China with production amounting to "millions of dollars annually."¹⁶

Unfortunately, Tseng's overture came just before both Setchell and Gardner retired in 1934. Shortly thereafter Gardner suffered a series of strokes that left him partially blind and unable to accept graduate students. Despite their advanced age, the Berkeley scientists worked hard to identify the samples Tseng sent them, providing him with reprints and herbarium samples and encouraging his pursuit of a career in phycology. Tseng was disappointed that the "two most outstanding phycologists of the Pacific region" were retiring but did not sway from his objective of seeking further education in the United States. Six years later, in 1940, he received a fellowship from the University of Michigan, where he continued to study his collection of Chinese marine algae with William R. Taylor, a leading expert on tropical marine flora.¹⁷

Tseng drove himself hard at Ann Arbor, working exclusively on taxonomy and at a fantastic pace, often spending nineteen-hour days in the laboratory. In 1941 two Chinese marine biological stations, eager for Tseng to return home, offered him directorships. Tseng declined because he recognized that in order to develop Chinese marine biology as a whole he would need to understand basic oceanographic methods. Running a marine station without these fundamental tools would be "ridiculous."¹⁸ In May 1942 he defended his dissertation, on red algae in Hong Kong, and completed his doctorate. Meanwhile, the Japanese attack on Pearl Harbor delayed his return to China; he would remain in the United States for the duration of the war. This decision was not easy, as he was concerned about the welfare of his family still in China. Communication was nearly impossible, although Tseng did manage to ask friends to smuggle them to a safer part of the country. With Taylor's help, Tseng won a Rackham Postdoctoral Fellowship from the University of Michigan that allowed him to visit marine stations and institutions on the West Coast and later to settle at the Scripps Institution of Oceanography in San Diego.¹⁹

¹⁶ Tseng to Gardner, 18 Apr. 1932, Gardner Papers. See also Richard L. Moe and Donald Browne, "W. A. Setchell (1864–1943) and N. L. Gardner (1864–1937)," in *Prominent Phycologists of the Twentieth Century*, ed. Garbary and Wynne (cit. n. 13), pp. 102–114.

¹⁷ Gardner to Tseng, 30 June 1933, Tseng to Gardner, 18 Apr. 1932, Gardner Papers; and Tseng, "My Research Life," p. 3. For biographical information on Taylor see Michael J. Wynne, "William Randolph Taylor (1895–1990)," in *Prominent Phycologists of the Twentieth Century*, ed. Garbary and Wynne, pp. 175–183. Taylor also trained a number of other Chinese botanists and phycologists.

¹⁸ Tseng to William R. Taylor, 20 Oct. 1942, 15 Sept. 1942, Taylor Papers, Bentley Historical Library, University of Michigan, Ann Arbor (hereafter cited as **Taylor Papers**). Tseng encouraged young Chinese scientists to take up oceanography. While in the United States, he persuaded He Chongben, later one of China's most prominent physical oceanographers, to switch from metal physics to oceanography: Tseng interview, 1994, Qingdao; and Xu Hongru, "Zeng Chengkui zhuanlue" [A brief biography of C. K. Tseng], in *Zeng Chengkui yu zhongguo haiyang kexue* [C. K. Tseng and Chinese ocean science], ed. Xu (Jinan: Shandongsheng Map Press, 1991), pp. 18–19.

¹⁹ Tseng to Taylor, 3 Feb. 1943, Taylor Papers; and Tseng, "My Research Life," p. 3. For a general history of Scripps see Elizabeth Noble Shor, *Eighty Years: Scripps Institution of Oceanography: A Historical Overview, 1903–1983* (La Jolla, Calif.: Scripps Institution of Oceanography, 1983). Although not a definitive history, Shor's book provides valuable insight into the research program at what would become the premier center for oceanography in the western United States.

At Scripps, Tseng turned once again to his goal of applying science to the field of mariculture. His first step was to learn more about the general ocean environment, for he knew that oceanography would form the foundation on which he could build a new field of maricultural science. Tseng enrolled in a physical oceanography course with Scripps director Harald U. Sverdrup, a well-known Norwegian oceanographer, and in Erik G. Moberg's course on oceanographic chemistry. Tseng's interest in general oceanography also reflected his attention to the wider needs of Chinese ocean science. At the time of his departure from China, the scientific fields that received national attention and attracted top talent were either closely connected to national economic life, such as geology, geography, meteorology, botany, chemistry, electrical engineering, and aviation, or of fundamental importance, such as mathematics and physics. There were no active Chinese oceanographers, and Tseng was the only student training in the West. This was hardly surprising, as oceanography was still a young field even in America.²⁰

World War II provided a valuable opportunity for Tseng to apply his scientific knowledge toward the cultivation of marine algae. In early 1942, after his arrival at Scripps, he was approached by scientists from the United States Fish and Wildlife Service, then part of the Department of Agriculture, who were concerned about the loss of agar imports from Japan and wanted to find a domestic source. Agar is an important product, derived from red algae, with numerous applications in the food and biomedical industries. Tseng learned that the Fish and Wildlife Service had "a fat file of letters and information about myself and is very much interested to enlist my help" in the government's agar project at Scripps Institution.²¹

Tseng jumped at the chance to expand his studies of plant physiology and to enhance his oceanographic expertise, but the move also touched off a remarkable debate with his advisor about the direction of phycology. The shift to agar research meant that he would have to change his postdoctoral subject from a basic research topic, "Monographic Studies of the Rhodophyceae of the South China Sea," to an applied, interdisciplinary project on agar. Throughout his career, Tseng believed that the best way to promote a basic science field such as phycology was by developing its applications, thus making it useful and interesting to society and attracting attention, support, and students. Taylor, however, did not share his former pupil's enthusiasm for applied research, commenting that "I doubt if the scientific results from the ecological study of agar plants *in one year* will justify such an important fellowship."²²

In a polite but firm response to his mentor, Tseng expressed a philosophy that emphasized the integration of basic and applied research for the purpose of nation building. Commenting on the interdisciplinary nature of the agar project, he explained:

It is a chance for me to "revive" and use some of my knowledge of the physical sciences I learned years ago [in China]. It is also a good opportunity for me to learn various techniques and methods in current oceanographic practices, as well as plant physiological studies. These

²⁰ Tseng, "My Research Life," pp. 3–4. There are no general histories of biological oceanography. For a history of plankton studies in Europe and the United States see Eric L. Mills, *Biological Oceanography: An Early History, 1870–1960* (Ithaca, N.Y.: Cornell Univ. Press, 1989). For a general history of oceanography see Margaret Deacon, *Scientists and the Sea, 1650–1900* (London: Academic Press, 1971); and Susan Schlee, *A History of Oceanography: The Edge of an Unfamiliar World* (London: Hale, 1973). See also Helen M. Rozwadowski, "Small World: Forging a Scientific Maritime Culture for Oceanography," *Isis*, 1996, 87:409–430.

²¹ Tseng to Taylor, 15 Sept. 1942, Taylor Papers.

²² Taylor to Tseng, 12 Sept. 1942, Taylor Papers (Taylor's emphasis). Tseng's views on promoting a basic science field are expressed in Tseng interview, 1994, Qingdao.

are, from a selfish point of view, of great importance, in my future career as a pioneer in Chinese marine biology. . . . Phycology, to me, is an integrated science of the various phases of the study of algae,—taxonomy, morphology, ecology, physiology, economic application, etc. Like all other sciences, its value lies in its cultural [worth] as well as its relationship with the human race in a way. Again like all other sciences, it should be brought closer to the general populace, whenever possible, especially during the war time. . . . When the factor of time comes into being, however, there is a question of relative urgency. That is why I said, whereas the taxonomical-geographical studies of the red algae “can wait,” the biological and cultural studies of the agariferous weeds should be done now. Maybe this time next year, the government will ask Science: We need a million pounds more of agar for ourselves and our allies; how can we get it?

Sensing that his expansive definition of phycology and the appeal to nationalism (both Chinese and American) might not persuade Taylor, Tseng added, “If I may have offended anyone in this choice it is due to my concept of my duty as a phycologist,—to promote the utilization of marine algae everywhere as much as possible. From a selfish point of view the more uses we can find in the algae the more valuable phycologists will be to the world. After all, science’s chief virtue lies in its service—materially or spiritually (culturally).” Tseng’s appeal and support from the oceanographers at Scripps convinced Taylor to allow him to use his grant to work on the agar project.²³

Meanwhile, Tseng’s survey of agar weeds had shown that the United States had a better grade of raw material for agar production, and perhaps a larger supply, than the Japanese. In a prophetic paragraph he remarked,

The impression I got from these trips, plus the local observation here, is that we have (in California) the most productive place for seaweeds, especially of economic ones, and it is certainly a pity to see all of these products of Mother Nature grow and rot, grow and rot, piles and piles on the beaches. The only conclusion I can reach is that “Americano” are too rich to bother with these weeds of the seas.

Upon joining the Fish and Wildlife group, Tseng immediately focused his research on biological problems associated with developing a renewable domestic source of agar. He began by surveying the algal resources of North America and touring factories that processed marine algae. These collecting expeditions were not without difficulty, as the strategic nature of the California coast meant that many areas were off-limits to civilians and foreigners. Tseng reported to Taylor that “being an Oriental I have also to refrain from going to the beaches and rocks as much as possible, in order to avoid putting myself in an embarrass[ing] position.” Tseng learned that *Gelidium*, a red alga containing agar, was already being collected along the coast of southern California by individual divers who, with the help of two assistants, harvested up to two wet tons a day. At \$260 per ton, the work was profitable enough to draw abalone divers into the harvest.²⁴

Soon Tseng would become the first scientist at Scripps and the first phycologist to conduct underwater research, recording growth rates of *Gelidium cartilagineum*. He learned to use the difficult and sometimes dangerous hard-hat equipment with a commercial diver who also advised him on the best conditions for observing marine algae. (See cover illustration.) His first dive nearly ended in disaster when a malfunctioning air valve leaked

²³ Tseng to Taylor, 15 Sept. 1942 (see also Tseng to Taylor, 20 Oct. 1944); and Taylor to Tseng, 23 Sept. 1942, Taylor Papers.

²⁴ Tseng to Taylor, 6 Aug. 1942; Tseng, quoted in H. H. Bartlett to Chief, Bureau of Fisheries, Washington, D.C., n.d. (“too rich to bother”); and Tseng to Taylor, 20 June 1942, Taylor Papers.

water into his suit as he stood on the ocean floor. Tseng was waist deep in very cold water—a terrifying experience for a novice diver. Overcoming these difficulties, he made monthly dives to measure and tag *Gelidium* at a depth of 10 meters in order to compare natural growth rates with those of plants grown in artificial conditions. He also collected water samples in bottles, analyzing them for nitrate and phosphate content, and studied photosynthesis of *Gelidium* in relation to carbon dioxide concentration, light, and temperature. Tseng was assisted in this project by Beatrice Sweeney, who later distinguished herself as a leader in the U.S. phycological community.²⁵

Most of Tseng's experimental work on *Gelidium* crossed the normal disciplinary boundaries of marine phycology, which at the time focused primarily upon classification. Tseng's in-the-ocean approach to marine phycology helped transform it from a descriptive to an experimental science, opening a new frontier for scientists interested in studying the growth of marine algae in their natural habitats. His was also the first attempt to cultivate marine algae in the United States. Certainly the emergency conditions of World War II influenced the project's multipronged approach, a pattern common in other wartime research programs as well. But the war by itself did not explain Tseng's unconventional initiative; a second team studying East Coast agar-producing marine algae did no more than survey available wild flora. Tseng's nationalist vision for developing Chinese marine science as a whole played a major role in his choice of experiments and in his broad approach. He purposely resisted specialization, as this might interfere with his emerging blueprint for a maricultural revolution.

With this wider end in mind, Tseng investigated harvesting and processing technologies as part of his survey of U.S. corporations engaged in processing wild marine algae. He focused in particular on the activities of Kelco, Inc., of San Diego (now a division of Monsanto), a company that harvested giant kelp (*Macrocystis pyrifera*) for its algin content. With the loss of Japanese agar imports, algin emerged as a substitute stabilizer or emulsifier with hundreds of food and industrial applications. For example, alginates are used to stabilize ice cream by preventing the formation of ice crystals, to suspend the chocolate in chocolate milk, and as a sizing material in the textile industry. Tseng was impressed with Kelco's many products but recognized that the corporation's reliance on an uncontrolled crop—natural stands of *Macrocystis pyrifera* off the California coast—would limit the growth of the industry.²⁶

By the end of the war Tseng was a leading authority not only on the distribution but also on the processing of marine algae. He wrote articles for popular and trade magazines and lectured on the various uses of algae to delighted audiences at Rotary Clubs and Lions Clubs. In the course of this work Tseng coined the term "phycocolloid," now widely used, to describe the class of colloids derived from marine algae. His publications on phycocolloids were much sought after, and in the summer of 1946 he was invited to give lectures

²⁵ On Tseng's research dives see Shor, *Eighty Years* (cit. n. 19), p. 127. Self Contained Breathing Apparatus (SCUBA) was not available until after World War II. For Tseng's *Gelidium* data see C. K. Tseng, "Report on Agarweed Research: November and Dec. 1942," copy of unpublished report in Taylor Papers. On Sweeney's assistance see Tseng interview, 1994, Qingdao; and Tseng, "My Research Life," p. 4. See also Beatrice M. Sweeney, "Living in the Golden Age of Biology," *Ann. Rev. Plant Physiol.*, 1987, 38:1–9.

²⁶ American corporations started harvesting wild marine algae during World War I and pioneered the use of algin as an emulsifier in food and industry. See Peter Neushul, "Seaweed for War: California's World War I Kelp Industry," *Technology and Culture*, 1989, 30:561–583. Kelco continued to expand in the postwar era but eventually replaced some of its algal products with substitute materials such as xanthan gums. The company was purchased in 1972 by Merck, Inc., and most recently by Monsanto, Inc., for over \$1 billion. See Milt Freudenhiem, "Merck Is Selling a Chemical Unit for \$1.08 Billion," *New York Times*, 21 Dec. 1994, p. C4.



Figure 2. Summer seminar for marine botanists at Woods Hole in 1941. C. K. Tseng (9) and his mentor W. R. Taylor (10) stand next to each other. (Courtesy Woods Hole Marine Biological Laboratory.)

on the commercial applications of algal products at the Marine Biological Laboratory at Woods Hole and elsewhere.²⁷ He became a prominent member of the growing community of American phycologists and participated in the formation of the Phycological Society of America in 1946. (See Figure 2.) Among American phycologists, Tseng was particularly close to Maxwell S. Doty, then at Northwestern University, who shared his dream of scientific mariculture and ranked alongside him as one of the great applied phycologists of the century.²⁸ Despite public interest, however, Tseng's and Doty's dreams of farming the ocean did not take hold in America. In fact, research on developing a U.S. source of agar weed did not resume until 1979, thirty-two years after the Scripps–USDA agar project, when the National Science Foundation provided funds for research on the cultivation of *Gelidium*.²⁹

²⁷ For the new term see C. K. Tseng, "The Terminology of Seaweed Colloids," *Science*, 1945, 101:597–602; and Tseng, "Phycocolloids: Useful Seaweed Polysaccharides," in *Colloid Chemistry: Theoretical and Applied*, ed. Jerome Alexander, Vol. 5 (New York: Chemical Catalog, 1946), pp. 629–734. Tseng describes his popular talks and articles in Tseng, "My Research Life," p. 5. See also his correspondence during 1946–1947, esp. Tseng to G. G. Hawley of Reinhold Publishing Corporation, 11 June 1947, Tseng Papers. Selected publications for this period include "Agar: A Valuable Seaweed Product," *Scientific Monthly*, 1944, 58:24–32; "Utilization of Seaweeds," *ibid.*, 1944, 59:37–46; "A Seaweed Goes to War," *California Monthly*, 1944, 52:35–46; "America's Agar Industry," *Food Industry*, 1945, 17:140–141, 230–234, 356–358; "Colloids from Kelp Give Rise to a Unique Process Industry," *Chemical and Metallurgical Engineering*, 1945, 52:97–100; "Seaweed Products and Their Uses in America," *Chemurgic Digest*, 1946, 5:141, 143–150; "Seaweed Resources of North America and Their Uses," *Economic Botany*, 1947, 1:69–79.

²⁸ Today the Phycological Society of America has a worldwide membership of approximately two thousand people. See Tseng to Maxwell S. Doty, 4 Apr. 1947, and Doty to Tseng, 27 Feb. 1947, Tseng Papers. Doty, who was a contemporary of Tseng's, provided the scientific and technological basis for cultivation of *Euचेuma* in the Philippines, an industry that now employs over four hundred thousand people. See Peter Neushul and Lawrence Badash, "The Blue Revolution: Harvesting the Pacific in China and the Philippines," *Osiris*, 1998, 13:186–209.

²⁹ This research was conducted by Michael Neushul (father of the first author), a phycologist at the University

Tseng's work in the United States was the prelude to a maricultural revolution in China. During the Scripps project he learned a great deal about plant reproduction, cultivation, harvesting, and processing. As the war drew to a close, Tseng was poised to undertake the next major step toward large-scale farming in the ocean. Like many of his fellow Chinese students, and in pursuit of his goal of developing Chinese mariculture, Tseng decided to return to China in 1947. Throughout World War II Tseng had remained a Chinese citizen, even though he was involved in a war-related project. In addition to studying alternate sources of agar, he contributed to the Allied war effort by providing the State Department with information on the geography of offshore Chinese islands, some of which were considered for military use in the Pacific theater. Tseng had traveled to these islands during his taxonomic survey of China's marine algae in the 1930s and was probably the only person in the United States familiar with that part of the Chinese coast. Ironically, Tseng's wartime act of patriotism was cited during the Cultural Revolution as evidence that he was an American agent; the fact that China had been a U.S. ally during World War II was ignored.³⁰

CHINESE SCIENCE DURING THE CIVIL WAR

Once World War II was over, Tseng accepted a position as professor and chair of the Department of Botany at the National University of Shandong at Qingdao, where he had taught between 1935 and 1938. He had fond memories of Qingdao, formerly a German territory, not only as a convenient seaside town where he could conduct marine research but also as "a model city . . . with clean streets, clean and beautiful houses, [and] nice beaches." Tseng was also offered a professorship at Xiamen University at the highest salary level and the directorship of the marine biological institute there. He declined Xiamen's offer to go to Qingdao, despite rumors of "Communist trouble" in the region, largely because Qingdao promised to allocate \$15,000 (U.S.) for the purchase of research equipment. Tseng shared his ideas for the study and utilization of the ocean in China with colleagues at Scripps and Woods Hole who gave him numerous duplicate books, journals, and reprints to take with him. He planned to found China's first institute of oceanography, modeled after Scripps and Woods Hole, and then to pursue his dream of cultivating and processing marine algae for food and for commercial applications.³¹

of California, Santa Barbara, who studied cultivation of *Gelidium* in the ocean. As a doctoral student at Scripps during the late 1950s, Neushul encountered Tseng's previous work and sought further publications. At that time Tseng's latest papers were published only in Chinese and Russian. Neushul's father, a Russian immigrant, translated Tseng's papers so that his son could follow the advance of algal mariculture in China. Interview with Michael Neushul by Peter Neushul, Dec. 1992, Goleta, California. For further information on Michael Neushul see Raymond J. Lewis, "Michael Neushul (1933–1993)," in *Prominent Phycologists of the Twentieth Century*, ed. Garbary and Wynne (cit. n. 13), pp. 217–225; and Daniel C. Reed *et al.*, "Dr. Michael Neushul, Jr.," *Botanica Marina*, 1994, 37:287–292.

³⁰ Tseng interview, 1994, Los Angeles. For a survey of Chinese scientists who studied in the United States and returned to China see Li, "Introduction of American Science and Technology to China" (cit. n. 15). Sverdrup, a Norwegian nationalist who became a U.S. citizen in order to engage in wartime research and who returned to Norway after the war, strongly supported Tseng's decision to return to China: Tseng interview, 1994, Qingdao.

³¹ On the decision to go to Qingdao and his plans for the institute see Tseng to Herbert L. Mason, 4 Apr. 1947, Tseng Papers (Mason was a professor at Berkeley); Tseng to Taylor, 15 Aug. 1946, Taylor Papers; and Tseng interview, 1994, Qingdao. On resources donated by colleagues see Doty to Tseng, 27 Feb. 1947, Tseng Papers; and Tseng to Taylor, 4 Oct. 1946, Taylor Papers.

There was a great gap between Tseng's expectations when he set sail for home and the reality he found in China. Arriving in Qingdao in January 1947, Tseng was dismayed to discover that the damage—both to his country and to the university—from the war against Japan and the ongoing civil war between the Nationalist government and the Chinese Communists was much worse than he had anticipated. “I never realized that we had lost so heavily,” he wrote a friend in the United States. “The school authority dared not tell me the entire truth, lest I may not come here!” To another friend, at Berkeley, he detailed the hardships he faced:

We have lost practically everything in the War—our equipment, books, the entire herbarium and museum. When I just arrived, the whole Botany Department has perhaps 10 books and a few old 1930's journals! . . . We are short of space, because the U.S. forces are still using our campus and the buildings [the university had moved inland following the Japanese invasion]. For the time being, therefore, we are using a former Japanese high school and three other schools in the near vicinity.³²

Tseng had to rebuild the department from scratch, both literally and figuratively. “For many weeks,” he wrote, “I plunged, body and soul, into organizing the department.” As the only professor in a department consisting of two lecturers and three assistants, Tseng first needed to recruit new faculty. This was no easy task: two professorial appointees failed to report to work for fear of the city's being overrun by the Communists. An unusually cold winter added to his woes. Owing to a serious coal shortage, Tseng and his colleagues had to work in subfreezing temperatures to make everything from chairs to simple laboratory equipment. Before his return Tseng had ordered \$10,000 worth of equipment and chemicals on behalf of the university, but the shipment was delayed owing to a lack of foreign currency. Soaring inflation added to the hardship in people's daily lives. To supplement his meager salary, Tseng moonlighted as a biology teacher at an American school in Qingdao. “This is in contrast with the prewar periods,” he commented ruefully, when a college professor could live “like a prince!” Financial hardships and the heavy administrative burden weighed on Tseng, causing him to observe that “time and again, I wish that I could go back to America, and do nothing else except my own research.”³³

Despite financial and political difficulties, Tseng managed to hire faculty for both the Department of Botany and the Department of Fisheries, of which he was acting chairman. By mid-1947 he had established, together with Tong Dizhou of the Department of Zoology, the Institute of Oceanography and Limnology. This was the first Chinese institution dedicated to the study of the ocean. Tong was the director and Tseng the associate director. Tseng also took his first steps toward developing mariculture by studying the life history of economically important local marine algae such as *Porphyra*. Ever the optimist, he ended a gloomy letter on an upbeat note:

³² Tseng to George Papenfuss, 9 June 1947 (Papenfuss was a professor at Berkeley, where he succeeded Setchell and Gardner as head of the herbarium); and Tseng to Mason, 4 Apr. 1947, Tseng Papers. Tseng was part of a three-member delegation from the University of Shandong that negotiated to convince the U.S. Army to pay some rent and eventually to give the campus back to the university. See Sun Guoyu, “Xiang Zeng Chengkui laoshi xuexi” [Learning from my mentor Tseng], in *Zeng Chengkui yu zhongguo haiyang kexue*, ed. Xu (cit. n. 18), pp. 73–77.

³³ Tseng to Papenfuss, 9 June 1947, Papenfuss Papers, Berkeley Herbarium, University of California, Berkeley (hereafter cited as **Papenfuss Papers**) (quotations); Tseng to Taylor, 17 Dec. 1947, Taylor Papers; Tseng to Mason, 4 Apr. 1947, Tseng Papers; Tseng to Papenfuss, 5 Apr. 1947, Papenfuss Papers; and Sun, “Xiang Zeng Chengkui laoshi xuexi,” p. 74.

Well, such is the life in China in Year No. 2 of the Atomic Age! We can only hope that the civil war will end soon, and that we can resume our normal work under normal conditions *back to our own campus!* Things seem to improve, however, and especially the weather has been very nice the last few days. Spring is coming, and flowers of *Prunus yezoensis* will come out in another week or two. Everything will be lovely, and we hope the same will be true with the Chinese political and economic situation!³⁴

The outcome of the civil war remained, of course, the greatest uncertainty facing Tseng and his grand plan. In early 1947, even after the Nationalist government overtook Yanan, the Communist capital, the People's Liberation Army was preparing a counteroffensive. Mao's troops occupied much of the countryside and encircled the cities. Qingdao was besieged and could communicate with the outside world only by air and sea. As a "liberal intellectual," Tseng had little sympathy for either side in the conflict, despairing that "if civil war continues, China is doomed to disintegration, and World War III is more than a probability." Given the corrupt nature of the Nationalist government, Tseng noted that if democracy did not come from within the present government "soon enough" the Communists would win the civil war. For months he tried unsuccessfully to obtain funds for the new institute from the Ministry of Education, and eventually he lost faith in the Nationalists' ability to support his plan for farming the Chinese ocean. The Communists were an unknown element and he was fearful of the extremists in their midst, but at least he thought that they shared his nationalistic aims. "Personally," he wrote an American friend, "I don't feel in any way uneasy about these unfriendly 'neighbors' who are, after all, fellow Chinese."³⁵

A combination of disappointment with the Nationalists and hope for a stable and supportive new regime led Tseng to remain in Qingdao when the Communist forces took over the city and the Nationalists fled to Taiwan in 1949. Under his influence, no one in the Department of Botany left for Taiwan. The friendly and highly disciplined troops he met on the street gave Tseng a very good first impression of the Communists.³⁶

NEW SCIENCE FOR A NEW CHINA

The new government placed great emphasis on the advancement of science and technology, especially those fields with economic and military applications. In July 1949, three months before the official founding of the People's Republic, Tseng and Tong were invited to Beijing to participate in a high-level conference on the planning of scientific work. Soon thereafter the Chinese Academy of Sciences, comprising dozens of institutes, was established as the overarching institution for advanced scientific research in the country.³⁷ After

³⁴ Tseng to Papenfuss, 9 June 1947, 5 Apr. 1947, Papenfuss Papers; and Tseng to Mason, 4 Apr. 1947, Tseng Papers (quotation).

³⁵ Tseng to S. F. Light, 12 Apr. 1947, Tseng Papers (Light was a professor at Berkeley); Tseng to Papenfuss, 9 June 1947, Papenfuss Papers; and Tseng to Victor Schaffer, 8 Apr. 1947, Tseng Papers (Schaffer worked with Tseng on the government's wartime *Gelidium* cultivation project).

³⁶ Sun, "Xiang Zeng Chengkui laoshi xuexi" (cit. n. 32), p. 74; Hou Guoben, "Zeng Chengkui jiaoshou yu zhongguo haiyang kexue" [Professor C. K. Tseng and Chinese marine science], in *Zeng Chengkui yu zhongguo haiyang kexue*, ed. Xu (cit. n. 18), pp. 40–42; and Tseng interview, 1994, Qingdao.

³⁷ For a general discussion of Chinese science policy during this period see Suttmeier, *Research and Revolution* (cit. n. 5). For further detail on the Chinese Academy of Sciences see *ibid.*; Hans Kühner, "Between Autonomy and Planning: The Chinese Academy of Sciences in Transition," *Minerva*, 1984, 22:13–44; Yao *et al.*, *Zhongguo kexueyuan*; Shuping Yao, "Chinese Intellectuals and Science: A History of the Chinese Academy of Sciences (CAS)," *Science in Context*, 1989, 3:447–473; and Cong Cao, "The Changing Dynamic between Science and Politics: Evolution of the Highest Academic Honor in China, 1949–1998," *Isis*, 1999, 90:298–324.

consultation with Zhu Kezhen, vice-president of the academy in charge of life and geophysical sciences, Tong and Tseng's Institute of Oceanography at the University of Shandong was reorganized and renamed the Marine Biological Laboratory of the Chinese Academy of Sciences.

The prompt action of the Communist government impressed Tseng, who had grown used to the indifference of the Nationalists. In February 1951, in what was probably his first communication with an American colleague after the Communist revolution, Tseng described the new government, somewhat formally, as clean, efficient, and "truly democratic." He invited his friends to write and discuss the "present political situation," commenting that "the Chinese are a peace-loving people, and we all love the American people, despite what your government is doing to hurt us." Tseng was no doubt referring to the ongoing Korean War. The main reason for the letter, however, was not propaganda but his new laboratory. "Let us turn away from politics," Tseng wrote, asking former colleagues to send him scientific books and journals. "We hope eventually to have at Tsingtao [Qingdao] an equivalent of the Scripps Institution plus Woods Hole Marine Biological Laboratory." It is remarkable that Tseng could communicate with American scientists at the height of the war, let alone refer to American scientific institutions in such a positive light. Fei Xiugeng, then one of Tseng's students, recalled strong anti-American sentiment at the time, especially when a wave of disease that struck Qingdao was attributed to U.S. biological warfare agents.³⁸

The lack of physical oceanographers in China led to a narrower focus on marine biology in Tseng's laboratory. The Chinese Academy of Sciences oversaw the laboratory from its Hydrobiology Institute in Wuhan and supplemented the staff with additional researchers. In 1952 Tseng and Tong fended off an attempt by the production-minded Ministry of Agriculture to annex the laboratory and merge it with the ministry's Central Fishery Institute, also in Qingdao. The laboratory was renamed the Institute of Marine Biology in 1957 and the Institute of Oceanology in 1959.³⁹

Even after shifting most of his time to the laboratory in the early 1950s, Tseng maintained strong ties with Shandong University. He continued to teach courses and drew the brightest graduates to work at the institute. One of Tseng's most fruitful collaborations was with Fang Zongxi, a faculty member in biology and one of the first geneticists in the world to work with marine algae. A student of Tseng's at Xiamen University in the 1930s, Fang completed a Ph.D. at the University of London under J. B. S. Haldane in 1949 before Tseng recruited him for Shandong. The collaboration between Tseng and Fang resulted

³⁸ Tseng to Marston Sargent, 5 Feb. 1951, Sargent Papers, Box 8, Archives of the Scripps Institution, La Jolla, California. Fei collected flies and other insects under Tseng's supervision. These disease-carrying agents were not normally present in Qingdao during the winter. See Fei interview.

³⁹ Tseng interview; Tseng, "My Research Life," p. 6; and Zhu, *Zhu Kezhen riji*, entries for 27 Aug. 1950, 21 Oct. 1950, 9 Sept. 1952, pp. 100, 113, 325. See also Yao *et al.*, *Zhongguo kexueyuan*, pp. 12–13. Despite occasional collaboration, Tseng's institute and the ministry's institute, which was later renamed the Yellow Sea Fisheries Institute, developed a rivalry that was symptomatic of the relationship between the various Chinese research systems, each with its own institutional culture. For example, while Tseng and his colleagues always published their research results promptly in open scientific journals, researchers at the Yellow Sea Fisheries Institute filed internal reports to the ministry. In 1991 Wang Zhiping, widow of Yellow Sea's longtime director Zhu Shuping, distributed leaflets and filed a suit accusing Tseng of plagiarizing Zhu's research on seaweed cultivation. Amongst the evidence she cited was a "secret" 1964 report from the Yellow Sea Fisheries Institute to the State Science and Technology Commission that mentioned its involvement in seaweed cultivation. Tseng's own claims could be supported by reference to open publications in the 1950s. The suit was dismissed by the court. See "Zhongguo keji shi shang yi da chouwen" [A big scandal in the history of Chinese science], undated; and Chinese Society of Oceanology and Limnology *et al.*, "Gong you suo de, dang zhi wu kui" [Deserved honor], June 1992. Both are in the authors' possession.

not only in new, economically important strains of *Laminaria* but also in one of the first monostrains of marine algae. These successes confirmed once more Tseng's belief in the need for an interdisciplinary approach to marine science and technology.⁴⁰

Within the new laboratory in the early 1950s, Tseng engaged in heated discussions with his colleagues over the direction of research that echoed his debate with Taylor almost a decade earlier. The Marine Biological Laboratory was divided into several departments: experimental embryology, invertebrate zoology, plankton, and botany. Tseng personally directed botanical research of three types: basic research in phycology, applied research in mariculture, and processing technologies. His colleagues objected to both mariculture and processing as inappropriate pursuits for the laboratory. Again, Tseng defended their inclusion by pointing to the material benefits they offered and to the importance of applied research to phycology as a scientific field.⁴¹

Tseng prevailed because of his position and prestige and the relative autonomy scientists enjoyed in choosing the direction of their research in the early years of the People's Republic. More significantly, his approach fit the new government's "revolutionary utilitarian" science policy. In June 1950, as war broke out in Korea, the State Council under Zhou Enlai mandated that the Chinese Academy of Sciences should "promote the function of science as a weapon in ideological reform and in training of well-rounded scientific talents for [national] construction, bring about close coordination between academic research and practical needs, and make [research] truly serve national construction in industry, agriculture, health, and defense." Much to Tseng's delight, other leaders of the laboratory soon began to engage in applied research themselves.⁴²

Beginning in 1950, Tseng led a research and development effort that successfully tapped the vast marine resources of the Chinese coastline, from the Yellow Sea in the north to the South China Sea in the south. He focused briefly on the brown alga *Sargassum* before shifting his attention to cultivation of the red alga *Porphyra* and *Laminaria japonica*, a brown marine alga with a high concentration of iodine and algin. Historically, both *Porphyra* and *Laminaria* were popular food items for Chinese (and other Asians). Although the Japanese had farmed *Porphyra* for centuries, no one understood the red algae's life history until the pioneering British phycologist Kathleen Mary Drew made the surprising discovery that the spores (seeds) actually underwent the early stages of growth in oyster shells. Tseng's research group built on this discovery with a detailed study of *Porphyra*'s life history after the *Conchocelis* (oyster shell) phase. Their work opened the way for large-scale cultivation of *Porphyra* in China.⁴³

Laminaria, referred to in the West as "kelp," has a long history of use as a source of potash, acetone, and algin. In China, *Laminaria*, or "haidai" ("sea ribbon"), was imported

⁴⁰ Tseng and Fei interviews. See also "Fang Zongxi," in *Zhongguo kexuejia cidian* (cit. n. 8), Vol. 3, pp. 53–55.

⁴¹ Tseng interview, 1994, Qingdao.

⁴² Yao *et al.*, *Zhongguo kexueyuan*, pp. 13–14; and Tseng interview, 1994, Qingdao. On the utilitarian orientation of Chinese science policy see also Suttmeier, *Research and Revolution* (cit. n. 5), pp. 34–42; and Wang, "Revolutionary Utilitarianism" (cit. n. 6).

⁴³ Kathleen M. Drew, "Conchocelis-phase in the Life-history of *Porphyra umbilicalis*, (L.) Kutz.," *Nature*, 1949, 164:748–751. Drew is revered in Japan, where a shrine commemorates her discovery that led to large-scale farming of *Porphyra* (known as "Nori" in Japan) in the postwar era. Tseng's work built on this discovery. See C. K. Tseng and Zhang Ruide, "Zicai rengong yangzhi shang de baozhi lai yuan wenti" [On the problem of the source of the spores in the artificial cultivation of *Porphyra*], *Kexue tongbao* [Science bulletin], 1954, no. 12, pp. 50–52, rpt. in *Selected Works of C. K. Tseng*, ed. Qin (cit. n. 7), Vol. 2, pp. 643–646.

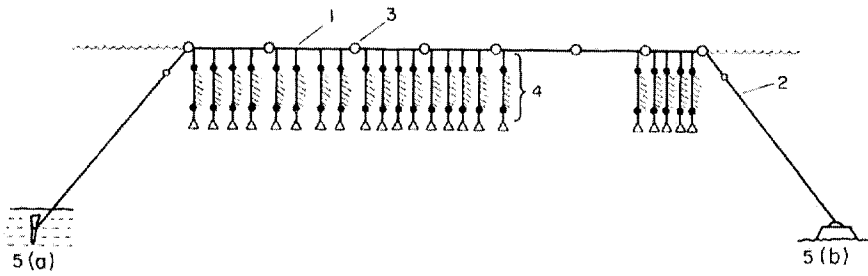


Figure 3. A Chinese farm for *Laminaria* cultivation includes the long line (1) anchored by a rope and weights at each end (2 and 5) and kept afloat by a series of buoys (3). Weighted ropes with seedlings attached are suspended from the long line (4).

in dried form from Japan and Korea.⁴⁴ The Chinese government supported Tseng's efforts, hoping that production and increased consumption of *Laminaria* would resolve the country's goiter problems. General Zhu De, a senior Party member, army leader, and, like so many of his countrymen, a *haidai* aficionado, encouraged Tseng's effort. Tseng knew from his previous surveys of Chinese marine algae that *Laminaria* grew naturally around Dalian on the cooler northern coast of the Yellow Sea, probably brought there initially by boats from Japan. The Japanese had attempted to promote this natural growth when they occupied the region during World War II, without success. With funding from the newly formed Chinese Academy of Sciences, Tseng set out to establish a domestic source of *haidai*.⁴⁵

Capitalizing on an intimate knowledge of marine algae gained through many years of taxonomic studies and an interdisciplinary understanding of the ocean acquired while working at Scripps, Tseng launched a systematic plan to grow *Laminaria*. His first step was to study artificial substrates as an alternative to the sea floor. In the past, primitive efforts to improve natural growth had included the rock scraping mentioned earlier and the provision of additional substrate material in the form of rocks and boulders. Both methods relied on natural seeding. Tseng decided to employ a floating substrate designed specifically for *Laminaria*. This method of cultivation included collection of spores from a mature alga; the spores were then allowed to attach themselves to seeding cords. Seeding took place on land in specially designed tanks. The cords were then suspended from a floating raft attached to the sea bottom by ropes. (See Figure 3.) This type of artificial substrate is commonly referred to as a "long-line" farm. Tseng's first "farms" were very small, ranging in size from one-eighth to one-fifth of an acre. As growth rates improved the farms expanded; eventually many small units were joined together to form one large farm. Once the farms were operating at optimum efficiency, one farmer could maintain production on an area of 2.5 acres.⁴⁶

Experiments conducted by the Qingdao scientists demonstrated that the most important function of the artificial substrate was maintaining the plants at an optimal depth. Marine

⁴⁴ "Kelp" is a Scottish term describing the ash of brown marine algae. See Neushul, "Seaweed for War" (cit. n. 26); and C. K. Tseng, "Kelp Farming: A New Industry," *China Reconstructs*, 1964, 13:36–38.

⁴⁵ Tseng interview, 1986; and Tseng interview, 1994, Qingdao. Bernard Courtois discovered iodine in 1811 while leaching ashes of marine algae for their potassium and sodium salt content. Shortly thereafter, in 1820, Jean Coindet introduced the scientific use of iodine in the treatment of goiter. See George B. Kauffman, "Discoverer of Iodine Never Published a Paper," *Industrial Chemist*, 1988, 9:20–21.

⁴⁶ Tseng interview, 1994, Qingdao.

algae depend for growth on a combination of light, water motion, and temperature. Unlike the sea floor, the depth of Tseng's floating rafts could be adjusted to take advantage of increased water motion, thus improving nutrient uptake. Once sporelings reached a size of 10–15 centimeters they were removed from the seeding cords and twisted into the strands of cultivation ropes.⁴⁷ These ropes were then suspended from the long-line farm units and later hoisted aboard boats for harvesting.

In addressing the many problems associated with farming the sea, Tseng's research group acted as a conduit between science and technology. In a move reminiscent of the tactics of Louis Pasteur and other practical-minded scientists, Tseng extended his research from the traditional water tables of the laboratory out into the ocean. His first major obstacle came in the effort to improve the first stage in the cord seeding process. When *Laminaria* spores were collected in the autumn (mid-October in Qingdao), the resulting sporelings were often overwhelmed by competitors such as *Ectocarpus*, *Enteromorpha*, *Licmophora*, and other "fouling" algae that covered the seedling cords and greatly reduced the amount of light, essential for photosynthesis, that reached the *Laminaria*. To solve the fouling problem, the Qingdao group conducted experiments to determine the optimal temperature for growth of *Laminaria* sporophytes. They then built temperature-controlled greenhouses on land, where so-called summer sporelings were cultured in an artificial environment prior to outplanting in the ocean in the fall. The head start afforded by the greenhouses gave the sporophytes a great advantage over the fouling algae and enhanced production by 30–50 percent while also cutting costs significantly.⁴⁸

Like many emerging technologies, ocean farming required a combination of basic research and technological innovations throughout the scaling-up process. The first successful long-line farms were anchored in bays at Dalian, Yantai, and Qingdao. Initial efforts to cultivate *Laminaria* outside of these inner bays failed owing to low nutrient levels. Tseng's research group knew that growth was largely affected by the nitrogen content in the water and soon recognized the connection between growth rates and proximity to coastal effluent. Needless to say, however, fertilizing the ocean is much more difficult than fertilizing a terrestrial environment. Tseng and his research team solved this problem first by suspending porous clay pots containing fertilizer from their long-line farms. The clay bottle fertilization method enabled farmers to grow *Laminaria* on small farms in the outer sea regions. Later, as the farms became larger, Tseng's group showed that for areas of 100 acres or more nutrient uptake was more efficient when fertilizer was sprayed than when it was laboriously applied via clay bottles. Scientists also studied nutrient uptake in *Laminaria* in order to optimize fertilization.⁴⁹

Tseng's research was interrupted during the early 1950s as Chinese scientists debated Lysenkoism. Chinese followers of Lysenko urged Tseng to expand *Laminaria* cultivation to the south by simply transferring the plants and waiting for them to adapt to the warmer, more turbid waters. Tseng warned against blindly following Soviet dogma and insisted that extensive scientific experiments be conducted before transplantation to the south was

⁴⁷ C. K. Tseng, "Marine Phycoculture in China," in *Proceedings of the Xth International Seaweed Symposium*, ed. Tore Levring (Berlin: De Gruyter, 1981), pp. 637–642.

⁴⁸ C. K. Tseng, Sun Guoyu, and Wu Chaoyuan, "Haidai de youmiao diwen duxia yangzhi shiyan baogao" [On the cultivation of haidai (*Laminaria japonica* Aresch.) by summering young sporophytes at low temperature], *Zhiwu xuebao* [Acta Botanica Sinica], 1955, 4(3):255–264, rpt. in *Selected Works of C. K. Tseng*, ed. Qin (cit. n. 7), Vol. 2, pp. 652–658.

⁴⁹ C. K. Tseng, "Qianhai shifei zengcan wenti" [On the problem of fertilizing the shallow seawater to increase production], *Kexue tongbao*, 1955, no. 12, pp. 73–76, rpt. in *Selected Works of C. K. Tseng*, ed. Qin, Vol. 2, pp. 647–651. See also Tseng, "Marine Phycoculture in China" (cit. n. 47), p. 759.

attempted. In 1955–1956 Tseng sent Sun Guoyu and two other scientists to Jiangsu and Zhejiang provinces to collect water samples for analysis by Fei Xiugeng at the laboratory in Qingdao. Fei's data showed that nutrient levels in these southern waters were up to eleven times higher than those in the Qingdao region. Temperature data also showed that there was a significant period each year when southern waters were cool enough for optimal *Laminaria* growth. Tseng and his colleagues now knew that farming was feasible in the south, especially through the use of appropriate maricultural technologies. Unlike in Qingdao, cultivation of *Laminaria* along the coast of Zhejiang and Fujian provinces did not require fertilization. The plants did not grow naturally in this region owing to the turbidity of the water, a problem the Qingdao group solved using artificial substrates. Once their basic research yielded promising results, Tseng sent his deputy, Wu Chaoyuan, and other scientists to Gouqi Island off Zhejiang province, where they established a successful pilot farm. Shortly thereafter they opened the vast Eastern China Sea coast for large-scale *Laminaria* farming.⁵⁰

In 1956, the same year that *Laminaria* was transplanted to the south, China's debate over Lysenkoism came to a head at a famous symposium held in Qingdao. As part of the liberal Hundred Flowers interlude, the Chinese Academy of Sciences and the Communist Party's Science Division invited biologists to express their opinions of Lysenkoism. The Qingdao Symposium became a showcase for the Party's new policy of encouraging academic freedom. Three local marine biologists, Tseng, Tong, and Fang, participated in the conference. Citing changes in *Laminaria* during its adaptation to new environments, Tseng commented that speciation resulted mostly from long, slow, and gradual adaptation to new and changing environments, in contrast to Lysenko's belief that new species suddenly sprang out of old ones in one or two generations. The Qingdao Symposium resulted in a decline in Chinese Lysenkoism, so that by 1966 the "genetics question" had virtually disappeared from Chinese science publications.⁵¹

THE GREAT LEAP FORWARD

In six years, Tseng's group solved all of the *Laminaria* cultivation problems. Their swift success met with praise from the Chinese Academy of Sciences, which awarded them a prize of 40 yuan. Though equivalent only to a typical researcher's monthly salary, the award was nevertheless important to the future of Tseng's program as an indication of governmental approval. By this point Tseng had taken up important positions in Chinese science and technology policy-making bodies and cultivated a network of contacts in

⁵⁰ On Tseng's insistence on experimentation see Sun, "Xiang Zeng Chengkui laoshi xuexi" (cit. n. 32), pp. 73–77. Although Tseng paid lip service to Soviet "advanced theory on the unity of organisms and their environments" in his publications and traveled to the Soviet Union several times in the early 1950s, his research and experiments far exceeded Soviet efforts, and in fact the Soviets sent students to Qingdao to learn from Tseng's group. See Tseng and Zhang, "Zicai rengong yangzhi" (cit. n. 43); and Fei interview. On *Laminaria* farming in the south see C. K. Tseng, "Haidai zai woguo yan'an de nayi yangzhi" [The cultivation of *Laminaria japonica* as transplanted into the southern coastal waters of our country], *Kexue tongbao*, 1958, no. 17, pp. 531–533, rpt. in *Selected Works of C. K. Tseng*, ed. Qin, Vol. 2, pp. 699–701.

⁵¹ For Tseng's comments see Li Peishan, et al., eds., *Baijia zhengming—Fazhan kexue de biyou zhilu* [A hundred schools contending—The road that must be followed for the development of science] (Beijing: Commercial Press, 1985), pp. 289–291. For an abridged English translation of the proceedings (Tseng's comments were not included) see Laurence Schneider, ed., "Lysenkoism in China: Proceedings of the 1956 Qingdao Genetics Symposium," *Chinese Law and Government*, 1986, 19:iii–97; pp. xviii–xix note the disappearance of the "genetics question" by 1966. See also Li, "Genetics in China: The Qingdao Symposium of 1956," *Isis*, 1988, 79:227–237.

fishery agencies. In 1958, with the advent of China's "Great Leap Forward," marine farming was pushed to the forefront as Party and government leaders, at Tseng's instigation, decided to expand the industry by increasing the number of farms. The Ministry of Fisheries had on its staff several former military officers who approached the problem of scaling up *Laminaria* farming as something of a military operation. Fortunately, the basic and applied science had already been perfected by Tseng's research group. Essentially, the only significant barrier to large-scale farming was lack of education. As a result, Tseng and his research group participated in a massive workshop organized by the Chinese Ministry of Fisheries at Dalian. Hundreds of fishermen from five provinces attended the two-month training seminar, living in barracks provided by the government. Courses on farming were given in land-based classrooms and in the ocean. The attendees then returned home and trained hundreds more in the techniques of farming *Laminaria*.⁵²

By venturing out of his laboratory to create maricultural policy and exploit the political climate of the Leap to scale up *Laminaria* cultivation, Tseng was going beyond the realm of science. In addition to their political efforts, Tseng and his colleagues maintained close contacts with fishermen engaged in farming *Laminaria* as well as with technicians and officials at maricultural institutions. Fei, the institute's cultivation expert, befriended hundreds of fishermen who provided him with a constant flow of data on the expanded farms. Using this information, the institute extended its knowledge of scaled-up farms in different regions. Because of their close contact with the marine farmers, Tseng's group was able to modify cultivation techniques quickly to match local conditions.⁵³

The *Laminaria* farms are a rare case where the much—and appropriately—criticized Great Leap Forward policies actually worked. In an amazingly short period, an enormous new industry was created by applying scientific knowledge accumulated by Tseng's research group at the Institute of Oceanology. (See Figure 4.) Annual production of *Laminaria* increased 155 times, from 40.3 dry tons in 1949 to 6,253.23 dry tons in 1958. Unfortunately, however, mariculture was an exception to the otherwise irrational and disastrous Great Leap Forward campaign, during which urban citizens engaged in primitive, wasteful backyard steel-making while their rural counterparts were absorbed into "26,000 communes embracing 98 percent of the farm population."⁵⁴ Mao's forced collectivization and industrialization devastated Chinese food production as communes competed for the highest yields, often leaving much of their rice and wheat crops rotting in the field. In contrast to Tseng's scientific approach to mariculture, the vast majority of Great Leap

⁵² Fei interview; and Tseng interview, 1994, Qingdao. Tseng was, among other things, chairman of the marine biology group in the State Science and Technology Commission. See Zhou Xiantong, "Zeng suozhang ren (jian) zhiwu biao" [A chart of the positions and adjunct positions of director Tseng], undated, Tseng Papers.

⁵³ Fei interview; and Tseng interview, 1994, Qingdao. For evidence of Tseng's contacts with other officials see, e.g., Li Hongji, "Zeng Chengkui yu Shandong de haidai yangzhi" [C. K. Tseng and *Laminaria* cultivation in Shandong], in *Zeng Chengkui yu zhongguo haiyang kexue*, ed. Xu (cit. n. 18), pp. 58–63. Li was the technical director of Shandong Fishery Hatchery in Qingdao in the 1950s.

⁵⁴ Hsu, *The Rise of Modern China* (cit. n. 12), p. 656. For the production figures see C. K. Tseng, "Farming and Ranching of the Sea in China," in *The Future of Science in China and the Third World: Proceedings of the Second General Conference Organized by the Third World Academy of Sciences* (Singapore: World Scientific, 1989), pp. 92–106, rpt. in *Selected Works of C. K. Tseng*, ed. Qin (cit. n. 7), Vol. 2, pp. 1235–1247. During 1978–1979, more than 18,000 hectares of marine farms were engaged in the commercial cultivation of *Laminaria*, with an annual production of 275,000 tons in dry weight (1 million tons in wet weight). In the United States, an equivalent natural harvest had a value of \$300 million. See C. K. Tseng, "Commercial Cultivation," in *The Biology of Seaweeds*, ed. Christopher S. Lobban and Michael J. Wynne (Berkeley: Univ. California Press, 1981), pp. 680–725.



Figure 4. A Great Leap Forward-era poster depicting successful marine farming (top) did not exaggerate the success of the new large-scale Laminaria farms (bottom). (Courtesy Sylvia Earle.)

Forward programs combined into a frantic mass mobilization intended to transform China into utopian communism overnight.⁵⁵

Even Tseng's institute could not escape the fever of the time. At one point Fei was compelled to engage in a bidding war with a local commune over how much *haidai* could be produced in a *mu* (a Chinese acre, equaling 0.16 acre). Under pressure from political cadres Fei's bid reached 4.4 million *jin* (0.5 kilo) per *mu*, but the other side won with a bid of 10 million *jin*. Sun Guoyu, one of Tseng's assistants, commented sarcastically that not even the seawater in one Chinese near-shore acre weighed 4.4 million *jin*, let alone producing 10 million *jin* of *haidai*. Tseng promptly removed Sun from the institute's Leap projects, perhaps as a protective warning to him. Fei's forced bidding war was a precursor to the radical "mass science" of Mao's Cultural Revolution that would later lead to the persecution of Tseng himself. As a result of failed Great Leap Forward programs, food shortages soon plagued China, causing one of the worst famines in history. The "Great Leap Famine" wiped out entire towns, claiming an estimated twenty to thirty million lives. Tseng worked hard to keep his team together during these difficult years. In 1962 the group produced a book on *Laminaria* cultivation, the first ever written on cultivation of a single species of marine algae. Fei recalled that work on the *Laminaria* book was a life-saver, as Tseng managed to procure a special ration of food for the scientists involved in the project.⁵⁶ Unfortunately, Tseng won the battle but lost the war: as his starving scientists strove to document their achievement, the bodies of their countrymen lined the village streets.

SCIENTISTS, POLITICS, AND SURVIVAL DURING THE CULTURAL REVOLUTION

Despite their maricultural success, Tseng and his scientists could not escape the impact of politics and ideological campaigns. In swift succession, the Anti-Rightist movement of 1957, the Great Leap Forward of 1958, the Four Cleansings of 1964, and, two years later, the Great Proletariat Cultural Revolution devastated China's scientific infrastructure. Even in the early 1950s, ideologues attacked Tseng for equipping his laboratories with American-made instruments. Mao harbored a deep suspicion toward Western-trained intellectuals, including scientists and engineers. In a meeting with an East German delegation in 1959, he said:

To cleanse the bourgeois ideology among the Chinese people is a long-term task. We can not do without those intellectuals. Without them, we cannot carry on our work. Without them, we would not have engineers, professors, teachers, reporters, physicians, writers, and artists. It is thus a very complicated job to both use them and also struggle with them. The bourgeois control

⁵⁵ Rone Tempest, "Starving a Nation with the Politics of Illusion," *Los Angeles Times*, 23 Dec. 1997, p. A16. Ever meticulous, Tseng calculated, for example, the costs and profits of pot fertilization. See Tseng, "Qianhai shifei zengcan wenti" (cit. n. 49).

⁵⁶ The book was published as C. K. Tseng and Wu Chaoyuan, *Haidai yangzhixue* [*Laminaria* cultivation] (Beijing: Science Press, 1962). See Sun interview; and Fei interview. See also Suttmeier, *Research and Revolution* (cit. n. 5); he suggests that both the Great Leap Forward and the Cultural Revolution represented a "mobilization model" of Chinese science policy. On the "Great Leap Famine" see Tempest, "Starving a Nation," p. A16; and Jasper Becker, *Hungry Ghosts: Mao's Secret Famine* (New York: Holt, 1996). See also Jonathan D. Spence, *The Search for Modern China* (New York: Norton, 1990), p. 583. For further discussion of scientists and the Great Leap see Lynn T. White, *Policies of Chaos: The Organizational Causes of Violence in China's Cultural Revolution* (Princeton, N.J.: Princeton Univ. Press, 1989), pp. 163–165.

the culture, art, education, and scholarship, and they are very stubborn! It's all their people, very few of our own.⁵⁷

Fortunately for Tseng and his colleagues, few high-level scientists at the institute suffered during the Anti-Rightist movement of 1957, thanks largely to the protection of Sun Ziping, the institute's vice-director and Party secretary. To meet the quota of "rightists" to be purged, however, Sun had to sacrifice a number of lower-level technicians at the institute, a painful move that may well have contributed to his own persecution at the hands of the Red Guards during the Cultural Revolution. Nationwide, over three hundred thousand scientists and other intellectuals fell into Mao's trap—they were first encouraged to criticize the Party and then sent to labor camps or the countryside as class enemies. There was another period of ideological relaxation in the early 1960s, during which the government encouraged basic research. Tseng put Sun Guoyu to work on marine microorganisms, while Fei studied primary productivity. Fei's experiments were based on the pioneering work of Tseng's old friend Maxwell Doty, from whom Tseng was able to receive reprints of papers. The respite did not last long, however, and in the mid 1960s, on the eve of the Cultural Revolution, both Sun and Fei were purged during a series of harsh ideological campaigns. Sun was accused of being a counter-revolutionary for his previous criticism of the Great Leap Forward. This crime could have brought capital punishment; Sun received a lighter penalty because of his peasant upbringing. He was banished from the laboratory, stripped of all political rights, and forced to work as a janitor in the institute. Fei, a longtime member of the Communist Party, fared slightly better. He was accused of the lesser offense of "detachment from politics" and of being a "white expert" (technically competent but politically neutral or untrustworthy) instead of a "red expert." The latter charge arose because of his work on primary productivity—basic rather than applied research—and a year spent studying English in preparation for a trip to Denmark. The trip, painstakingly arranged by Tseng, was immediately canceled.⁵⁸

Despite its record of service to China, Tseng's institute was among the hardest hit by mass violence and anti-intellectual campaigns during the Cultural Revolution. The new radical Maoist ideology, emphasizing revolutionary class struggle, replaced the earlier moderate utilitarian policy that had governed scientific research. In a crucial directive on the launching of the Cultural Revolution, issued on 16 May 1966, Mao called upon China's youth to "hold high the banner of the Proletariat Cultural Revolution" and "expose the reactionary bourgeois stand of those so-called 'academic authorities' who opposed the party and socialism." He urged them to "criticize and repudiate the reactionary bourgeois ideas in the sphere of academic work, education, journalism, literature and art, and publishing" and to seize leadership in these institutions. Another decree from the Party's central committee explicitly targeted the sciences, denouncing "reactionary bourgeois academic 'authorities'" and their views, including those "in theories of natural science."

⁵⁷ "Transcription of [Mao's] Talk When Meeting with the Delegation from the German People's Republic on 27 Jan. 1959 (Excerpt)," in *Xuexi wenxuan* [Selected documents for study], 4 vols., internal Chinese compilation of Mao Zedong speeches and writings, n.p., ca. 1967, Vol. 3, p. 2. On the ideological campaigns' influence on science see Yao *et al.*, *Zhongguo kexueyuan*; and Wang, "Revolutionary Utilitarianism" (cit. n. 6). The criticism of Tseng for using American-made instruments is noted in Sun interview; and Fei interview.

⁵⁸ Fei interview. On the fate of the three hundred thousand scientists and intellectuals see Hsu, *Rise of Modern China* (cit. n. 12), pp. 795–797; and Yao *et al.*, *Zhongguo kexueyuan*, pp. 86–89. On the argument that the Hundred Flowers was a trap see Xu Liangying, "Guanyu fanyou yundong de pianquan huiyi he sikao" [Recollections and reflections on the Anti-Rightist movement], *Beijing zhichun* [Beijing spring], Aug. 1997, pp. 77–82.

Although a moderating clause asked that “special care should be taken of those scientists and scientific and technological personnel who have made contributions,” in reality that protection was extended only to a very few weapons scientists; the remainder, along with the rest of the country, were consumed by the violent and chaotic frenzy of the Cultural Revolution.⁵⁹

The Chinese Academy of Sciences was turned upside down during the first few months of the Cultural Revolution, when Red Guards and other rebels seized power and stopped virtually all research. Scientists, especially those in the leadership, were criticized and persecuted. Among the 170 senior CAS scientists in the Beijing area, 131 were attacked. Altogether, 27 senior scientists and 79 scientists of lower rank in the CAS died during the political repressions of the Cultural Revolution. In Shanghai, 40 percent of the staff at the CAS’s Institute for Plant Physiology were accused of being enemy agents. Hundreds of scientists were beaten and tortured, and some were killed, on the basis of trumped-up charges of anti-Communist conspiracy during the Nationalist years. In 1967 Fan Gongju (Kungchu Fan), a Berkeley-trained phycologist at Jinan University in Guangzhou who maintained ties with Tseng’s group, sent his former mentor a note resigning his membership in the Phycological Society of America. This terse message, written in Chinese, was clearly meant to appease the Red Guards and to indicate to his American colleagues that further communication would not be possible. By 1969, many scientists who had so far survived the ordeal were sent to the countryside for re-education, along with other “stinking” intellectuals. The only members of the scientific community spared the worst of the violence were those who worked on nuclear weapons. Premier Zhou Enlai removed these institutes from the CAS and put them into the military R&D system. Even there they were not safe, as the Cultural Revolution soon spread to the military as well. Yao Tongbin, a prominent metallurgist who worked on the Chinese missile program with the well-known Chinese rocket scientist Qian Xuesen, was publicly beaten to death in 1968.⁶⁰

At the Institute of Oceanology, all research came to an abrupt halt soon after Mao’s call for the young rebels to seize power. Red Guards took over the institute and imprisoned Tseng, a “reactionary academic authority,” in his laboratory. He was beaten, starved, placed in solitary confinement, and forced to write confessions about alleged crimes committed by himself and others. Fei recalled that when his mentor was finally released from the *niupeng* (“cow-shed”) he looked like a skeleton. Tseng was assigned to work as a janitor alongside Sun and Fei and forbidden to read scientific journals or correspond with colleagues. The rebels also persecuted Tong and other scientists in the institute. Sun Ziping, the institute’s “good Party man” who had supported all of Tseng’s research, was among five members of the institute who committed suicide during the Cultural Revolution after

⁵⁹ “Circular of the Central Committee of the Communist Party of China, 16 May 1966,” in *The People’s Republic of China, 1949–1979: A Documentary Survey*, ed. Harold C. Hinton (Wilmington, Del.: Scholarly Resources, 1980), Vol. 3, Pt. 1, pp. 1508–1511, on p. 1511; and Chinese Communist Central Committee, “Decision Concerning the Great Proletarian Cultural Revolution,” 8 Aug. 1966, in *China’s Cultural Revolution, 1966–1969: Not a Dinner Party*, ed. Michael Schoenhals (Armonk, N.Y.: Sharpe, 1996), pp. 33–43, on pp. 40–41.

⁶⁰ Kungchu Fan to Papenfuss and Paul Silva, 5 Apr. 1967, Papenfuss Papers. See Yao *et al.*, *Zhongguo kexueyuan*, pp. 141–157, particularly pp. 154–157 for the figures and pp. 146–148 on military scientists. On the fate of Yao Tongbin see Chang, *Thread of the Silkworm* (cit. n. 5), pp. 245–254. See also Wu Heng, *Keji zhanxian wushinian* [Fifty years on the scientific and technological front] (Beijing: Science and Technology Documentation Press, 1992), pp. 331–402.

his wife, head of Qingdao's Bureau of Education, was publicly clubbed to death by the Red Guards.⁶¹

The institute's Red Guards were well aware of Tseng's academic background; he was punished for attending a U.S. college, for modeling the institute after Woods Hole and Scripps, and for his wartime assistance to the U.S. military. In addition, he was condemned for working under the Nationalist government and for conducting scientific exchanges with the Soviets during the 1950s. Fortunately, Zhou Xiantong, his assistant, though a member of the Red Guards, appreciated what Tseng was trying to do for the country and remained loyal. Indeed, he risked his own life to preserve Tseng's scientific papers.⁶² Tseng and his colleagues were not always confined to the institute. At times they were transported to the countryside, where they worked harvesting wheat or assembling railroad cars. Hence Tseng was relegated to participating in the subsistence agriculture that he had sought so long to improve through science. One of the most arduous tasks was digging a large air raid shelter in the center of Qingdao in anticipation of a Soviet nuclear attack. Even when Tseng and Fei worked alongside each other, Red Guards prevented them from engaging in any prolonged discussion. Hence, Tseng endured several years of total isolation from science. Those few Chinese scientists who continued working during the Cultural Revolution had to alter their research programs radically so as to address practical topics. For example, some botanists moved to the countryside, where they studied biological nitrogen fixation as a means of increasing agricultural productivity.⁶³

The Cultural Revolution extended through the early 1970s, although many of the most flagrant abuses stopped in January 1967, when Mao ordered the People's Liberation Army to put an end to Red Guard-induced anarchy and restore order. For Tseng, relief came after an army group took over the institute in 1970; in September 1971 the charges against him were downgraded to "historical problems." That same month tension was further relieved nationwide with the death of army chief Lin Biao following his failed coup against Mao. Tseng was now allowed to participate in applied research at the institute. Gradually he returned to his scientific work and even attended some national conferences on science and science policy, including one on national science planning in Beijing and another on taxonomy in Guangzhou. These meetings marked the beginning of the recovery of Chinese science from the Cultural Revolution.⁶⁴

⁶¹ Zhu, *Zhu Kezhen riji*, entry for 6 June 1970, p. 457; Sun interview; and Fei interview. Tseng's experience is in sharp contrast to Trong R. Chai's analysis, which indicated that senior scientists suffered less than others because of their academic standing. According to Chai, "the real victims of the Cultural Revolution were the Reds and the 'non-real' Experts rather than the non-Reds and the 'real' Experts." At Qingdao both groups—as represented by Tseng and Sun Ziping—were persecuted. See Trong R. Chai, "The Chinese Academy of Sciences in the Cultural Revolution: A Test of the 'Red and Expert' Concept," *Journal of Politics*, 1981, 43:1215–1229.

⁶² Zhu, *Zhu Kezhen riji*, entry for 9 Mar. 1970, p. 343; and Tseng interview, 1994, Los Angeles. Zhou was still employed as Tseng's personal assistant in 1994 when we visited the institute. He showed us Tseng's carefully preserved correspondence in the very file cabinets Tseng had brought from the United States: Zhou interview. Other scientists were not so fortunate. Ye Duzheng, an eminent atmospheric physicist and global change specialist who studied under Carl-Gustav Rossby at the University of Chicago, lost ten years worth of research data at the hands of marauding Red Guards. Interview with Ye Duzheng by Zuoyue Wang, Peter Neushul, and Lawrence Badash, Sept. 1994, Beijing.

⁶³ The research involved the selection and cultivation of *azolla*, a water fern with high nitrogen content, for use as fertilizer in the rice field. See P. S. Tang, "Aspects of Botany in China," *Search*, 1981, 10:344–349; and Tang, "Fifty Years of Plant Physiology in China," *Bioscience*, 1980, 30:524–528. By the 1990s, the immense tunnel dug as an air raid shelter was converted into an underground shopping mall, complete with a hotel, restaurants, and storefronts.

⁶⁴ Zhu, *Zhu Kezhen riji*, entries for 5 Jan. 1972, 14 June 1972, pp. 503–504, 532; and Tseng interview, 1994, Qingdao. On the army intervention in January 1967 see Hsu, *Rise of Modern China* (cit. n. 12), p. 702. For a discussion of the overall impact of the Cultural Revolution see White, *Policies of Chaos* (cit. n. 56).



Figure 5. C. K. Tseng meets President Gerald Ford, fellow University of Michigan alumnus, in October 1975. Tseng was one of the first Chinese scientists to visit the United States after Nixon's trip in 1972. (Courtesy Gerald R. Ford Library.)

Sylvia Earle's 1973 visit came in the wake of Mao's nationally recognized reception of Richard Nixon the year before. Local authorities in Qingdao were reminded of Tseng's international prominence, which now appeared in a much more positive light. A further unmistakable sign of Tseng's rehabilitation came two years later, when Deng Xiaoping, who was purged early during the Cultural Revolution, was reinstated by Mao and Zhou Enlai to salvage the tattered national economy. Deng put his protégé Hu Yaobang in charge of the Chinese Academy of Sciences. Hu asked Tseng to be vice-chairman of a delegation of Chinese scientists visiting the United States. The trip was one of the most important in a series of scientific exchanges between the United States and China, cosponsored by the semiofficial Chinese Science and Technology Association and the Committee on Scholarly Communication with the People's Republic of China of the U.S. National Academy of Sciences. Tseng's group toured major scientific institutions in the United States, including Scripps and Berkeley, for a month in September and October 1975. The highlight of the trip was a meeting with President Gerald Ford in the White House, where a photographer captured a cheerful exchange between Tseng and Ford about the University of Michigan, their alma mater. (See Figure 5.)⁶⁵

The 1975 trip to the United States was the first for Tseng in twenty-eight years. American

⁶⁵ See Frank Press to Gerald R. Ford, 30 July 1975, and other documents in White House Central Files Subject Files, Box 13, Folder "CO-34-2: People's Republic of China, 8/1/75-10/31/75," Gerald R. Ford Library, Ann Arbor, Michigan.

oceanographic advances made a deep impression upon him, especially the use of computer and satellite-positioning technologies. He believed that if the gap between China and the West in marine science and technology had been ten years before the Cultural Revolution, it was now more like thirty years. Not without a trace of satisfaction, in view of his debate with Taylor more than thirty years before, Tseng noted in an internal report that many marine science institutions in the United States now funded programs that focused in part on the cultivation of marine algae. The trip allowed Tseng to reestablish ties with old friends and meet a new generation of Western phycologists who admired his pioneering work. On his return home, however, Tseng's connection to the United States was once again a liability, as Deng's political fortunes fell again when he was attacked by the radical Maoist "Gang of Four."⁶⁶

The politics of Chinese science did not change until Mao's death in 1976, when Hua Guofeng, his designated successor, ordered the arrest of the Gang of Four. Deng later forced the dogmatic Hua out and returned to power yet again in the late 1970s; he quickly launched the Four Modernizations Drive, first proposed by Zhou Enlai, to improve Chinese agriculture, industry, defense, and science and technology. The pragmatic Deng introduced market-oriented reforms and restored the utilitarian policy that had governed science in much of the pre-Cultural Revolution period. Tseng was appointed director of the Institute of Oceanology in 1978 and started an ambitious program to revitalize Chinese marine science and technology.⁶⁷ In 1980 he finally became a member of the Chinese Communist Party, to which he had first applied in 1956. He shuttled between Qingdao and Beijing to gain funds for his institute, visited the United States, Canada, Japan, and Europe, and sent students and assistants to study abroad. In 1985 he was elected a member of the Third World Academy of Sciences.⁶⁸ During the 1990s he devoted his energy to promoting what he called "farming and ranching of the sea," while also conducting research on marine biotechnology. The Dengist reform was a mixed blessing for China's scientific enterprise, as basic science was neglected in favor of short-term money-making technologies. Tseng, who had defended applied research during the 1950s, now found himself fighting to sustain China's basic research establishment, using the success of his maricultural enterprise as evidence of the value of theoretical scientific work.⁶⁹ (See Figure 6.)

⁶⁶ Zhongguo kexue jishu daibiaotuan [Chinese Science and Technology Delegation], *Chuguo canguan kaocha baogao: Meiguo rougan ziran kexue qingkuang jieshao* [Observations on several aspects of natural sciences in the United States], for internal distribution (Beijing: Chinese Science and Technology Press, 1977), Ch. 2: "Marine Science," p. 38; and Tseng interview, 1994, Qingdao. See also Zuoyue Wang, "U.S.-China Scientific Exchange: A Case Study of State-Sponsored Scientific Internationalism during the Cold War and Beyond," *Historical Studies in the Physical and Biological Sciences*, 1999, 30:249-277.

⁶⁷ See Roderick MacFarquhar, "The Succession to Mao and the End of Maoism, 1969-1982," in *The Politics of China: The Eras of Mao and Deng*, ed. MacFarquhar, 2nd ed. (Cambridge: Cambridge Univ. Press, 1997), pp. 248-339. Tseng characteristically made the well-being of the institute and marine science his top priority, even retaining some researchers who had been members of the institute's Red Guards during the Cultural Revolution. Only a trace of bitterness was detected in 1977, when Walter Munk of Scripps, a distinguished physical oceanographer, became the first U.S. scientist to visit Qingdao as part of a delegation led by Philip Handler, president of the National Academy of Sciences. Munk provided a detailed report on the state of oceanography in China and was particularly impressed with Tseng's achievements. He questioned Tseng about his experiences during the Cultural Revolution but found the scientist hesitant to discuss those unproductive years. Finally, one day, Tseng pointed to a passing truck driver and informed his astonished visitor that "this gentleman was the director of our institute during the Cultural Revolution." Telephone interview with Walter Munk by Peter Neushul and Zuoyue Wang, Sept. 1997.

⁶⁸ On Tseng's acceptance as a Party member see Bo, "Zeng Chengkui" (cit. n. 11), p. 427. For further information on the Third World Academy of Sciences (TWAS) see <http://www.ictp.trieste.it/TWAS/TWAS.html>.

⁶⁹ For some of Tseng's work during the 1990s see *Selected Works of C. K. Tseng*, ed. Qin (cit. n. 7), Vol. 2, pp. 1203-1273; an argument on behalf of basic research is C. K. Tseng, "Wuoguo haiyang shengwuxue yanjiu

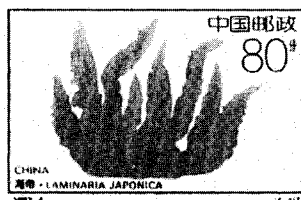


Figure 6. The achievements of Qingdao's Institute of Oceanology were honored by the creation of a Chinese postage stamp depicting *Laminaria* in 1992.

CONCLUSION

Within C. K. Tseng's life and career are many ironies and contradictions that speak to the tensions in Chinese science and society in the twentieth century. As a youthful nationalist, Tseng wanted to become an agricultural expert to improve the lives of his starving countrymen, but in order to achieve this goal he had to enroll in a foreign missionary school that refused to register with the Nationalist government. Later, the only way he could study Chinese marine algae was to seek a mentor in the United States. Rejecting a promising career in the West, Tseng returned home after World War II to pursue his dream of "agriculture in the sea." In an unusual departure from the traditional view of "basic" feeding "applied" research, Tseng maintained that in many instances applications work actually advanced the study of phycology. In China he used a flexible combination of basic and applied research, appropriate technologies suitable to local conditions, and "heterogeneous engineering" to sustain his scientific program. This enabled him to adapt to an increasingly unstable and often dangerous social and political milieu. Just as he succeeded in supplying China with a new source of food, the country was plunged into a devastating famine during Mao's Great Leap Forward. Hence his triumph was eclipsed by the total failure of the "mass science" that characterized what is now universally regarded as a Great Leap Backward.

Full of patriotic enthusiasm, Tseng welcomed the Communists in the 1950s, but his American education made him a political suspect during ideological campaigns and kept him out of the Communist Party for a quarter century. Indeed, his wartime assistance to the Allies (China included) was a key charge leveled against him during the Cultural Revolution. Tragically, a man who sought to save the nation via science and technology was rewarded with imprisonment and humiliation because of his foreign ties.

How do we explain the seemingly irrational persecution of scientists and engineers who gave up comfortable lives in the West to return and help China? The revolutionary utilitarian science policy of the 1950s and the outright abuse of scientists and engineers during the Cultural Revolution reflected Mao's distrust of these Western-trained "white" experts. This anti-intellectualism finds its roots in China's ambivalence toward the Western use of science and technology to pry open the heavenly gate of the Middle Kingdom. Mao used this long-standing ambivalence to bolster his image as a nationalist hero who saved China from foreign powers. The dark side of this rampant nationalism reached its nadir with the

cujin liao haiyang nongmuhua shiyan de fazhan" [Marine biological research in our country has advanced the cause of the farming and ranching of the sea], *ibid.*, pp. 1229–1234. On the Dengist reform see Miller, *Science and Dissent in Post-Mao China* (cit. n. 5), pp. 69–124.

formation of fanatic Maoist personality cults that fueled the mass violence of the Cultural Revolution.

One should not, however, conclude from Mao's persecution of scientists that the Communist Party or the Red Guards were monolithically evil. Tseng had welcomed the new government and its support for his flourishing research programs. Sun Ziping, the Party secretary of the Qingdao institute, did his best to provide both material support and political protection. Zhou Xiantong, the Red Guard who remained loyal to Tseng, took a considerable political and personal risk to save his mentor's scientific papers. To be sure, some lower-ranked people were sacrificed to save senior scientists during the Anti-Rightist movement, and Tseng himself removed the outspoken Sun Guoyu from the Great Leap Forward projects. These measures were necessary to save the institute and the maricultural enterprise during ideological purges. Similar compromises have occurred in other totalitarian regimes.⁷⁰

These and other tragedies should not obscure the significance of Tseng's maricultural revolution, which thrived despite the political turmoil and at a time when exchange of ideas with the West was sporadic at best. Tseng and his coworkers were the first to breach the oceanic frontier with a unique combination of new maricultural science and technology. Largely a Chinese achievement, this success breaks the stereotypical image of China and other developing countries copying Western technology.

Tseng's ocean farming experiment suggests that science and technology can be socially constructed, but only to a certain degree. To be sure, the social and political environments in China shaped maricultural research in many ways. Indeed, Tseng's nationalist spirit fueled his drive to farm the sea and dictated his philosophy of science and technology. The new Chinese Academy of Sciences provided crucial institutional and ideological support for his research. Above all, Tseng took advantage of the Great Leap Forward, making a critical transition from laboratory science to large-scale farming. But the wider failure of "mass science" and communes—an experiment in the social construction of agriculture—during the Great Leap Forward parallels that of Lysenkoism and collectivization in the Soviet Union. In both instances reality intervened, demonstrating beyond a doubt that there are limits to the social construction of science and technology. Sadly, in both countries millions of people paid the price for the warped fantasies of their leaders. Tseng's experience demonstrates that neither science nor technology can reach its full potential without addressing human concerns.⁷¹ Minus basic freedoms, science cannot enjoy prolonged success. Totalitarian regimes may provide science with money and opportunity, but inevitably their lack of stability and of democratic governance lead to upheavals such as the Great Leap Forward and the Cultural Revolution, devastating science along with the rest of society.

⁷⁰ On compromises made by Soviet scientists during their "cultural revolution" in the 1920s and 1930s and beyond see Alexei Kojevnikov, "President of Stalin's Academy: The Mask and Responsibility of Sergei Vavilov," *Isis*, 1996, 87:18–50.

⁷¹ On the social construction of science and technology in the Soviet Union see Graham, *What Have We Learned?* (cit. n. 5). See also Graham, *Ghost of the Executed Engineer* (cit. n. 5); and Xu Liangying, "Essay on the Role of Science and Democracy in Society," in *Chinese Studies in the History and Philosophy of Science and Technology*, ed. Fan Dainian and Robert S. Cohen (Boston: Kluwer, 1996), pp. 5–11.