

Life with Tetrapods: The Nature of Concrete in Okinawa

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Note: This essay accompanies the photo essay of the same title, which can be accessed online at the link above.

The well-prepared mainstream visitor to Okinawa—the kind who pores over standard travel guides and promotional material—will likely know about the famed *hoshizuna* (star sand), minuscule exoskeletons of a tiny marine organism. Washed ashore by the millions onto the beaches of the outlying Taketomi, Iriomote, and Hatoma islands, *hoshizuna* are collected as common souvenirs. These tiny star-shaped grains represent a bit of bottled paradise. It is unlikely, however, that the Okinawa-bound will come across any mention of the far more conspicuous denizen of Okinawa's shores: the tetrapod. The ubiquity and sheer mass of these multi-ton, four-footed concrete structures forcefully assert their claim as true icons of the island's coast, even though they are invisible in the iconic images that boosters produce and tourists consume. Also invisible in this most visible of objects bulwarking Okinawa's coastline are the multidimensional circumstances and intersecting forces of their existence and their evolution into other cultural forms. This photo essay seeks to make some of these circumstances and forces visible through, ironically, what the images might lead us to think about *beyond* their overt visual content. The aim here is modest: to open up thinking in several directions about this prominent form of coastal development, one that seems to fly in the face of Okinawa's public image as a place of abundant natural beauty and tropical resort beaches.



View from along the seawall at Shiosai Park, Okinawa, looking toward Senaga Island, which parallels the landing approach at Naha Airport. Photo by Gerald Figal.

Presenting raw photographs of concrete-hardened stretches of coastline as if they speak for themselves risks limiting them to the role of evidence in a critique of the environmental degradation of Okinawa's natural shoreline. Such a critique is as legitimate as it is common, and I share in the sense of loss it implies, but stopping short at the surface of the image does little to advance insights into how tetrapods have proliferated and how they have been accommodated and exploited by life around them. Common, too, is critique of well-known influence-peddling and corruption within Japan's construction industry, which keeps the concrete flowing; I'd like to move beyond those controversies.¹ The images presented here are intended not as endpoint evidence, but rather as visual cues to thinking about life with tetrapods beyond the surface and outside the obvious. With these images I'd like to prod viewers to consider tetrapods as a complex growth—or growth complex—spawned and sustained by particular political, economic, commercial, cultural, and environmental conditions in Japan in general, and in Okinawa in particular. In hopes of encouraging more nuanced thinking about the relationships between natural and built environments, I consider the ways local wildlife and human culture have, for better or worse, reacted and adapted to the spread of this curious concrete form.

I have been one of those well-prepared visitors to Okinawa who, for research and leisure, have consumed a great deal of promotional material designed to cast Okinawa in the most attractive light (see Figal 2010). But, when touring the island, analog film camera slung over my shoulder,² I have not always been a typical visitor. Whether on fieldwork forays or personal photo walks, I tend to look for things not commonly looked at and linger longer than the time it takes to snap a shot with a smartphone. For as many photos I have taken of picture-postcard landscapes, seascapes, and cultural sites, there are as many images of urban ephemera, coastal effluvia, and junkyards. The passed-over, half-baked, and discarded draw my attention as much as the landmarked, well-designed, and highlighted. Tetrapods fall into a more specific category of object that captures me and vice versa: odd artifacts. Before looking at what this particular odd artifact is doing in Okinawa, let's review its origins and global spread.

The Birth of a Sea Monster

After various preliminary studies the outline took shape: a sort of sea monster with four tentacles which was patented under the name "tetrapod."

—Pierre Danel, at the Fourth Conference on Coastal Engineering, Chicago, October 1953

¹ For the best quick English-language overview of tetrapods in Japan and a profile of their supporters and detractors, see Hesse (2007).

² For starters, I almost always use analog film cameras of many varieties and formats. Most of the images in this photo essay are scans of film negatives or prints taken during trip to Okinawa in 2017 and 2018. A few were taken on an iPhone 6s+ because circumstances dictated it. All of the images are mine unless otherwise indicated.

The “sea monster” that French hydraulic engineer Pierre Danel unveiled to the international community of coastal engineers in 1953 was the result of research and testing at the pioneering Laboratoire Dauphinois d’Hydraulique Neyrpic in Grenoble, France. The project grew out of a commission from the French Navy to secure the stability of seawalls at its naval base in Mers-el-Kébir, Algeria.³ Danel and his team aimed to improve on three main aspects of the walls: their hydraulic properties (stability of components, overall strength of structure, reduction of wave overtopping, wave reflection), construction properties (weights of materials, ease of fabrication, simplicity of installation), and cost. After testing various designs, he dubbed the one that hit the sweet spot in satisfying these goals the “tetrapod.”⁴ The first real-world application of this invention was completed in early 1951 at Casablanca, Morocco where 256 tetrapods, each weighing 15 metric tons were positioned over two existing jetties to protect the cooling water intakes of a thermal power station (Danel and Greslou 1962, 473). In March 1951, Danel filed for a U.S. patent, which was granted in October 1956 for “Artificial Blocks for Structures Exposed to the Action of Moving Water” (figure 1⁵).

The title and the cross-section drawing included in the patent application highlight the first important thing to understand about tetrapods: they were designed as secondary structures to shield primary structures (seawalls, jetties, rubble-mound breakwaters, and building foundations) against deterioration caused by wave action. In coastal engineering parlance, their function is “armor,” and tetrapods are often referred to as “armor units.” Tetrapods were not intended to be stand-alone structures, but such installations do exist on beaches in mainland Japan and Okinawa. In other words, tetrapods typically do not add to the length of built coastlines; rather, they add to their bulk and longevity.

Nine years after introducing the tetrapod at the Fourth Conference on Coastal Engineering, Danel followed up at the Eighth Conference in 1962 with a report assessing how well the fifty-five tetrapod installations around the world had performed over several years of service. The tetrapods had met expectations, sometimes in the face of brutal storm surges. The few cases of minor damage were largely attributable to building below manufacturer recommendations because of budget shortfalls. The tetrapod had proven itself and had reached a level of acceptance that, as Danel concluded, “can be said to have entered the field of standard practice” (Danel and Greslou 1962, 481). What is striking—besides the early success of the tetrapod—is its quick adoption worldwide. Danel’s examples included installations in Morocco and Tunisia (French protectorates until 1956);

³ A major French naval base, Mers-el-Kébir gained notoriety for the British Royal Navy’s attack on it July 3–6, 1940, to liquidate the French fleet before it fell into German hands after the fall of France the previous month. After the war ended, France retained the base where, in addition to naval operations, it hosted an underground atomic testing facility. The Évian Accords that ended the Algerian War in 1962 included provisions for the French to retain control of Mers-el-Kébir until 1977, but they withdrew earlier, in 1967.

⁴ The fascinating details of the physics, engineering, and economics that make tetrapods such a successful and elegantly simple design are beyond the scope of this article.

⁵ Figure numbers refer to image order in the accompanying photo essay, which may be accessed online at <https://cross-currents.berkeley.edu/e-journal/issue-30/figal>.

Wellington, New Zealand; Maui, Hawai'i; Crescent City, California; Mumbai, India; the Carmague Coast, France; and Westerland, Isle of Sylt, Germany. Japan was not among Danel's examples, but by the late 1950s the "sort of sea monster with four tentacles" could be spotted here and there in Japanese waters, where they would later proliferate to a globally unprecedented extent along Japan's approximately 30,000-kilometer coastline.

A chronological examination of the proceedings of the Conference of Coastal Engineering, the flagship international gathering of field specialists, offers hints about the tetrapod's foothold in Japan. The first Japanese presenters appeared at the Seventh Conference held in The Hague, Netherlands, in August 1960. The occasion for the participation of the twelve researchers who presented six papers was the coastal damage caused on September 26, 1959 by Typhoon No. 15 (The Ise Bay Typhoon), the most destructive storm to hit Japan since World War II, killing more than five thousand people and causing vast damage throughout the Tokai region.

The first paper provided an overview of coastal problems in Japan and efforts to solve them. Given Japan's geography, authors Homma Masashi and Horikawa Kiyoshi noted, human settlement has historically been concentrated among fertile coastal plains, often on reclaimed estuary land that is developed for habitation, agriculture, and fisheries "utilizing the coastal areas to an utmost extent for survival as well as prosperity" (Homma and Horikawa 1961, 904). In the modern period, ports and new industries associated with overseas import-export accelerated this development and further concentrated populations and commerce near coastlines. Homma and Horikawa also reminded their audience that Japan's coasts are among the most battered in the world, suffering seasonal typhoons, earthquake-induced tsunami, and strong yearlong wind waves. Post-World War II reconstruction further sharpened this convergence of economic-driven human settlement (including "artificial interferences" such as dams for hydropower and upstream flood control projects) and geographical-meteorological conditions prone to threatening this pattern of rapid growth. The presenters shared a scenario in which Japanese national survival is naturally dependent on securing and protecting coasts for human livelihood. Put another way, the development of coastlines is largely predetermined by natural circumstances, even though that development is challenging to sustain *because of* natural circumstances. In their examples of then-recent coastal protection measures, Homma and Horikawa mentioned a last-ditch effort to reinforce and raise the height of a slumping breakwater in Niigata with the use of 4-ton tetrapod blocks. Unfortunately, the tetrapods did nothing to mitigate the slumping.

The impression is that although tetrapods were known at the time, they were not in widespread standard use yet. In presenting another paper at the 1960 conference, Hosoi Masanobu and his colleagues compared the damage to coastal dikes in Ise Bay caused by the 1959 typhoon to that of an earlier smaller typhoon in 1953, supporting this impression. They provided an argument for the adoption of tetrapods: the dikes that suffered the least damage in 1953 had their back sides sheathed in concrete slabs, rather than leaving the usual packed clay, turf, or sand bags exposed, but even they were breached in 1959 because of the excessive storm

surge and resulting water pressure in the backflow that scoured and cracked the slabs (Hosoi et al. 1960).

The dispersal of backflow water pressure was precisely one of the aims of Danel's tetrapod design; his experiments indicated that a semi-open structure of heavy, interlocked, rough rounded forms was superior to surfaces of flat concrete slabs and square concrete blocks in dispersing wave energy while standing up to water pressure. So why then was there not wider use of tetrapods in places like Ise Bay prior to Typhoon No. 15, given the well-known issues of storm damage to Japan's coastal development and the growing number of successful tetrapod installations worldwide?

The answer is likely economic. The Allied occupation of Japan had just ended in 1952, and it was not until 1955 that the Japanese government's "Economic White Paper" announced that Japan's per-capita gross national product had surpassed its prewar levels. However, the majority share of Japan's industrial infrastructure in 1955 was still in agriculture, not manufacturing. Reconstruction and economic recovery were also uneven throughout the country; provincial coastal towns did not necessarily share in the development witnessed in Tokyo and other large cities. Large-scale port development throughout the country did not take off until the early 1960s. Moreover, 1950s Japan was still a time of getting by and making do, not one of adopting cutting-edge industrial innovations for coastal protection. Those concrete slabs covering the exposed clay back sides on Ise Bay's dikes *were* the innovation, despite being made obsolete by the advent of the tetrapod worldwide. The large-scale deployment of such innovations would come only after Japan's high-growth period gained traction in the early 1960s. In its brief historical outline of wave-dissipating blocks in Japan, the Nihon Shōha Nagatame Burokku Kyōkai (Japan Wave-Dissipating Block Association; hereafter, the NSNBK) highlights the 1960s as the decade of their rapid spread in Japan, following the 1960 publication of government plans for coastal protection and the first of a series of seaport development plans in 1961 (Nihon Shōha Nagatame Burokku Kyōkai 2017, 4). In their surveys of typhoon damage, Japan's coastal engineers of the 1950s had brought attention to an issue that policymakers of the 1960s saw in terms of national economic development; they also, in effect, identified a market opening. With increasing capital and government-directed initiatives for port development, all that was needed was a company to exploit this opening.

The Tetra Corps Comes to Japan/Okinawa

In May 1961, the same year the papers of the Japanese coastal engineers were published, Nippon Tetrapod Co., Ltd. (Nihon Tetrapodda Kabushiki Gaisha 日本テトラポッド株式会社) was founded in Tokyo "with production and sales of tetrapods, and design and installation of the construction thereof as the primary business objectives."⁶ Registered as a construction business, it added a technology research center in 1969; merged with Shutoken Printing and Binding Company, in

⁶ Fudo Tetra Corporate History <http://www.fudotetra.co.jp/english/about/enkaku.html> (Japanese version: <http://www.fudotetra.co.jp/about/enkaku.html>).

1972, as the surviving company; established Tetra Trading Company in 1993; changed its name to Tetra Corporation in 1995; became a subsidiary of Fudo Construction Corporation in 2004; and, a month after buying Toa Civil Engineering Company in September 2006, merged with Fudo Construction (with Fudo, the surviving company, changing its name to Fudo Tetra). Fudo Tetra exists today as a general contractor for civil engineering projects and has a portfolio that includes expressway interchanges, viaducts, railway tunnels, dams and levees, sewer systems and waste water processing plants, gas and electrical power facilities, airports and artificial islands, ports, and coastline facilities. Tetrapods still form a core of Fudo Tetra's business, and the company holds the rights to the trademark "Tetrapod," which was originally applied for in 1971 and granted in 1976.⁷ Fudo Tetra is one of fifteen major companies in Japan that manufacture some form of *shōha burokku* 消波ブロック (wave-dissipating block; or, *shōha negatame burokku* 消波根固ブロック, wave-dissipating foundation block), the trademark-neutral term for any block designed for armoring coastal structures against wave action.⁸ Fudo Tetra itself offers twelve different types of wave-dissipating blocks, including *the* Tetrapod, the granddaddy of them all.

It is estimated that since the advent of Japan's high-growth period from the early 1960s, coastline altered by concrete has, by some measures, reached nearly 50 percent of Japan's coast, with about 30 percent in the form of tetrapods and other types of wave-breakers. A natural candidate for coastal armor, given its greater frequency of damaging storms, Okinawa nonetheless lagged behind mainland Japan because of the U.S. occupation of Okinawa until 1972, during which mainland companies like Japan Tetrapod Corporation were restricted from doing direct business in Okinawa, and the Okinawa District of the U.S. Army Corps of Engineers did not invest in this type of coastal armoring. Even if Japan Tetrapod Corporation had been able to lease its tetrapod molds to local construction companies, there was no locally owned, large-scale cement production in Okinawa until 1964. The occupation did, however, introduce to postwar Okinawa the widespread use of concrete and cement blocks for military base construction, public facilities, and commercial buildings in the early 1950s. Despite the fact that such construction did a better job of standing up to storms, Okinawans resisted it for private residences because of climate, cultural, and economic reasons. They could not afford the air conditioning needed for concrete homes in Okinawa's heat and humidity, stone structures were associated with traditional Okinawan graves and prewar *fuuru*

⁷ Japanese Registered Trademark 1184901. Registration data and a facsimile of the Tetrapod trademark can be found at https://www.j-platpat.inpit.go.jp/web/TR/JPT_1184901/3D7C5C9BF22BF53CC2DC539667C19B34. Unless there is a reason to specify Fudo Tetra's actual product, I use lowercase "tetrapod" generically to refer to the original four-footed block and other types of wave-dissipating blocks.

⁸ Sometimes the first two characters are reversed—波消ブロック—and pronounced "*namikeshi*." A good example appears in a pamphlet (figure 30) produced by the NSNBK to explain the function and value of coastal armoring to elementary schoolchildren. All fifteen major manufacturers of *shōha burokku* and their molds are NSNBK members. I discuss this long-standing trade association's work later.

(pigsty latrines), and timber was, on balance, less expensive. With limited local timber suitable for construction and a rise in prices in the mid-1960s for timber imported from mainland Japan—limited by U.S. policy on Japanese business in Okinawa—concrete became more cost-effective than timber. Demand for concrete even for residential construction doubled between 1965 and 1971, the year before Okinawa reverted to Japanese rule (Chinen and Shiba 2015, 148–150). After the 1972 reversion, cultural resistance to homes built with concrete fell as living standards rose and air conditioners became widespread.



View of an industrial site from among the tetrapods piled along a walkway at the mouth of the Kokuba River, which empties into the East China Sea just north of Naha Airport. Photo by Gerald Figal.

Reversion opened the floodgates to mainland businesses and brought massive construction to Okinawa, buoyed by special development funds and finance loans from Tokyo. Japan Tetrapod Corporation was among the wave of contractors arriving in Okinawa to modernize its infrastructure, including its coastal protection. With promises to close the gap between development of Okinawa and that of the mainland, the Japanese government has, since reversion, provided Okinawa Prefecture support for infrastructure construction that has arguably gone beyond

what is needed. Labeled “compensation politics,” these funds appear to many as de-facto bribes in exchange for hosting U.S. bases. It is no wonder that dams, highways, and coastal armoring appear more cutting-edge than most residential and commercial buildings in this local manifestation of what critics refer to as Japan’s “Construction State.”⁹ Ironically, whereas Okinawa was behind the mainland in tetrapods per capita because of U.S. bases before reversion, it is now ahead of the mainland in tetrapods per capita, in part because of the compensation politics of U.S. bases after reversion. I lack full data on the chronology and volume of tetrapod introduction into Okinawa—that is among my pursuits for further planned research—but presently approximately 55 percent of Okinawa Island’s coastline is either fully artificial (with various types of seawalls) or landfilled (by a combination of seawalls and asphalt over natural earth) (Masucci, Acierno, and Reimer 2018). Fudo Tetra has a branch office in Naha and features four Okinawa-based projects in its “Tetrapod Pamphlet,” including one on the cover (figure 2). Because of their enormous weight and the large numbers needed for any given project, tetrapods are not factory-made and distributed. Rather, the molds used to make them, available from Fudo Tetra in sizes from 0.5 to 80 metric tons, are leased, and the concrete is poured onsite. Prices for Okinawa and Hokkaido Prefectures run about 9 percent higher than the rest of Japan, with a standard 4-ton mold costing ¥10,530 with tax (about US\$100) for a two-month lease, not including maritime shipping costs to remote islands or ground transportation within remote islands.¹⁰ It is unclear whether the higher costs for Okinawa and Hokkaido are due to their peripheral locations or reflect a markup that exploits the government development funds that both areas receive. This lease system cuts overall shipping costs and offers flexibility for production but also requires special equipment onsite and coordination with local transport and material suppliers. The largest recent coastal armoring project in Okinawa is associated with the construction of a second runway at Naha International Airport. As in the case of Kansai International Airport (for which Fudo Tetra provided the seawall armoring), the runway is being built on an artificial island created by landfill secured with a perimeter of seawalls reinforced by tetrapods. The first phase of this ¥200-billion (approximately US\$1.8-billion) project funded by the central Japanese government began in 2014—after environmental impact studies and transplantation of existing coral and grassy seabed—and is on track to be completed in time for the 2020 Tokyo Olympics. By mid-2017, a clear outline of the tetrapodded perimeter materialized (figures 3 and 4).¹¹

⁹ See, for example, McCormack (1995). American writer and Japanologist Alex Kerr (2000) pulls no punches in his critique of Japan’s “Construction State.” He singles out coastal concrete, especially in Okinawa, as the prime culprit for the ruination of Japan’s natural coastlines. Influence-peddling and corruption in Japan’s construction industry is, as Kerr details, well known.

¹⁰ An overview of Fudo Tetra’s Tetrapod products and price lists for leasing Tetrapod molds are available at <http://www.fudotetra.co.jp/products/tetrapod.html>.

¹¹ Onsite Journal of the Naha Airport Project website maintained by the Okinawa General Bureau overseeing the project at <http://www.dc.ogb.go.jp/Kyoku/information/nahakuukou/genbanikki.html>.

Of course, not all of the engineered coastline in Okinawa is armored by tetrapods, but much is. They have become an integral and impactful part of commercial, residential, and public leisure spaces, whether or not they are visible in the tourism promotion materials highlighting beach swimming and marine sports. If you look closely at tourist guides to beaches in Okinawa, however, tetrapods are sometimes visible in the background, especially of public-access beaches, because most of those photos have been artificially enhanced. Upscale hotel beach resorts not already blessed with natural beaches tend to minimize use of raw concrete to capture and secure their sands if they can, relying more on using natural rocks or building more refined structures in high-visibility areas.¹² The majority of sandy public-access beaches on Okinawa Island, on the other hand, have been engineered, shaped by the effects of groins, seawalls, and jetties constructed from the shoreline. These structures accumulate sand transported by wave-driven longshore drift, depositing it on the updrift side of the structure, thus building up the beach on the updrift side at the expense of the loss of deposits on the downdrift side. The Google Maps satellite photo of the overtly engineered public Zanpa Beach and adjacent private Uza Beach (restricted to guests of the Okinawa Zanpa Misaki Royal Hotel and Uza Terrace Beach Club) clearly reveals the pattern of the longshore drift generated by waves off the East China Sea and the corresponding buildup of sand against the groin on Zanpa Beach. The contrast with the thinner, but more discreetly engineered and more natural-looking Uza Beach to the south is also evident (figure 5). Public beaches in Okinawa enhanced in this way typically display two or three groins or seawalls designed to generate one or two defined areas. A central T-shaped groin-jetty combination that does double duty to capture sand and break waves distinguishes many Okinawan swimming beaches, such as Nishihara Kirakira Beach (figure 6). A close-up of the T-shaped head at this beach reveals a line of hundreds of tetrapods piled over a submerged breakwater in front of the structure to absorb and dissipate the brunt of the wave energy directed at the jetty (figure 7). In this kind of deployment, the most visible material is the more natural-looking—but more erosion-prone—quarried natural stone that forms the foundation of the visible structure, while the potential eyesore of the concrete tetrapod armoring is practically invisible from the beach. There are, in fact, indications of a trend in Japanese coastal engineering to think more about shoreline aesthetics by submerging breakwaters further offshore and camouflaging seawalls with native vegetation (Baird 2016).¹³

¹² Most of the premier resorts featuring more natural white sand beaches in Okinawa are on the smaller, less populated outlying islands around Okinawa Island or farther south in the Miyako-Yaeyama island chain. Photos of their beaches are often highlighted in tourism promotion for the entire prefecture.

¹³ Taiwan-based designer Sheng-Hung Lee has recently won several awards with his “TetraPOT” (<http://shenghunglee.wixsite.com/design/tetrapot>). Promoted as sustainable “greener sea defense,” TetraPOT is an ingeniously semi-hollowed-out tetrapod designed to allow mangrove trees and other plants to grow from it such that their natural root systems intertwine to help anchor the tetrapods for more natural, and more natural-looking, shoreline protection. Given the design, it is more suited to such environments as mangrove estuaries (like those in Taiwan and the southern Ryukyus) than ocean coasts.



Close-up of Nishihara Kirakira Beach's groin-jetty structure with the most visible part in natural stone hiding tetrapods piled on a submerged breakwater offshore. *Source:* Google Maps.

By contrast, little attempt is made to mask the vast majority of tetrapods at industrial sites and commercial ports (sea and air) or along miles of coastal roads and walkways where function precedes aesthetics (figure 8). That is not to say they do not possess their own brutalist beauty in an industrial setting (figures 9 and 10), incite geometrical wonder through sheer scale of deployment to a vanishing point (figures 11 and 12), or offer opportunities for provoking ironic and un-ironic juxtapositions (figures 13 and 14). As we will see, there are people who consider tetrapods beautiful—even cute—regardless of context. Nonetheless, aside from situations where their rough concrete bulk might seem especially incongruous, tetrapods exist in plain public view on miles of Okinawa's coastlines, and one is never too far from a coast. Urban access points to the sea—even those used for leisure activities—forego attempts to minimize or camouflage use of tetrapods given the density of surrounding seaside development in need of protection from storm surges. At Naminoue Beach in Naha, for example, tetrapodded seawalls conspicuously compete with crisscrossing highway overpasses in asserting a concrete presence (figures 15 and 16). The beach draws more local residents than tourists, the latter coming to the area instead to visit famed Naminoue Shrine situated on the cliffs above, so grooming the beach for the tourist gaze is probably not a priority. Indeed, if not for the shrine and its sacred association with *nirai kanai*, the overseas mythical paradise of the gods, the entire area might have very well been further landfilled for commercial use or to expand the walkway to the park that lies nearby to the south. In any case, locals looking to cool off from city heat, though perhaps chagrined at having to share the shoreline with so much concrete, seem to accept the circumstances and make the best of such bits of beach in urban areas. But theirs is a passive adaptation to this built environment. Elsewhere, others—human and animal—have actively evolved their lives around them.

Unnatural Selection

Darwin tells us, roughly, that species who best adapt to their circumstances stand a better chance of long-term survival. For centuries, humans have settled in fertile coastal plains, harvested the ocean for sustenance and profit, and established ports for overseas commerce. When their seaside structures have faced the erosive effects of ceaseless waves and damage from periodic storms, people have acted to protect their expanding economic and territorial interests, typically by hardening harbors and coastal settlements with breakwaters and seawalls of wood, stone, concrete, and steel. Tetrapods represent the latest refinement—or evolutionary step, if you will—to this particular approach to securing coastlines for human life and exploitation. Whether this combative stance (human versus nature) is sustainable in the future is debatable as studies of the long-term effects of these coastal interventions on beach erosion and shoreline ecologies suggest mixed benefits. Still, it is no surprise that inhabitants of Japan, geographically squeezed into settlement on coastal plains while at the same time exposed to seasonal typhoons and occasional tsunami, have operated under a bunker mentality and have enthusiastically deployed coastal armoring as a key defense against nature's maritime threats. In Okinawa, this scenario, parallel to its tetrapod use, is intensified: located in the heart of the Western Pacific's Typhoon Alley, Okinawa receives on average three times the number of typhoons per year compared to mainland Japan, and most of its population of approximately 1.4 million resides within two miles of the coast. Seen from the perspective of tetrapods, Okinawa is the most evolved prefecture in Japan. But how has human and animal life there evolved around this evolution in coastal protection?

I had noticed—even photographed—tetrapods during trips to Okinawa but had never really looked at them closely, let alone clamber among them. That all changed during a photo walk one night in June 2018, thanks to three stray cats skipping along the tetrapods that buttress a promenade along the harbor in Naha (see aerial Google Maps image [figure 10]), where I took figure 9, 17, and 18. After my initial surprise, I took a seat on the short wall separating promenade from tetrapod pile and readied the flash on my film camera. I spent perhaps a half-hour marveling at the nimbleness and familiarity these strays displayed quickly appearing, disappearing, and reappearing through the openings among the concrete blocks that seawater lapped against just a few feet below. These cats displayed familiarity with people too, nearing the one who had a camera but not the promise of food that likely propelled their approach. Even the camera flash didn't scatter them. They weren't going anywhere; the wall of tetrapods was their home.

After that night, I began to wonder about the capacity of tetrapods to create new, unplanned habitats, and started to seek out creatures who have adapted to living with them. I don't think those three stray cats were a fluke; there were numerous signs of life among the tetrapods. For example, several species of crabs—including eviscerated ones that had seemingly fallen prey to predators—are easily spied above and below the waterline, joined by a variety of barnacles, limpets, snails, slugs, worms, algae, seaweeds, birds, fish, and humans. On one of my spontaneous Google Maps-guided drives in Okinawa (whereby I select a destination

solely by the cartographical intrigue it presents), I found myself at a small harbor—a glorified boat landing, really—on Hamahiga Island, one of many small islands connected to Okinawa Island by overwater roads and bridges (figure 19). I was intrigued by how the harbor was formed by integrating two small natural outcroppings tied to the island with seawall pathways and two breakwaters fortified by tetrapods. A marker for the “Grave of Amamichu” (a female deity credited, along with her partner, Shirumichu, with creating the first inhabitants of the Ryukyu Islands) on one of the outcroppings drew my interest, but I ended up spending far more time on the other outcropping where the lifeforms among the tetrapods stacked along the outer wall of a wide concrete extension captured my attention (figure 20). I took out a panoramic pinhole film camera and my iPhone. There was no indication why one lone tetrapod had been placed on the pavement, but it acted almost like a signpost or display piece (figure 21). Following the natural outcropping to the water’s edge led me to a short stretch of tetrapods shared by fishermen on the far end and, closer by, a striking crab (figure 22). Placing my pinhole camera as close to the waterline as possible to capture the fishermen brought me within view of limpets, barnacles, and snails above the surface of the clear blue-green water and small fish below (figures 23 and 24). These creatures are not especially unusual for any artificial or natural shoreline, but the open form and the larger, more varied surface area of a tetrapod wall distinguishes it from a plain seawall and makes them more akin to a reef with some of the function of a tide pool.¹⁴ The combination of creatures and their forms of interaction also distinguish the particular ecological environments that tetrapods generate.

Fishing from jetties and seawalls is also not unusual, but *ana-zuri* (hole-fishing) among tetrapods has its own well-developed leisure-sports culture in Japan, with an ardent following in Okinawa (figure 25). This pastime represents a very particular human adaptation to the way marine life has adapted to the presence of tetrapods. Scores of groups, online chat forums, how-to YouTube videos, and obsessively detailed printed and online guides attest to the popularity of *ana-zuri*. The consensus among enthusiasts is that it is popular for two reasons: first, tetrapods attract within easy reach species of marine life that usually inhabit rocks and reefs offshore, thus offering greater variety of catch near the shore; second, fishing among tetrapods is flat-out cheap and simple. Although there are rods, lures, hooks, and jigs specially designed and marketed for *ana-zuri* among tetrapods (such as the “Tetora Dama”—Tetra Ball—in figure 26), a hook, line, and sinker will do.¹⁵ Drop a line in a deep gap between tetrapods and hits can be frequent, especially in

¹⁴ In fact, the latest trends in ecological engineering for coastlines include the development of bio-enhanced submarine concrete structures that actively foster marine life growth on them, effectively serving as scaffolding for the creation of reefs. See, for example, the products of the recent Israeli startup company EConcrete at <https://econcretetech.com/>.

¹⁵ The introduction to tetrapod fishing gear at <https://kurashi-no.jp/10008686> is one of the more comprehensive and best organized. To see some of that gear in (successful) action on the tetrapods of Tomari Port in Naha, see <https://www.youtube.com/watch?v=JZJRFwJMFqE>. For a demonstration of cheap and easy fishing among tetrapods with minimal gear, check out this video of two locals on the coast of Kadena Town, Okinawa, the site of the largest U.S. Air Force base in Asia at <https://www.youtube.com/watch?v=GpIKXLOUlmw>.

Okinawan waters where a relative abundance of fish thrive (figure 27). Fishing guides do point out the dangers of fishing from tetrapods. These safety concerns—falls against the concrete, cuts from barnacles, slipping and getting trapped under water and drowning—are also cited by those who oppose tetrapods for environmental and aesthetic reasons. The combination of ease, low cost, and species variety is, however, compelling. (I have yet to hole-fish among tetrapods, but intend to do so during my next research trip to Okinawa.) Many *ana-zuri* enthusiasts appreciate the opportunity to fish for species that would otherwise require a boat to reach their natural habitats, but tetrapod critics claim that the fish drawn to tetrapods for shelter and to feed on the smaller marine life also drawn to tetrapods are often invasive, upsetting natural ecologies. That claim may be true, but my interest here is focused on the creation of new ecologies around tetrapods. I intend to explore the full impact and sustainability of such formations in future research. For now, I propose we make room to think outside the traditional dichotomies of natural/artificial and native/nonnative. Revolving around “invasive” tetrapods—above, below, on, and in between them—we witness the interaction of many “invasive” species (including human), arguably forming new ecologies that neither exist naturally nor are consciously human-made, something we might identify as a formation born of naturally evolving unnatural selection.



Hole-fishing (*ana-zuri*) among tetrapods, Hamahiga Island. Photo by Gerald Figal.

Collateral Undamage

I am not the first to consider tetrapods as infrastructure for new, unintended ecologies. The NSNBK, the wave-dissipating block industry association to which Fudo Tetra and fourteen other Japanese wave block companies belong, has been pushing that idea for at least a decade, although from a different angle. I don't share this group's self-interested, uncritical position—or more precisely, its sidestepping of legitimate critique through aggressive promotion of benefits without addressing environmental costs—but I view its research projects and public relations campaigns as a fascinating intersection of culture, media, politics, economics, science, and

technology worthy of closer study. It unapologetically presents an understanding of natural environment with humans fully in it, and does so in a persuasive way. Here I want merely to highlight briefly the NSNBK's efforts (also reflected in Fudo Tetra's own advertising) to define coastal armoring as critical for human life in Japan and as protective—even nurturing—of marine life and coastal ecosystems.

Founded in 1967, six years after the incorporation of Japan Tetrapod, the NSNBK states its goals as follows:

The Association's activities aim to conduct research surveys of construction technology related to civil engineering that uses wave-dissipating blocks, to work diligently on construction methods and technology, and to contribute to the preservation of national land and the improvement of the environment, thereby improving the everyday life of the national citizenry.¹⁶

The key phrase here is *kankyō no seibi* (improvement of the environment). The word *seibi* appears regularly in construction and development documents. With a euphemistic resonance, it suggests the mutual benefits of development for human society and natural environment. The NSNBK's promotion of improvement of the environment through wave-dissipating blocks is advanced largely by hosting research conferences and lectures, publishing research results and industry news, and—most important for our consideration here—public outreach that involves all of the above. The highlights of the history of wave blocks in Japan presented by the NSNBK in an illustrated pamphlet produced for its fiftieth anniversary follow a thematic arc starting in the 1960s with depictions of research and development, coastal preservation policy statements, and various coastal engineering projects and then moves on to foreground the harmonious protection and even enhancement of natural environments through wave block technologies from the 2000s. On that timeline is the organization's 2007 leaflet *Shizen to tomoni...* (With nature...), whose artwork and catchphrases currently adorn its homepage.¹⁷ In a handful of colorful pages, the leaflet captures this recent emphasis on coastal armor units working to protect and enhance the natural as much as the human world. In this framing, from the viewpoint of a tetrapod's function, there is no difference between the natural and the human. This message is overt in the first full foldout spread featuring wave blocks such as tetrapods, humans, and nature flourishing together in safety; it claims that wave block installations *rejuvenate ruined nature* as they simultaneously protect against natural disasters made increasingly more frequent and extreme by climate change and other human impact (figure 28). Dozens of photos from longitudinal studies of the ecological effects of block installations serve to demonstrate empirically that sea life thrives with them as they “foster an ecosystem with an outstanding natural symbiosis function and preserve the marine environment, thus contributing to a safe and secure society” (Nihon Shōha

¹⁶ Nihon Shōha Nagatame Burokku Kyōkai, <http://www.shouha.jp/about/> (my translation).

¹⁷ Links to a PDF for *Shizen to tomoni* and to the NSNBK's fiftieth-anniversary materials are available from its homepage at <http://www.shouha.jp/>.

Nagatame Burokku Kyōkai 2007, 2). Note the connection between a “safe and secure society” (which in this context means physically safe and economically secure) and a “preserved” marine environment within a redefined ecosystem that naturalizes artificial structures. This is the core message of the NSNBK website, which gives dozens of detailed examples of “the flow of natural symbiosis” between marine life and wave blocks throughout Japan. Only by reading the text does the viewer realize that what at first glance appears to be a visual record of environmental damage caused by artificial marine structures is the opposite—it is presented as proof of side benefits to nature, of collateral *undamage*.

Consider one of several examples from Okinawa, three breakwaters situated in Naha Port. The data given indicates that the structures were installed between 1974 and 1983 using tetrapods and another type of wave block known as a *dorosu* (dolos), both from Fudo Tetra.¹⁸ An outline map shows the breakwaters in relation to the port and area shoreline, accompanied by a cross-section drawing of construction type. The six sample photos, supplied by the Okinawa General Bureau that oversees development projects in Okinawa, were taken in 1997, 1999, and 2005 from between one meter above water and 5 meters below. As the accompanying commentary explains, they show not only the coral growth observed accumulating on the wave blocks from the late 1980s but also the blocks before and after a major bleaching event in 1998 that weakened and killed coral throughout the area.¹⁹ The blocks in the 1999 photo are stripped of the coral visible in the 1997 photos, and the 2005 photos reveal the resumption of modest growth (figure 29). This example does double duty: it demonstrates that coral can naturally take to wave blocks placed in their midst and that wave blocks can serve as a substratum for the recovery of coral in places where it has weakened or died. This latter phenomenon opens the way to the creation of artificial reefs, a whole other category of wave blocks and business that the NSNBK website features. One of its examples of an artificial reef installation is from Kunigami, the northernmost section of Okinawa Island.²⁰

The efforts by the industry to cast wave blocks as environment-friendly and even environment-enhancing correlate with growing general public awareness of the environmental impact of coastal development. In recent years, environmental activists and local residents have demanded the curbing of the use of tetrapods and their removal from some areas.²¹ Fudo Tetra and the NSNBK are well aware of this

¹⁸ The dolos, which is shaped like an “H” twisted 90 degrees at the center of the crossbar, has South African origins. Its inventor, Eric Mowbray Merrifield, did not patent the design.

¹⁹ Data and commentary for this example are available at http://www.shouha.jp/case1/100/103_1/168.php. A coral-bleaching event occurs when unusually warm waters drive out the algae that symbiotically inhabits the coral, turning it white. If the absence of algae is prolonged, the coral becomes overly stressed and vulnerable to dying.

²⁰ See details at <http://www.shouha.jp/case1/100/102/243.php>.

²¹ For example, residents of Nakagusuku, on the east coast of central Okinawa Island, made their complaints known to Okinawa Prefectural Government officials, who put together an action plan to remove some tetrapods and consider more careful siting of installations in order to provide better direct access to areas around Nakagusuku Harbor (Okinawa-ken 2017, 3).

criticism and have acted to blunt and preempt it by researching more ecological and aesthetically appealing approaches to coastal armoring and showcasing what they frame as “natural symbiosis” between nature and concrete. There do appear to be genuine efforts in the industry to work toward greener coastal engineering solutions, but public relations campaigns are already very green now. Like its seagrass-green and ocean-blue company logo, Fudo Tetra’s public face exudes environmental friendliness as it presents itself as a steward of Japan’s beautiful natural patrimony. Much of Fudo Tetra’s 2018 Corporate Social Responsibility (CSR) Report emphasizes its partnership with nature and efforts at improving civil engineering technologies and construction techniques for the sake of natural and human environments.²² Perhaps the most farsighted area of industry public relations, however, is educational outreach to children, like the NSNBK’s leaflet for elementary schoolchildren, *Namikeshi burokku tte nani?* (What are wave-dissipating blocks?), which is full of anthropomorphized cartoon tetrapods (figure 30). Fudo Tetra sponsors educational events to familiarize children with tetrapods, including the opportunity to make your own miniature concrete specimens (figure 31). Teaching children that Mr. Tetrapod is a “natural” denizen of the sea as well as their friend and protector like a policeman or firefighter aims to produce adults who are less prone to question tetrapods in the future. And bringing tetrapods down to a child’s size as a handmade art object may cultivate affection for them.

Cute Cool Concrete

Public outcry over the concrete encasing Japan’s coasts is something I expected to find when doing this research; a vibrant community of tetrapod lovers was not. The manifestations of this love are too numerous and too varied—and too fascinating—to present a full survey here, but I would like to conclude by introducing this phenomenon as a next-stage evolution of tetrapod-generated ecologies, moving onto land and inhabiting the world of popular culture and consumer goods in which tetrapods have become cute and cool.

Otaku hobbyist culture is the most obvious context in which to find the most serious subset of tetrapod enthusiasts. Most commonly associated with obsessive zeal for manga, anime, video games, computers, and garage kits (scale models, often of anime characters), otaku hobbyists—typically male, but not always—are distinguished by the extreme lengths to which they will go to master the data and details of their chosen subject. They are particularly prevalent for industrial and technological objects, but not limited to obvious and globally popular hobbyist items like trains, planes, and automobiles. A fanaticism for coastal engineering and its tetrapods is much more in otaku style. There are several forums on popular Japanese bulletin boards discussing minute details and sharing information, images, and observations about tetrapods, but the most extensive single-authored wave block web presence is the Engan Bōeitai Kenkyūjo 沿岸防衛体研究所, also known (by its own translation) as the Coastal Defence Object Institute (CDOI), authored by

²² Fudo Tetra CSR Report, 2018, available at <http://www.fudotetra.co.jp/csrreport.html>.

Ganboken (an acronym of the site's name and also the author's Twitter handle).²³ The CDOI's main feature is a set of personal onsite surveys of wave block installations and related sites across Japan, with photos, technical data, narrative descriptions, and a Google Map pinpointing each site visited. As of February 2019, there were 123 entries. The website also includes more than 150 entries on particular types of wave blocks, special reports, videos, and links to other collections of tetrapod photos. Ganboken's impulse for comprehensive and in-depth recording of data about the hobbyist object is classic otaku and, as someone researching the world of tetrapods, I'm grateful for it. Ganboken's profile indicates an early fascination with tetrapods that blossomed with the introduction of the Internet and led to his August 2006 creation of the Shōha Burokku Mania Site, which became the CDOI in 2009. It is still active today with more than seventy-seven thousand total visits. With a manga-style tetrapod as his avatar, Ganboken has been tweeting since June 2013 (figure 32).

Not all love for tetrapods is technical. For some fans, it's emotional and physical. Eleven months after Ganboken created the Shōha Burokku Mania Site, *Japan Times* contributor Yumi Wijers-Hasegawa picked up on this quirky cultural trend and wrote about it in a short article, "Tetrapodistas: Beauty Beheld in Huge Concrete Forms" (Wijers-Hasegawa 2007). "Astonishingly," she begins, "despite their unsightly impact on natural scenery, the Internet is full of geeks who appear to love tetrapods." Wijers-Hasegawa relates finding online romantic odes to tetrapods and other expressions of their allure among fan sites. She quotes a man, whose website displayed several kinds of tetrapods: "Why did I come to like such a thing? ... The minute I saw it, I felt like something inside of me was awakened. Why did I get so excited? I always liked shapes, but that feeling was different from any other time." Another man also professed his attraction to the shape of tetrapods, buying a railway model kit only for the tiny plastic tetrapods that were included in it: "I was just fascinated by their shapes." The bulk of the article is an interview with freelance photographer, writer, and industrial-form aficionado Ōyama Ken, coauthor of *Kōjō Moe* (Factory affection), a photo book catering to factory and industrial-site *otaku*.²⁴ He gushes about the functionality, soundscape, and construction of tetrapod walls, noting they are randomly "assembled together with the same shapes.... It's so lovely!" He even philosophizes about the existential tension felt walking over them, knowing that something dropped between them is irretrievably lost. He understands the widespread attraction to tetrapods from the viewpoint of a serious observer of industrial forms: "When you look at them carefully, there are very few things with such unusual shapes.... I even think that it's in human beings' nature to be attracted to such things" (quoted in Wijers-Hasegawa 2007).

²³ The name Engan Bōeitai puns on the name of the Japanese *jietai* (land, sea, and air self-defense forces) by replacing *rikujō/kaijō/kōkū* (land/sea/air) with *engan* (coast) and substituting the *tai* 隊 (force) of *jietai* with *tai* 体 (body or object); tetrapods are the coastal defense forces. Explore the CDOI at <http://ganboken.blog26.fc2.com/blog-category-2.html>.

²⁴ The word *moe* is a slang term from *otaku* circles connoting a strong affection among typically male fans for typically cute female fictional characters depicted in manga, anime, and video games. Ōyama extends this sense of *moe* to industrial forms, including tetrapods.

Not too long after this interview, on February 15, 2008, Ōyama posted on the popular website *Daily Portal Z* patterns and photos for making a tetrapod from a sheet of paper. His photos were accompanied with text describing quasi-erotic attraction for the objects, proclaiming that “after that [writing an article on appreciating out-of-water tetrapods] my passion for tetrapods hasn’t cooled. A tetrapod-covered coast is cooler than a white-sand beach. My Gold Coast is the tetrapod group on the southern tip of the Miura Peninsula.”²⁵ His paper tetrapod pattern caught the eye of a designer who approached him for the rights to use it as a model for a *nuigurumi* (plush toy), which he freely granted. Within the year, a plush tetrapod was manufactured and marketed as a gray felt-covered cushion called Tetogurumi. It sold well online and in selected boutiques. On January 30, 2009, its appearance on the market elicited a follow-up story on *Daily Portal Z* entitled “Tetogurumi ga kawaii” (Tetogurumi is cute). At that time, complications arose. A reader recognized the pattern as the one that he had posted on another website before Ōyama’s post on *Daily Portal Z*. He did not blame Ōyama for passing the publicly posted pattern to others (Ōyama posted an apology for presenting the pattern as his own creation), but he did hold the makers of Tetogurumi responsible for seeking proper licensing from its true inventor. Tetogurumi was taken off the market for over a year until public demands for its return brought it back, this time properly licensed.



A tetrapod tote, one of many tetrapod-themed items available for fans online and in select brick-and-mortar boutiques. Source: <http://tetogurumi.seesaa.net/>.

²⁵ Ōyama Ken’s post is archived at <http://s04.megalodon.jp/2009-0429-1819-50/portal.nifty.com/2008/02/15/b/>. The original accompanying images have been removed because of the ensuing intellectual property rights dispute sparked by his tetrapod pattern. However, screenshots of the original post with images can be found on *Gigazine*’s reportage of the incident at http://gigazine.net/news/20091030_danchidanchi_dpz/.

Today, Maniapparel manufactures Tetogurumi, which comes in three sizes—12, 25, and 38 centimeters (just under 5, 10, and 15 inches)—and two shades of gray, and is distributed through online sites, such as Tetogurumi Official Web Store, and brick-and-mortar retail outlets (figure 33).²⁶ Moreover, the cult popularity of Tetogurumi has gone mainstream, opening the market to other tetrapod-shaped products, such as phone and camera straps, erasers, soap, doorstops, lamp shades, and modeling kits, as well as all manner of tetrapod-themed apparel and accessories (shirts, totes, hand towels, hats, rubber stamps, smartphone cases, stickers, clear files, and so forth) (figures 34 and 35). And as one might imagine, tetrapod-themed goods are well established in Okinawa as well. Tetrapots—a “fishing fashion brand from Okinawa” co-founded by fishing enthusiasts and the well-known Okinawan drummer Takazato Satsohi of the punk rock band Mongol800—now sells a large line of Tetrapots-branded clothes and fishing gear featuring a classic tetrapod figure as part of its trademark (figure 36).²⁷ The brand’s catchphrase is “Save the Ocean, Love the Ocean,” and its identity is formed around fishing, street fashion, ocean conservation, and coastal beautification. It has supported conservation and beautification efforts by donating portions of sales of silicone bracelets to coral transplantation projects and through activities such as organizing coastal cleanups. It has not publicly stated a position on the tetrapods on Okinawan coasts.

Closing Remarks

With his invention of the tetrapod in 1949, Pierre Danel created something that has since proven itself attractive in expected and unexpected ways. Much of that attraction comes from its shape, size, and setting. As a piece of engineering, its design represents a brilliant example of midcentury modern form and function. The elegant combination of its physics, fabrication, installation, economics, and effectiveness is seductive to engineers, contractors, policymakers, and artists alike. “I think the attraction of tetrapods,” art student Kobori Motohiro opined, “lies in their contrast with nature. The material of a tetrapod is concrete and its shape is formal, which can’t be found in nature. Also, it is manufactured by pouring concrete into molds. The tetrapod is a symbol of artificiality. Setting hundreds of tetrapods on a big scale that matches that of nature is simply art” (quoted in Hesse 2007, 3–4). Or, as graphic designer Kobayashi Ryo explained, “Tetrapods are massive and practical but at the same time sexy when you look at their curvilinear beauty. If concrete had a life, I think a tetrapod is the orthodox way that concrete should evolve” (quoted in Hesse 2007, 9). In Japan, where tetrapods have evolved as orthodoxy, and in Okinawa, where they share coastlines with beach resorts and coral reefs, they appear—contrary to Kobori’s echoes of Christo—naturalized, or at least pragmatically accepted within an understanding of nature that accommodates, rather than excludes by definition, humans and their built environments. Under contemporary conditions of advanced consumer capitalism in a country chock full of technological knowhow, design sense, artistic creativity, ardent hobbyists, tinkerers,

²⁶ Tetogurumi Official Web Store is at <https://tetogurumi.thebase.in/>.

²⁷ Order your Okinawan fishing fashion at <http://tetrapots.com/>.

and aficionados of all things cute, the transformation of this coastal armor unit into art piece, plush toy, brand logo, and object of desire should not be, upon reflection, too surprising. It might be only a matter of time until we see tetrapods featured in a travel guide to Okinawa.

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