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The Attack of the Kelp on K: A Prospective Look into a Nutritional Phenomena on Carrying Capacity

Introduction

6.6 billion. There is little doubt the first humans would have fathomed that their successors would now reach such population numbers (CIA, 2008). It is beyond even more doubt that our population numbers have reached prodigious growth rates. Human beings reached their first billion in population at around 1804, a feat estimated at 200,000 years to come by. The second billion took 123 years, the third at 33 years, and since then, a billion additional people every 13 or 14 years. The six-billion-people mark was reached in 1999. (Raven, p. 12). The fact of the matter is, human populations numbers, especially in the past few decades, are higher than any other point in known history.

Reverend Oto Diederich Lutken in 1758 proclaimed, "since the circumference of the globe is given and does not expand with the increased number of its inhabitants…the wise Creator…did not intend…that multiplication should continue without limit" (Cohen, p. 7). His sentiments concluded that there are more people than the physical world can have room for. This *given* circumference, as Lutken describes, finds itself at a challenging dilemma between a fixed amount of "earth" - physical, biological, and social environments – and a growing number of inhabitants on this earth. The dilemma leads itself to an upper limit of growth that human populations have endured for millennia known as a "global human carrying capacity".

Human Carrying Capacity

Previous verbal definitions of human carrying capacity have varied in context in the past few decades. Some incorporate the integration between humankind and earth's natural resource base. It has been described "as the level of human activity that a region can sustain at acceptable 'quality of life' levels" (House and Williams, pp. 54-55). James Kirchner took it a bit further, noting that maximum populations can be sustained if there is not "degradation of the natural resource base" (Kirchner, et al., p. 45). One must inquire, then, "…at what quality of life does one live at"? Richly? Poorly? In addition, how can a human society sustain themselves without degrading their surrounding natural resources? Could a man not chop down a nearby tree knowing his family could not survive that evening without the firewood for fuel?

Other definitions find a cultural dimension to population limits, as first coined by Garrett Hardin as "cultural capacity", or "what the environment will carry in the way of cultural amenities" that "includes all of the artifacts of human existence" (Hardin, p. 603). Can these embedded cultural artifacts – buildings, language, education systems, or currency – define how many people will live in a given population?

More recent definitions have included more external forms of existence such as technology, economics, and consumption. Gretchen Daily and Paul Ehrlich find that "carrying capacity varies marketly with culture and level of economic development", while Maurice King sees given technology and consumption patterns, two qualifications that consumes our ecosystems' natural resource base, instrumental to human population gradients (Daily and Erlich, pp 762-63, King, 23). At what rates can technology affect one's standard of living? Will a country with greater material consumption rates have more or less carrying capacity than those with fewer consumption patterns? How would these rates affect the *total* global capacity?

Finally, there are scholars who are unsure of qualitative or quantitative measures to human carrying capacity due to future populations' unpredictability. According to Donella Meadows, carrying capacities are "always changing with weather and other external changes and with the pressure exerted by the species being carried" (Meadows et al., p. 261). Similarly, Gerhard Heilig notes that it "is not a natural constant – it is a dynamic equilibrium, essentially determined by human action" (Heilig, 255). A truly comprehensive definition, one could imagine today, would encapsulate all those mentioned above. Thus, a global human carrying capacity is the maximum number of persons that can be supported indefinitely on an area, with given technologies, economic development, cultural identities, and set of consumption and waste habits, without causing physical, biological, and social degradation.

With that, there are few people known in the world who yearn to live in dire, unhealthy situations. It is certain, ideologically, that human beings will want the best for fellow human beings. It is this sense of "well being" that all individuals should have the right to. A sense of true human well being is comprised of many facets. In the *Millennium Ecosystem Assessment*, it consists of five different, but interconnecting categories: security (personal safety, resource access), basic materials (access to goods, nutritious food, shelter), health (strength, access to clean air and water), social relations (mutual respect, ability to help others), and freedom of choice and action (Millennium Ecosystem Assessment, p. 4).

Joel Cohen uses the calorie as a simple and quantifiable measurement to well being. Cohen states that "any single number is a ridiculously simple measure of well being [like a calorie] for a creature as complex as a human being" (Cohen, p. 283). The calorie is a single number to emphasize the freedom of choice an individual has in contrast to natural constraints like water. Food is core to humanity's existence. It is the lifeline for human beings, families, and communities. Jay Forrester, a systems scientist at the Massachusetts Institute of Technology, has explained that food also plays an integral role to human carrying capacity. He noted in 1971, "…the world [that] has normally existed in…sensitive region[s] where food regulations birth and death rates so that population maintains its precarious existence at the maximum number of people that the available food can sustain" (Forrester, 1971). This measurement of the calorie, which allows for the freedom of choice, will then be adapted to quantify well being. In this context, the calorie will be explored as a working definition to determine the limits and possibilities to the human carrying capacity defined earlier.

Life is unpredictable and unforeseeable, regardless of humans' constant preparation. History can attest to a multitude of events, acute and chronic, that have had beneficial and detrimental effects to human well being, carrying capacity, and global populations. History can also attest to natural human adaptations to such events, whether it be through policy, technological innovation, change in institutional management, migration, or market appropriations (Raven, pp. 10-11).

Shock Scenario

A new phenomena, then unpredictable and unforeseeable, has now manifested itself to life. A new kelp variety, with fifty times the North American yield of potato, is highly nutritious, easily flavored, and thrives in polluted water. This new variety has been researched for the past decade in the laboratories of one of the largest global agribusiness corporations settled in developed nations. Because it is not formally sanctioned by any international agreements or policies on free trade, the corporation plans to invest strategic development plans of the kelp through developed countries – governments, for-profit businesses conglomerates, and affluent global economies – and then market the variety to coastal third-world developing nations.

Food security, defined as "access by all people at all times to enough food for an active, healthy life" provides people the right to an adequate diet (World Bank, 1986). The ability to provide food is a priority for most sovereign states, and doing so will depend on access to commodities and will power of government support and the action of its people. The agribusiness corporation acknowledges this right to food security and considers partnering with governments and farmers to attain that right. It recognizes that nearly 800 million people do not have access to food for healthy and productive lives and an additional 1.5 billion are undernourished, most of which are in Africa. (Raven, p. 55 and Matthew, May 6). It also realizes that providing this new kelp variety will be a mechanism to stimulate sustainable economic development.

"Launch Year' Carrying Capacity

Global production of food has been insurmountable in the past half century. From 1950 to 1991, world grain production rose by a factor of 2.7, while at the same time, the area harvested for grain grew only seventeen percent (Postel, 1994). Global grain production doubled only in the past three decades (Holmes, 1993). In order to keep average grain supplies per from decreasing, world grain production will have to double again in the next half century. It is estimated that providing better food and seed varieties, new technologies, and expert knowledge may increase present harvests by fifty percent (Holmes, 1993 and Smil, 1994).

One particular model of carrying capacity that will be adapted is Joel Cohen's projected population assumptions based on a natural constraint (domestic water) and a human choice (kilocalories from irrigated agricultural yields). The model carries various assumptions: fraction of available water captured for use (20% and 100%), two extreme caloric assumptions about diet (2,350 kilocalories and 10,000 kilocalories per day), and two extreme assumptions about plant growth loss (10% and 40%) (Cohen, 1995). To best quantify the shock scenario, caloric values were increased by an average of an additional 500 kilocalories to the original wheat diets, as a simple estimate. This is under the indirect assumption that the kelp provides an individual with more caloric intake to their diet and it is easily accessible to all people. The amount of available water and plant growth loss were held constant. (Table 1).

Table 1

Renewable freshwater requirements per person for irrigated agriculture, and the maximum population that can be provided with domestic water and food produced from irrigated agriculture, under various assumptions.

Usable Fraction of Water	Wheat Equivalent for Avg Diet	Fraction of Lost Calories	Water Required Just for Irrigation	Maximum Population if 41,000 cubic km water/yr	Maximum Population if 14,000 cubic km water/yr	Maximum Population if 9,000 cubic km water/yr
(%)	(kc/day)	(%)	(m3/person/ day)	(billions)	(billions)	(billions)
20	2,350	10	1,306	30.5	10.4	6.7
20	2,850	10	1,583	25.3	8.9	5.6
20	2,350	40	1,958	20.5	7.0	4.5
20	2,850	40	3,420	11.9	6.1	2.6
20	10,000	10	5,556	7.3	2.5	1.6
20	10,500	10	5,833	7.0	2.4	1.5
20	10,000	40	8,333	4.9	1.7	1.1
20	10,500	40	8,750	4.7	1.6	1.0
100	2,350	10	261	137.5	47.0	30.2
100	2,850	10	317	115.8	39.5	25.4
100	2,350	40	392	95.6	32.7	21.0
100	2,850	40	475	80.1	27.3	17.6
100	10,000	10	1,111	35.7	12.2	7.8
100	10,500	10	1,167	34.1	11.62	7.5
100	10,000	40	1,667	24.1	8.2	5.3
100	10,500	40	1,750	22.9	7.8	5.0

*Calculations assume that 1,000 kc per day of edible wheat require 100 m3 per year of irrigation water. (Actual use of water in the United States is about four times this minimal amount.) The amount of renewable fresh water that must be available (in cubic meters per year per person) = (kilocalories per day)/[10X fraction of water used X (1 – fraction of calories lost)].

*Calculations based on added shock scenario (new kelp variety). It is assuming that the new kelp variety will increase the two extreme caloric consumptions of a wheat diet by an average of an additional 500 calories. Example: 2,850/(10 X 0.2 X 0.9) = 1,583. The maximum population supportable with 37 cubic meters of water for domestic uses plus food from irrigated agriculture (in billions) = 41,000/(37 + cubic meters per year per person for food). Example: 41,000/(37 + 1,583) = 25.3.

Adapted from Joel Cohen's *How Many People Can the Earth Support?* (1995: Table 14.2, p.316)

Based on the assumption that the new kelp variety would provide an increase in caloric diet, the results yielded a decrease human carrying capacity in all scenarios, provided there is domestic water and food produced from irrigated agriculture. For example, if there is 20% available renewable fresh water and the average diet requires the growth of wheat that yields 2,350 kilocalories and the fraction of calories lost is 10%, then the amount of renewable fresh water that must be available for irrigated food crops along is 1,306 cubic meters per person per year. Under this particular conditional statement, if 41,000 kilometers per year of water are available, then the maximum population is 30.5 billion.

If a new kelp variety is added to a diet, and thus increases kilocalorie intake under the same situations, the amount of renewable fresh water increases to 1,583 cubic meters per person per year. If 41,000 kilometers per year of water are available, then the maximum population is now 25.3 billion, nearly a 17% drop from the original conditional statement. Simply, greater caloric intake (human choice) requires more irrigated water (natural constraint), resulting in less land for agriculture, and thus, lower human carrying capacity. Water's control as a natural constraint limits food production and carrying capacity.

Nevertheless, this conclusion is somewhat misleading in calculating carrying capacity. The model proposed by Cohen does not take into consideration various factors like possible technological innovation, economic development, cultural identities, and consumption and waste habits. These factors, included earlier in the comprehensive definition "global human carrying capacity", are varying phenomena and events that can appreciably affect population rates.

Shock Impacts

Technological Trends

Technological innovation for increased food production is not a new phenomena. As Cohen describes in the "Local Agricultural Evolution" of 8000 B.C. – 4000 B.C., "the ability to produce food allowed human numbers to increase greatly and made it possible, eventually, for civilizations to arise". Irrigated agriculture and the plow were, then, new concepts that contributed to great rises and falls to populations. The "Global Agricultural Evolution" from 1650-1850, Cohen describes, brought the exchange of Old and New World foods and the introduction of food industrialization. Improved nutrition reduced disease susceptibility (McKeown, 1976). By the end of these two centuries, the population doubled.

Developing a new kelp variety through the use of technology, however, takes time. Let along, it has taken nearly 10,000 years since the "local agricultural evolution" to get to where food production is today. For example, a variety of barley started breeding in 1938 by the Max Planck Institute for Plant Breeding in order to improve agricultural production and become sensitive to a fungal disease. It wasn't until 1962, 24 years later, that breeders could produce best-yielded offspring resistant to the fungus (Cohen, p. 333). If it may not have been for the rise of industrial mechanization of agriculture during that period – often coined the "Green Revolution" – human carrying may have decreased dramatically or been at a standstill due to innovative technological time constraints.

While technological innovation does take time, it has been proven as a progressive tool for societal food production, particularly the emergence of biotechnology. Kent Bradford, director of the Seed Biotechnology Center at the University of California, Davis states, the "reason we have been able to have food and [have] not had these shortages for the last 40 years is in fact the green revolution and the technologies that went with it" (Moscowitz, 2008). Mechanisms such as optical sensors that scan crops in order to customize fertilizer to plants' needs and multi-crop machines that would allow farmers to grow a variety of crops in changing climate conditions can drastically improve agricultural yields.

Environmental Trends

Agricultural technological innovation, while historically lauded for immediate fixes in food production, has come with environmental degradation. Often overlooked until after the technology has been implemented, the introduction of new agricultural methods and crop varieties have proven more environmentally destructive and than its ecologically minded counterpart of organic and sustainable methods of production. The invention of the plow, for example, made soil more vulnerable to erosion by wind and water by sieving the soil and plant covers (Cohen, p. 36).

In addition, future changes to the climate are predicted to be much more variable than in the past. Increasing temperatures slow down rates of photosynthesis, and thus, plant reproduction. South Asia, producing nearly 15% of all the world's wheat, is projected to shrink by about half over the next 50 years, even as the number of mouths to feed increases. Short growing seasons won't be a problem for areas currently too cold for crop cultivation such as Siberia, North America, and Alaska de to rising temperatures

(Black, 2006). Kelp, thriving in cool water regions in 50-65 degrees Fahrenheit range, may find itself in unenviable situations growing in warmer waters, if the agribusiness corporation decides to do so (Weisz, 2007).

If unable to be grown naturally and organically, the agribusiness may decide to alter kelp genome through genetic modification and engineering to adapt to projected climatic changes. The research and development of “climate-proof” crops in the recent decade has spurred excitement and controversy. Climate-proof crops are being developed by drought-persistent regions in Africa and heavily flooded plains in Asia, all in the name of food security. One particular mechanism being explored on crops like rice is the transition from Carbon-3 (C3) to Carbon-4 (C4) plants. Maize, a C4 plants, is known to more efficiently utilize the sun and its greater carbon intake for its photosynthetic processes (Black, 2006). Thus, more maize is available and grown in a shorter period of time. This can potentially be beneficial news to not only the agribusiness, in hopes of providing food faster and more effectively, but also to those societies incessantly struck by natural disaster, famine, and food insecurity.

While genetic modification of kelp may assist those in high dietary need, the agribusiness must be cautious of their operations and handling of genetic engineering towards the environment and the people it serves. Monsanto, one of the largest multinational agricultural biotechnology companies in the world, began operations in the early twentieth century and holds more than seventy percent of the global market share on genetically-modified seeds. In 1999, Monsanto acquired Delta & Pine Land Company, a company that had been involved with a seed technology nicknamed "Terminator", which produces plants that make sterile seed to prevent farmers from replanting their crop's seed. In recent years, widespread opposition from environmental organizations and farmer associations has grown, mainly out of the concerns that these seeds increase farmers' dependency on seed suppliers (having to buy these each year for seeding new crops) (Vidal, 1999). In another example, the company dumped thousands of tons of toxic waste from their genetic seed operations into England landfills between 1965 and 1972. Toxins included Agent Orange, dioxins and polychlorinated biphenyls (PCBs) (Barlett and Steele, 2008). In both instances, as with many others caused by the company, governmental regulations were criticized for not having acted fast enough to prevent such environmental and human damage. As such, if an agribusiness corporation plans to introduce a new kelp variety, it is not necessarily what they produce, but *how*.

Little research has been conducted on the feasibility of food production in polluted waters. Of the studies that have been done, current conclusions show that the growth of plants is not significantly altered by the accumulation of heavy metals and toxins in the soil (Barman et al., 2000). However, this conclusion brings up two important points of discussion. First, the accumulation of metals, toxins, and unnatural inputs may cause deleterious effects to food production. Why are they there in the first place? Secondly, food production is not the only use for water. Globally, it is utilized for a variety of daily activities: washing, cooking, bathing, and most importantly, drinking. What considerations do these activities receive if, one day, we find all water resources, then polluted, being used solely for crop production?

Demographic Trends

While giant kelp has been harvested for nearly a century, it is a relatively new species, one in which we don't know much about. In February of this very year, a new genus of kelp, known as "Golden V" for its distinctive physical characteristics and flaxen color, was discovered near the Aleutian Islands in Alaska. With its scientific name, Aureophycus alueticus , the newly-found kelp is a boon to science. A National Oceanic and Atmospheric Administration (NOAA) scientist, Mandy Lindeberg, who was part of the team that discovered it states that "…the distinctive morphology of the Golden V Kelp, its unique geographic location, and its position in the phylogenetic tree provide important clues to the evolution and spread of kelps throughout the Pacific Ocean" (McLean, 2008). Kelps provide critical habitat for a wide variety of marine life, and represents a major step forward in understanding this resource. Thus, it may prove scientifically advantageous to conserve kelp biodiversity as opposed to domesticating its seed for food production.

Kelp is best grown in colder oceanic temperatures and has been found and mainly harvested in such latitudes as North America, Europe, and Japan. However, the current global distribution of per-capita calorie availability is greatly contrasted to kelp availability. Low-income food-deficit countries (LIFDCs) are defined by the Food and Agriculture Organization (FAO) as "those that do not have enough food to feed their populations, and for the most part lack the finances to make food the deficit with imports". Most LIFDCs are situated in arid, sub-Saharan regions of Africa in which the per-capital calorie availability is less than 2,000 calories per day. Coincidentally, the area parallels itself with the equator and consequently, warmer waters potentially unsettling for kelp varieties (AAAS, 56-57). With this comes an intermingled paradox: the areas that need to eat may not even be able to grow the kelp variety simply due to their climate.

Such weather adaptations yield the question: if it can't even be grown in such areas, are its people then willing to eat it?

Tastes, Preferences, and Moral Judgments

If the criterion for the distribution for human well being were radically changed, it would greatly affect population projections. As stated earlier, one definition adapted by the Millennium Ecosystem Assessment included five different categories that ideally encapsulates "human well being": security (personal safety, resource access), basic materials (access to goods, nutritious food, shelter), health (strength, access to clean air and water), social relations (mutual respect, ability to help others), and freedom of choice and action (Millennium Ecosystem Assessment, p. 4).

However, these varying categories may not be adequate enough to define well being for potentially three reasons. For one, all of the aforementioned categories aren't necessarily evident in all societies and cultures. Some human societies may not have access to food due to limited agricultural infrastructure or freedom of choice because of political turmoil, economic instability, or social injustice served to its constituents. Secondly, even if all known societies and cultures were quantifiably measured for well being by each independent category, there would be stratified results. A third-world, developing Southeast Asian island community may have an entirely different sense of human well being then, say, one in the United States. Cultural identities may begin to come into effect: one culture may embrace the new kelp variety while others simply may not. Finally, simply having too many categories lends itself to more difficult and complex projections to global carrying capacity. And while there have been carrying capacity projections utilizing a population surface of two elements (diet and water), the reality of creating an interactive population model with five elements (security, basic materials, health, social relations, and freedom of choice and action) seems formidable (Cohen, p. 360).

As such, substantially changing the acceptable level of material comfort may drastically change population projections as well. Material comfort denotes choice. In LIFDCs mentioned earlier, it is assumed that individuals are not given much choice in educational pursuits, economic stability, and political influence, let alone a choice in what to eat. As Kinsley Davis noted in 1991, "…there is no country in the world in which people are satisfied with having barely enough to eat" (Davis and Bernstam, 1991).

Enhancing material comfort allows for the choice of what to eat. As nations grow wealthier, the question of caloric intake goes beyond the amount eaten to *what is eaten*, or the nutritional quality of the food. Given the choice to eat usually results in foods with greater nutritional value such as meat and fish. For example, world meat production has more than quadrupled in the past half-century to some 220 million tons annually to emerging markets in East Asia, Latin America, and the Middle East. And as countries grow wealthier and urbanize, there is growing demand for meat (Ehui, 1999). What will be the choice for LIFDCs if they become economically viable and wealthier: meat or kelp?

Finally, ethical values must be considered in such a situation like the introduction of a new kelp variety. First, do the rights of individuals have priority over the rights of governments of groups, or vice versa? In a prime example spotlighting Bangladesh, families attempt to reduce vulnerability to disaster by compensating economic and mortal risks. Their short fallow periods, even in fertile soil, is little solution to incessant famines and floods that frequent the heavily-populated land (Homer-Dixon, 1992). In such a situation, the Bangladeshi people, its government, and international stakeholders must understand their community needs. As Al Gore in 1992 expressed such sentiments: “The emphasis on the rights of the individual must be accompanied by a deeper understanding of the responsibilities to the community that every individual must accept if the community is to have an organizing principle at all” (Gore, p. 277). This organizing principle, if adopted by the agribusiness corporation, must incorporate the rights of the individual and the responsibilities of the community. Unless rights are not given and responsibilities are not met, the organizing principle falls short and one group of individuals may become suppressed of their rights to exist.

The organizing principle can be extended to anthro- and eco-centric ethical viewpoints, as well. The introduction of a new kelp variety may yield various moral conflicts. For example, industrial production of this kelp through large mechanical processes may find itself as an economic stimulus to an area with previously low unemployment rates. Employees, while initially earning high profit from the agribusiness company, soon find themselves in poor working conditions - exposed to undesirable toxins, laboring for long hours without sufficient breaks, and scoffed by management. How does an employee deal with such a dilemma? Do they continue working in less-than-desirable situations in compensation for a high financial salary? The World Health Organization Commission on Health and Environment finds a middle ground to the dilemma through the establishment of first-order and second-order ethical principals. First-order principals ensure human survival, and second-order principals respect nature and control environmental degradation unless it conflicts with survival needs (WHO, 1992).

Summary

Whether it is climate change, genetic modification, water restraints, or human choice of food intake, the effects to human carrying capacity by the introduction of a new kelp variety are uneven. Population demographics influence political organization and effectiveness. Environmental goals interconnect with economic regardless. The influences of human choices, whether it be through domestic and international political institutions, technological innovations, economic development, demographic arrangements, or changes in the physical, chemical, and biological environments, are extremely complex. An agribusiness corporation, or any human entity for that matte, cannot simply produce a new kelp variety in means to extend human carrying capacity. It must consider how to interconnect external societal forces, natural constraints, environmental trends, and ethical values as mechanisms to global population control.

References

Barlett, D. L., & Steele, J. B. (2008, May). Monsanto's Harvest of Fear. *Vanity Fair*, May 2008.

Barman, S.C., Sahu, R.K., Bhargava, S.K., & Chaterjee, C. (2000). *Distribution of Heavy Metals in Wheat, Mustard, and Weed Grown in Field Irrigated with Industrial Effluents.* Bulletin of Environmental Contamination and Toxicology, 64:489-496. Springer-Verlag New York Inc.

Black, R. (2006, December 3). New crops needed to avoid famines. British Broadcasting Company. Retrieved May 10, 2008 on BBC News Web Site: http://news.bbc.co.uk/2/hi/science/nature/6200114.stm.

Central Intelligence Agency. (2008). *The World Factbook.* Washington D.C.: Office of Public Affairs.

Cohen, J. (1995). *How Many People Can the Earth Support?* New York, NY: W. W. Norton & Company Ltd.

Daily, G. C., & Ehrlich, P. (1992). Population, sustainability, and Earth's carrying capacity. *Bioscience* 42 no. 1 (November): 762-63.

Davis, K., & Bernstam, M. (1991) *Resources, environment, and population: Present knowledge, future options.* Supplement to vol. 16 of *Population and Development Review*, 1990. New York: Population Council, and New York/Oxford: Oxford University Press.

Durand. (1974). *Historical Estimates of Word Population*. University of Pennsylvania Population Studies Center, mimeo.

Ehui. (1999). *2020 Vision*, International Food Policy Research Institute (IFPRI).

Forrester, J.W. (1971). *World Dynamics*. Cambridge, Mass.: Wright-Allen Press.

Gore, A. (1992). *Earth in the balance: Ecology and the human spirit*. New York: Houghton Mifflin.

Hardin, G. (1986). Cultural carrying capacity: A biological approach to human problems. *Bioscience* 36, no. 9: 603.

Heilig, G. (1994). How many people can be fed on earth? In *The future of world population: hat can we assume today,* ed. Wolfgang Lutz. London: Earthscan, p. 255.

Holmes, B. (1993). A new study finds there's life left in the green revolution. *Science* 261 (17 September): 1517.

Homer-Dixon, T.F. (1992). Malthus in the real world: Environmental scarcity and the ingenuity gap in developing countries. Unpublished manuscript.

House, P. W, & Edward, R. W. (1975). *The carrying capacity of a nation: Growth and the quality of life*. Lexington, Mass.: Lexington Books (D. C. Heath).

King, M. (1993). Demographic entrapment. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 87 (supplement 1): 23.

Kircher, J. W, Ledec, G., Goodland, R., & Drake, J. (1985). Carrying capacity, population growth, and sustainable development. In *Rapid population growth and human carrying capacity: Two perspectives*, ed Dennis J. Mahar. World Bank Staff working Papers Number 690, Population and Development Series Number 15. Washington, D.C.: World Bank, pp. 40-89.

Matthew, R. (2008, May 6). *Natural Resources*. Lecture in Planning, Policy & Design:

Global Sustainability II. University of California, Irvine, Irvine, California.
McKeown, T. (1976). *The modern rise of population.* New York: Academic Press; London: E. Arnold.
McLean, S. (2008, February 28). Researchers discover new kelp species in Aleutians. *NOAA Fisheries*, National Marine Fisheries Service, Alaska Region. Retrieved May 10, 2008 on National Oceanic and Atmospheric Administration (NOAA) Web Site: http://www.fakr.noaa.gov/newsreleases/2008/kelp022808.htm
Meadows, D. H., Meadows, D. L, Randers, J. (1992). *Beyond the limits: Global collapse or a sustainable future.* London: Earthscan publications.
Millennium Ecosystem Assessment. *Our Human Planet: Summary for Decision-makers*. Washington, D.C.: Island Press.
Moscowitz, C. (2008, April 23). Radical Science Aims to Solve Food Crisis. *LiveScience.* Retrieved May 10, 2008 on LiveScience *Web Site:* http://www.livescience.com/environment/080423-food-shortage.html.
Postel, S. (1994). *Carrying Capacity: Earth's bottom line.* In State of the world 1994, ed. Lester R. Brown et al. New York: W.W. Norton, pp. 3-21.
Raven, P. (2000). *AAAS Atlas of Population and Environment.* Berkeley, CA: The University of California Press.
Smil, V. (1994). How many people can the Earth feed? *Population and Development Review* 20, no. 2 (June): 255-92.
UNPD. (1999). *World Population Prospects: The 1998 Revision*.
Vidal, J. (1999, October 6). World braced for terminator 2. The Guardian. Retrieved May 10, 2008 on The Guardian Web Site: http://www.guardian.co.uk/science/1999/oct/06/gm.food2
Weisz, A. (2007). Eat Kelp. *X-Ray Magazine*, 15.
World Bank. (1986). *Poverty and Hunger: Issues and Options for Food Security in Developing Countries*, World Bank Policy Study, The World Bank, Washington, DC.
World Health Organization Commission on Health and Environment. (1992). *Our planet, our health*. Geneva: World Health Organization.