全国大学生数学建模竞赛

通　讯

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全国大学生数学建模
竞赛组织委员会主办

创新意识　　团队精神　　重在参与　　公平竞争

目　录

《全国大学生数学建模竞赛通讯》征稿启事

《全国大学生数学建模竞赛通讯》主要面向全国各赛区组委会、参赛院校教育行政部门、指导教师和学生。征稿内容为：

- 赛区组委会在组织报名、培训、竞赛巡视、评阅等方面的经验和具体作法；
- 参赛院校和指导教师在组织报名、培训等方面的经验和具体作法；
- 参赛学生的体会；
- 竞赛在培养创新人才、推动教学改革中的典型事例；
- 争取社会各界支持竞赛的成功经验和作法，及社会各界对竞赛的理解；
- 国内外有关信息。

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PROBLEM B: Energy and the Cell Phone

This question involves the "energy" consequences of the cell phone revolution. Cell phone usage is mushrooming, and many people are using cell phones and giving up their landline telephones. What is the consequence of this in terms of electricity use? Every cell phone comes with a battery and a recharger.

Requirement 1

Consider the current US, a country of about 300 million people. Estimate from available data the number *H* of households, with *m* members each, that in the past were serviced by landlines. Now, suppose that all the landlines are replaced by cell phones; that is, each of the *m* members of the household has a cell phone. Model the consequences of this change for electricity utilization in the current US, both during the transition and during the steady state. The analysis should take into account the need for charging the batteries of the cell phones, as well as the fact that cell phones do not last as long as landline phones (for example, the cell phones get lost and break).

Requirement 2

Consider a second "Pseudo US"—a country of about 300 million people with about the same economic status as the current US. However, this emerging country has neither landlines nor cell phones. What is the optimal way of providing phone service to this country from an energy perspective? Of course, cell phones have many social consequences and uses that landline phones do not allow. A discussion of the broad and hidden consequences of having only landlines, only cell phones, or a mixture of the two is welcomed.

Requirement 3

Cell phones periodically need to be recharged. However, many people always keep their recharger plugged in. Additionally, many people charge their phones every night, whether they need to be recharged or not. Model the energy costs of this wasteful practice for a Pseudo US based upon your answer to Requirement 2. Assume that the Pseudo US supplies electricity from oil. Interpret your results in terms of barrels of oil.

Requirement 4

Estimates vary on the amount of energy that is used by various recharger types (TV, DVR, computer peripherals, and so forth) when left plugged in but not charging the device. Use accurate data to model the energy wasted by the current US in terms of barrels of oil per day.

Requirement 5

Now consider population and economic growth over the next 50 years. How might a typical Pseudo US grow? For each 10 years for the next 50 years, predict the energy needs for providing phone service based upon your analysis in the first three requirements. Again, assume electricity is provided from oil. Interpret your predictions in term of barrels of oil.

B 题：能源和手机

本问题与手机革命对“能源”会造成什么后果有关．手机的使用正在迅速扩大，而且许多人正在使用手机而放弃了他们的固网电话(座机)．就所用的电力而言这样做的后果是什么？每部手机都伴随有一个电池和一个充电器.

要求 1：考虑当前约有 3 亿人口的美国的情况．从可以获得的数据来估计过去有座机服务的每户人家有 m 口人的户数 H．现在，假设所有的座机都被手机替代了；即，每户人家的 m 口人每人都有了手机．就这种改变 — 无论是在转移的过程中或者是已经达到了稳定的状态 — 对当前美国的电力

使用所造成的后果进行建模. 建模分析应该考虑手机电池充电所需要的电力, 以及手机不会像座机那样使用长久(例如手机丢失或者毁坏).

要求 2：考虑一个与当前约有 3 亿人口以及同样经济状况的美国类似的第二个“虚拟美国”. 这个新兴国家既没有座机也没有手机.从能量的角度看, 什么是向这个国家提供电话服务的最佳方式. 当然, 手机有许多座机没有的社会影响和用途. 讨论只使用座机、只使用手机, 或者两者混合使用会带来的广泛的和潜在的后果.

要求 3：手机需要定期充电. 但是许多人总是把充电器插在电源上. 此外, 许多人不管他们的手机是否需要充电, 每天晚上都对他们的手机进行充电. 基于你们对要求 2 的回答, 对这个虚拟美国的这种浪费的做法的能量费用进行建模. 假设该虚拟美国是用石油来提供电力的. 用所消耗的原油桶数来解释你们的结果.

要求 4：估计由各种充电器类型(电视、DVR[2]、计算机外围设备, 等等) — 当它们插在电源上, 但是没有对仪器充电时 — 所消耗的能源多少的差异. 利用准确的数据对当前美国浪费掉的这种能源进行建模, 用每天消耗的原油桶数来表示.

要求 5：现在来考虑今后 50 年的人口和经济增长. 典型的虚拟美国可能会有怎样的增长. 根据你们在前三个要求中的回答对今后 50 年里每隔 10 年预测一下提供电话服务所需要的能源量. 再次假设电力是由原油提供的. 用原油桶数来解释你们的预测.

(译注: 本题的作者为位于美国纽约州牙买加市的约克学院(York College in Jamaica, NY) 的Joe Malkevitch.)

PROBLEM C: Creating Food Systems: Re-Balancing Human-Influenced Ecosystems

Background

Less than 1% of the ocean floor is covered by coral. Yet, 25% of the ocean's biodiversity is supported in these areas. Thus, conservationists are concerned when coral disappears, since the biodiversity of the region disappears shortly thereafter.

Consider an area in the Philippines located in a narrow channel between Luzon Island and Santiago Island in Bolinao, Pangasinan, that used to be filled with coral reef and supported a wide range of species (Figure 1). The once plentiful biodiversity of the area has been dramatically reduced with the introduction of commercial milkfish (Chanos chanos) farming in the mid 1990's. It's now mostly muddy bottom, the once living corals are long since buried, and there are few wild fish remaining due to over fishing and loss of habitat. While it is important to provide enough food for the human inhabitants of the area, it is equally important to find innovative ways of doing so that allow the natural ecosystem to continue thriving; that is, establishing a desirable polyculture system that could replace the current milkfish monoculture. The ultimate goal is to develop a set of aquaculture practices that would not only support the human inhabitants financially and nutritionally, but simultaneously improve the local water quality to a point where reef- building corals could recolonize the ocean floor and co-exist with the farms.

A desirable polyculture is a scenario where multiple economically valuable species are farmed together and the waste of one species is the food for another. For example, the waste of a fin-fish can be eaten by filter feeders and excess nutrients from both fish and filter feeders can be absorbed by algae which can also be sold, either as food or commercially useful by-products. Not only does this reduce the amount of nutrient input from the fish farming into the surrounding waters, it also increases the amount of profit a farmer can make by using the fish waste to generate a

[2] 数字视频录像机也叫数字硬盘录像机 (Digital Video Recorder). — 译注

greater quantity of usable products (mussels, seaweed, etc.)

For modeling purposes, the primary animal organisms involved in these biodiverse environments can be partitioned into predatory fish (phylum Chordata, subphylum Vertebrata); herbivorous fish (phylum Chordata, subphylum Vertebrata); molluscs (such as mussels, oysters, clams, snails, etc., phylum Mollusca); crustaceans (such as crabs, lobsters, barnacles, shrimp, etc., phylum Arthropoda, subphylum Crustacea); echinoderms (such as star fish, sea cucumbers, sea urchins, etc.; phylum Echinodermata); and algae. By feeding types, there are primary producers (photosynthesizers—these can be single cell phytoplankton, cyanobacteria, or multicellular algae); filter feeders (strain plankton, organic particles, and sometimes bacteria out of the water); deposit feeders (that eat mud and digest the organic molecules and nutrients out of it); herbivores (eat primary producers); and predators (carnivores). Just as on land, most of the carnivores eat herbivores or smaller carnivores, but in the ocean they can also eat many of the filter feeders and deposit feeders. Most animals have growth efficiencies of 10-20%, so 80-90% of what they ingest ends up as waste in one form or another (some dissipated heat, some physical waste, etc.). The role of coral in this biodiverse environment is largely to partition the space and allow species to condense and coexist by giving a large number of species
each its own chance at a livable environment in a relatively small space—the aquatic analogue of high-rise urbanization. Coral also provides some amount of filter feeding, which helps clean the water. The ability of an area to support coral depends on many factors, the most important of which is water quality. For example, corals in Bolinao are able to live and reproduce in waters that contain half a million to a million bacteria per milliliter and 0.25ug chlorophyll per liter (a proxy for phytoplankton biomass). The fish pen channel currently sees levels upwards of ten million bacteria per milliliter and 15ug chlorophyll per liter. Excess nutrients from the milkfish farms encourage fast-growing algae to choke out coral growth, and particulate influx from the milkfish farms reduces corals ability to photosynthesize. Therefore, before coral larvae can begin to grow, acceptable water quality must be established. Other threats to coral include degradation from increasing ocean acidity due to increased atmospheric CO_2, and degradation from increasing ocean temperature due to global warming. These can be considered second order threats which we will not specifically address in this problem.

Problem Statement

The challenge for this problem is to come up with viable polyculture systems to replace the current monoculture farming of milkfish that would improve water quality sufficiently that coral larvae could begin settling and recolonizing the area. Your polyculture scenario should be economically interesting and environmentally friendly both in the short and long term.

1. MODEL THE ORIGINAL BOLINAO CORAL REEF ECOSYSTEM BEFORE FISHFARM INTRODUCTION: Develop a model of an intact coral reef foodweb containing the milkfish as the only predatory fish species, one particular herbivorous fish (of your choice), one mollusc species, one crustacean species, one echinoderm species, and one algae species. Specify the numbers of each species present in a way you find reasonable; cite the sources you use or show the estimates you make in arriving at these population numbers. In articulating your model, specify how each species interacts with the others Show how your model predicts a steady state level of water quality sufficient for the continued healthy growth of your coral species. If your model does not yield a high enough level of water quality, then adjust your number of each species in a way you find most reasonable until you do achieve a satisfactory quality level, and describe clearly which species numbers you adjusted and why your changes were reasonable.

2. MODEL THE CURRENT BOLINAO MONOCULTURE MILKFISH:

a. First examine the impact if milkfish farming were to suppress other animal species. Do this by removing (setting the population to zero of) all herbivorous fish, all molluscs, all crustaceans, and all echinoderms. Set all other populations to be the same as in your full model above. Since you have removed the milkfish's natural food supply, you will need to introduce a constant term that models farmer feeding of the penned milkfish; choose this term to keep your model in equilibrium. What steady state level of water quality does your model now predict? Is water quality sufficient for the continued healthy growth of your coral species? Compare and describe how your result compares to observations.

b. Milkfish farming does not totally suppress all other animal species and water quality is probably not as bad as your results from part 2a suggest, so use your model to simulate the current Bolinao situation by reintroducing all deleted species and adjust only those populations until water quality matches that currently observed in Bolinao. Compare your populations with those currently observed in Bolinao and discuss what changes to your model could bring your population predictions into closer agreement with observations.

3. MODEL THE REMEDIATION OF BOLINAO VIA POLYCULTURE: You now strive to replace the current monoculture with a polyculture industry, seeking to make the water clear enough that the original reef ecosystem that you modeled in part 1 can re-establish itself without any help from humans. The idea is to introduce an interdependent set of species such that, whatever feed the milkfish farmer puts in, the combination of all of his/her "livestock" will use it entirely so that there are no (or only minimal) leftover trients and particles (feed and feces) falling onto the newly growing reef habitat below. Additionally, you seek to commercially harvest edible biomass from this polyculture in order to feed humans and increase value.

a. Develop a commercial polyculture to remediate Bolinao. Do this by starting with your "current" penned model from part 2b, and introduce into it additional species that both help clean the water and yield valuable, harvestable biomass. For example, you could line the pens with mussels, oysters, clams or other economically valuable filter feeder to remove some of the waste from the milkfish. Economically valuable algae could be grown on the sides of the pens near the surface (where they get enough light), and some of these could feed the small herbivorous fish that feed the milkfish. Clearly present your model and its steady state populations.

b. Report on the outputs of your model. What did you optimize, what constraints did you enforce, and why? What water quality does your model yield? How much harvest does your model yield, and what is its economic value? How much does it cost you to further improve water quality? In other words, from your optimal scenario, how many dollars of harvest does it cost you to improve water quality by one unit?

4. SCIENCE: Discuss the harvesting of each species for human consumption. How do we use your model for predicting or understanding harvesting for human consumption? Does a harvested pound of carnivorous fish count the same as a harvested pound of seaweed so that we seek to maximize total weight harvested, or do we differentiate by value (as measured by price of each harvested species) so that we seek to maximize the value of the harvest? Or do we seek to maximize the total value of harvest minus cost of milkfish feed? Should we define the value of edible biomass as the sum of the values of each species harvested, minus the cost of milkfish feed?

5. MAXIMIZE THE VALUE OF THE TOTAL HARVEST: We now wish to maintain an cceptable (maximal) level of water quality while harvesting a high (maximal) value of marketable (because edible and sell-able for byproducts are equally legitimate ways to maximize value) biomass from all living species in the model for human consumption. Change your model to harvest a constant amount from each species. What is the total value of biomass (as defined above) you can harvest and the corresponding water quality? Try different harvesting strategies and different levels of milkfish feeding (always choosing values that will keep your model in equilibrium), and graph water quality as a function harvest value. What strategy is optimal and what is the optimal harvest?

6. CALL TO ACTION: Write an information paper to the director of the Pacific Marine Fisheries Council summarizing your findings on the relationship between biodiversity and water quality for coral growth. Include a strategy for remediating an area like Bolinao and how long it will take to remediate. Present your optimal harvesting/feeding strategy from part 5 above along with persuasive justification, and present suggested fishing/harvest quotas that will implement your plan. Show the leverage of your strategy by presenting the ratio of the harvest value under your plan to the harvest value under the current Bolinao scenario. Discuss the pros and cons from an ecological perspective of implementing your polyculture system.

Getting Started References
http://en.wikipedia.org/wiki/Integrated_Multi-trophic_Aquaculture
http://en.wikipedia.org/wiki/Coral_reef
http://www.seaworld.org/infobooks/Coral/home.html

Supplementary Information

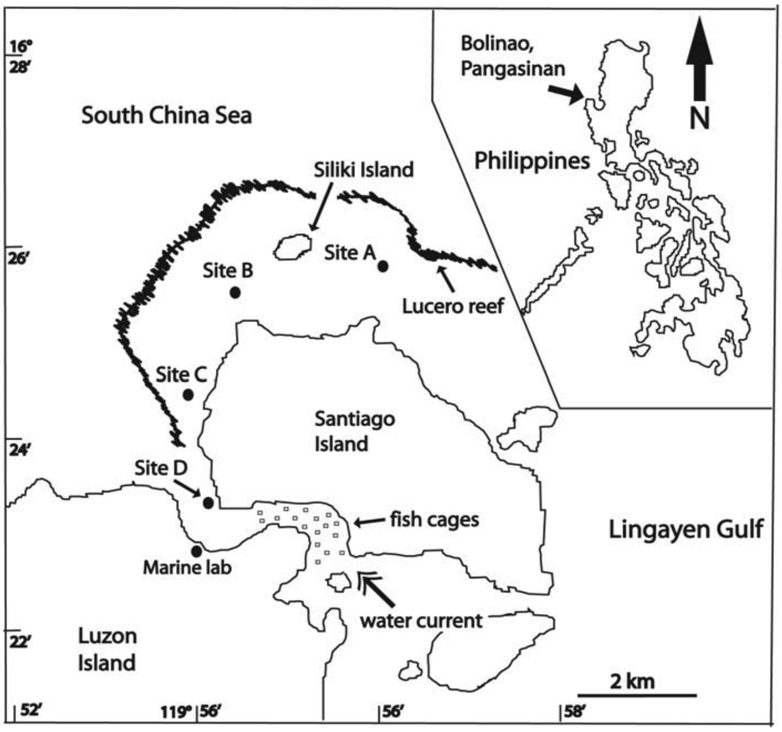

Figure 1. Map of the Bolinao area and the sites sampled for water quality data listed in Tables 1 and 2. Sites A and B have fairly healthy coral reefs while Site C has fairly degraded reefs, Site D has a few corals still holding on but is mostly dead coral and algae at this point in time, and the area under the fish pens no longer has live coral at all. In the fish pen channel, farmers employ nets measuring roughly 10m x 10m x 8m with stocking densities of ~ 50,000 fish per pen and 10 pens per hectare. (Fig. from Garren et al. 2008)

The following tables are representative of the data you will be able to find through public searches. These data may not be complete for your purposes and are intended only to help give you ideas on how to get started. You should use the best-suited and most complete data that you find. Characteristics of Site Water

Site	**Dissolved Organic Carbon (DOC) (uM)**	**Total Nitrogen (Dissolved, uM)**	**Chl a (ug/L)**	**Particulate Organic Carbon (POC) (ug/L)**	**Total Nitrogen (Particulate, ug/L)**
A	**69.7± 1.3**	**7.4±0.4**	**0.25± 0.03**	**106± 4**	**9±15**
B	**80.4± 2.9**	**8.0± 0.2**	**0.28± 0.03**	**196± 57**	**39± 15**
C	**89.6± 1.7**	**14.2± 0.7**	**0.38± 0.03**	**662± 68**	**54± 17**
D	**141± 2.9**	**30.5± 1.3**	**4.5± 0.2**	**832± 338**	**86± 45**
Fish Pens	**162± 18.5**	**39.8± 2.7**	**10.3± 0.2**	**641± 60**	**86± 18**

Table 1. Water characteristics of Bolinao sites. (from Garren et al. 2008)

Microbial Abundances and Particle Characteristics of Site Water

Site	Virus-like Particles Abundance (#/ml)	Free-living Bacteria Abundance (cells/ml)	Particle-Attached Bacteria Abundance (cells/ml)	% of total bacteria attached to particles	# of Particles per ml (particle defined as larger than 3um)		Avg Particle size (um^2)
					Detritus	Phytoplankton cells	
A	$1.0 \pm 0.07 \times 10^7$	$5.4 \pm 0.3 \times 10^5$	$5.3 \pm 2.2 \times 10^2$	<0.1	$3.4 \pm 0.2 \times 10^3$	$1.6 \pm 0.2 \times 10^2$	42.7
B	$0.8 \pm 0.04 \times 10^7$	$4.2 \pm 0.6 \times 10^5$	$3.9 \pm 0.6 \times 10^2$	<0.1	$4.4 \pm 0.2 \times 10^3$	$1.0 \pm 0.1 \times 10^2$	19.7
C	$1.7 \pm 0.1 \times 10^7$	$3.0 \pm 0.04 \times 10^5$	$113.7 \pm 3.6 \times 10^2$	3.7	$9.6 \pm 0.8 \times 10^3$	$1.1 \pm 0.1 \times 10^2$	65.8
D	$7.0 \pm 0.3 \times 10^7$	$6.1 \pm 0.6 \times 10^5$	$144.5 \pm 5.6 \times 10^2$	2.3	$14.4 \pm 0.1 \times 10^3$	$9.7 \pm 0.7 \times 10^2$	576.1
Fish Pens	$6.1 \pm 0.7 \times 10^7$	$9.9 \pm 0.3 \times 10^5$	$583.2 \pm 28.1 \times 10^2$	5.6	$11.3 \pm 0.5 \times 10^3$	$78.4 \pm 5.5 \times 10^2$	280.8

Table 2. Bacteria and particle abundances in Bolinao. (from Garren et al 2008)

Organism Information

Organism	Trophic Classification	What it eats	How much it eats	What it excretes	Value when harvested
Milkfish (data from Homer et al. 2002)	predator	Fish feed or smaller fish	In pens: 6.58kg/m^2 of Pen/ 5months	242–493 g dry weight of sediment/ m^2/day. This sediment is ~ 10% carbon, 0.4% nitrogen, and 0.6% phosphorus (as % dry weight)	$1,278 USD/metric ton (from Agribusiness Weekly)
Herbivorous Fish (*Siganus doliatus*, a rabbit fish, used as representative)	herbivore	Macro algae (fleshy algae)	~18–22 cm^3 of algae material/ m^2 of reef/ month (from Fox & Bellwood 2008)		
Crustaceans (data averaged over one crab (*Menaethius monoceros*) and one amphipod (*Cymadusa imbroglio*) from Cruz-Rivera & Paul 2006)	Herbivore	Macro algae and cyanobacteria	~10-20mg wet weight of food/ individual/ day		Values for the various edible crustaceans can be found through public.
Molluscs (Averaged over 5 species of mussels and oysters from Hawkins et al. 1998)	Filter Feeder	Particles 1-16um in diameter	They clear 5-7L of water/hr of particles and absorb 4-15mg organic material per gram dry soft tissue weight (a measure of animal size) per hour		Also available on web for variety of species.

Echinoderm (urchin, *Tripneustes gratilla*, from the Philippines as representative. Data from Dy et al. 2002)	Herbivore	Fleshy algae	~0.05 g wet weight algae/ g dry weight urchin/ hour where the average dry weight of an individual urchin was 6.9 g	0.2-11.5mg dry weight feces/g dry weight urchin	
Algae (Yokoya and Oliveira 1992)	Primary producer	Sunlight, carbon dioxide, nitrogen and phosphorus	Depending on temperature, economically important red algae can double their mass (wet weight) in as little as 2.8 days (*Hypnea cornuta*) and as long as 50.0 days (*Pterocladia capillacea*)	These organisms can extrude excess photosynthate in the form of dissolved organic carbon but this is a difficult number to quantify. Simply keep in mind that this process is occurring as you think about the ecological perspective in part 6.	

References for Information found in the Table（略）

C 题:创建食物系统 — 重建受到人类影响的生态系统

背景

只有不到 1%的海底是由珊瑚覆盖的. 然而, 这些海域却支持了 25%的海洋生物多样性. 环保工作者非常关心珊瑚的消失, 因为从此该地区的生物多样性也将很快消失.

考虑在菲律宾的位于 Pangasinan(邦阿西楠)的 Bolinao(波里纳奥)的 Luzon(吕宋)岛和 Santiago(圣地亚哥)岛之间的狭窄的通道区域, 那里过去曾经布满了珊瑚礁并支持着大量物种的生存(图 1). 由于 1990 年代中期引进的商业性的虱目鱼(*Chanos Chanos*)养殖, 该海域曾经有过的丰富的生物多样性大大降低了. 现在那里大部分都变成了浑浊多泥的海底, 曾经活着的珊瑚早就被埋葬了, 由于过度的捕捞和鱼类栖息地的丧失只剩下很少的野生鱼种了. 尽管对于哪个地区的居民来说提供足够的食物是重要的, 但是同样重要的是要寻找一种能使自然的生态系统能够继续欣欣向荣的革新的方法; 即建立一种能够代替目前的虱目鱼单一养殖的令人满意的混养体制. 最终目标是研发一套水产养殖的做法使得不仅能够支持人类居民经济上和营养上的需求, 而且能够同时改善当地的水质到一定的水平使得在暗礁上建立起来的珊瑚能重新拓展到海底并和养殖场共存.

令人满意的混养体制应该展现这样一种情景: 多个有经济价值的物种养殖在一起, 而一个物种的排泄物正好是另一个物种的食物. 例如, 有鳍鱼的排泄物可供滤食性动物食用而且有鳍鱼和滤食性动物的过量的营养物质可以被海藻吸收, 海藻既可以作为食物也可以作为商业上有用的副产品. 这不仅减少了从鱼类养殖输入到周围水体的营养物质, 也由于利用鱼的排泄物生成大量的有用的产品(贻贝、海藻等)而使渔民增加了收益.

为了建模的目的，在这种生物多样性的环境里主要的动物生物体可以分为捕食鱼类(脊索动物门、脊椎动物亚门)；食草鱼类(脊索动物门、脊椎动物亚门)；软体动物(诸如贻贝、牡蛎、蛤蜊、蜗牛等，软体动物门)；甲壳类动物(诸如蟹、龙虾、藤壶、河虾等，节肢动物门，甲壳动物亚门)；棘皮动物(诸如星鱼、海参、海胆等，棘皮动物门)；还有藻类. 就喂养的类型而言，有初级生产者(光合作用制造者 — 它们可以是单细胞浮游植物、蓝藻或多细胞藻类)；滤食动物(菌株浮游生物、有机颗粒，有时候是水里的细菌)；食碎屑动物(吃泥土并消化其中的有机分子和养分)；食草动物(吃初级生产者)；以及捕食动物(食肉动物). 和在陆地上一样，大多数食肉动物吃食草动物或更小的食肉动物，但是在海洋里它们也吃很多滤食动物和食碎屑动物. 大多数动物具有 10-20%的生长效率，所以它们所摄入物的 80-90% 转化这种或那种形式的排泄物(一些转化为耗散的热量、另一些转化为身体的排泄物，等). 在生物多样性环境中珊瑚的作用主要是划分空间，并通过给予大多数物种在其相对比较小的空间里有其自己发展的生存环境使得各物种可以凝聚和共存 — 都市化高层建筑在水里的类似做法. 珊瑚还可以提供有助于清洁海水的一定数量的滤食动物. 海域能支持珊瑚生长的能力有赖于许多因素，最重要的因素是水质. 例如，Bolinao 的珊瑚可以在含有 50-100 万个细菌/每毫升和 0.25 ug 叶绿素/每升(一种光合作用的生物量的替代物)的海水中能够生存和繁殖. 而在用围栏圈养鱼的水域里当前看到的情况却是高于 1000 万个细菌/每毫升和 15 ug 叶绿素/每升. 由于虱目鱼渔场过量的营养物促进了窒息珊瑚生长的海藻的快速生长，以及来自虱目鱼渔场的颗粒流降低了珊瑚进行光合作用的能力. 所以，在珊瑚幼体能够开始生长前，必须确立可以接受的海水的质量. 对珊瑚的其他威胁包括由于大气中二氧化碳的增加导致的海水酸度的增加造成的珊瑚礁的退化，以及由于全球变暖导致的海水温度升高造成的珊瑚礁的退化. 可以把这些看作是二级威胁，在本问题中我们不予专门的处理.

问题的陈述

本问题的挑战在于要提出切实可行的混养系统来替代当前虱目鱼的单一养殖使之能够大大改善水质，从而使珊瑚幼体能够在该区域生根扩展. 无论从短期和长期的角度看，你们的混养系统都应该经济上是吸引人的而且对环境是无害的.

1. 对引进渔场前 Bolinao 原先的珊瑚礁生态系统进行建模：研制一个完整的珊瑚礁食物网的模型，该食物网包括唯一的捕食鱼种虱目鱼，(由你们选择的)一种特殊的食草鱼，一种软体动物，一种甲壳动物，一种棘皮动物以及一种海藻. 以一种你们认为是合理的方式详细说明每个物种的数量；列出你们所用的原始资料或者说明你们是怎么估计出这些种群的数量. 就清楚表述你们的模型而言，详细说明每个物种怎样和其他物种相互作用. 说明你们的模型是怎样预测足以保证珊瑚物种能够持续健康生长的稳定的水质水平的. 如果你们的模型没有给出足够高的水质水平，那么就按你们认为最合理的方式来调整每个物种的数量直到确实达到了满意的水质水平为止，并清楚描述你们调整了那些物种的数量以及为什么你们所做的改变是合理的.

2. 对 Bolinao 当前的虱目鱼单一养殖建模

a. 首先假设虱目鱼的养殖会抑制其他动物物种的生长，研究它将产生的影响. 通过移去(即，令种群数目为零)所有的食草鱼，所有的软体动物，所有的甲壳动物以及所有的棘皮动物. 令所有的其他物种数量和你们在上面的完整模型中的数量相同. 因为你们已经移去了虱目鱼的自然食物供应；你们需要引进一个常数项，该常数项是渔民对圈养虱目鱼的喂养；选择这项使得你们的模型保持平衡. 你们的模型现在预测的是什么样的稳定水质水平？该水质水平足以保证你们珊瑚物种能够持续健康生长？与观察结果比较，并描述怎样把你们的结果与观察结果进行比较.

b. 虱目鱼的养殖并非完全抑制所有其他的动物物种的生长，而且水质也可能并不像你们在 2a 中建议的那么坏，所以通过重新引进所有被移去的物种并且只调整它们的数量直到水质和当前在 Bolinao 观察到的水质一致来模拟当前 Bolinao 的生态情况. 把你们得到的这些物种的数量与它们当前在 Bolinao 观察到的这些物种的数量进行比较，并讨论对你们的模型做什么样的改变会使得你

们对各种群数量预测与观察结果更加接近.

3. 对经由混养来抢救 Bolinao 的生态环境进行建模：你们要寻求无须人类活动的帮助的前提下力争用混养渔业来替代当前的单一养殖使得海水足够清洁从而能够重建你们在问题 1 中建模的原来的珊瑚生态系统. 想法就是引进一组互相依赖的物种使得无论养殖虱目鱼的渔民投放的是什么样的饲料，他/她的“牲畜”都会把它们全部吃掉，而不会有(或只有极少的)剩余营养物和颗粒物(饲料和粪便)掉进下面的新长出来的珊瑚生长地. 此外，为了向人类提供食物并增加其价值你们还要设法从这种混养系统中获得具有商业价值的可以食用的生物物质.

a. 研发一种商业性的混养系统来抢救 Bolinao 的生态环境. 从你们在 2 b 部分的“当前”的圈养模型开始，并且引入既能清洁海水又能生产有价值、可收获的生物物质的额外的物种来做这件事. 例如，你们可以用贻贝，牡蛎，蛤蜊或者其他的有经济价值的滤食动物排成围拦来去掉虱目鱼的某些排泄物. 有经济价值的藻类植物可以在靠近水面的围拦边上生长(在那里他们可以获得足够的光线)，而且某些藻类还可以作为喂养虱目鱼食物的小食草鱼的饲料. 清楚地表述你们的模型以及达到稳定状态的各物种的数量.

b. 报告你们的模型的输出信息. 你们优化的是什么，所加的约束是什么，为什么？你们的模型给出的是什么样的水质？你们的模型给出的收获有多少，其经济价值怎样？为进一步改善水质你们要付出多少费用？换言之，从你们的最优的结果而言，为提高水质一个单位你们要付出的费用相当于多少与收获物等价的美元?

4. 科学：讨论人类消耗所需的各物种的捕捞量. 我们怎样利用你们的模型来预测或者理解人类消耗所需的捕捞量？捕捞一磅食肉动物的鱼类和捕捞一磅海藻同样重要，所以我们应该寻求极大化总的捕捞重量，或者我们应该区分(按照每种鱼种的价格来度量的)价值所以我们应该寻求极大化所捕捞的物种的价值？或者我们应该极大化所捕捞的物种的总价值减去饲养虱目鱼的费用？我们是否应该把可以食用的生物量的价值定义为各捕捞物种的价值之和再减去饲养虱目鱼的费用?

5. 极大化总捕捞量的价值：现在我们希望在人类消耗模型中在保持一种可接受(最好的)水质水平的同时使来自所有活的物种的捕捞量达到高(最大)的市场价值(因为可食用和可销售的副产品都是极大化价值的合法的方式). 改变你们的模型使得捕捞的各个物种等于常量. 什么是你们可以捕捞的(如同上面定义的)生物量的总价值以及相应的水质？试一下不同的捕捞策略和不同的虱目鱼喂养水平(永远选择能够使你们的模型保持平衡的价值)，并且画出水质作为捕捞价值的函数的图像. 什么样的策论是最优的以及什么是最优的捕捞量?

6. 号召采取行动：给 Pacific Marine Fisheries Council (太平洋水产委员会)的主任写一份你们发现的有关珊瑚生长中生物多样性和水质的关系的结论的信息报告. 报告要包括修复像 Bolinao 那样的生态环境的策略以及要多长时间才能修复. 用有说服力的理由来提出第 5 部分中你们的最优捕捞/喂养策略，并提出能执行你们的计划的捕捞/喂养配额策略. 通过提出你们计划下的捕捞价值和当前 Bolinao 情况下的捕捞价值之比来说明你们的策略的优势. 从生态学的角度来讨论你们的混养系统的利弊得失.

开始你们的研究时可以利用的参考资源

http://en.wikipedia.org/wiki/Integrated_Multi-trophic_Aquaculture
http://en.wikipedia.org/wiki/Coral-reef
http://www.seaworld.org/infobooks/Coral/home.html

补充信息(略)

(译注：本题的作者是位于加州的斯克里普斯海洋研究所(Scripps Institute of Oceanography, CA) 的 Melissa Garren.)

(叶其孝译，吴庆宝校，原题来源于http://www.comap.com)