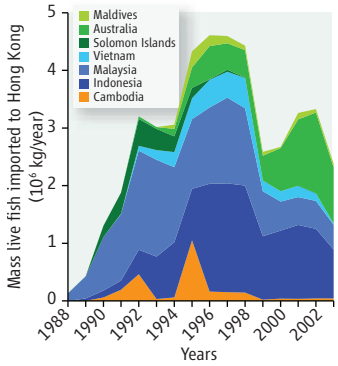
Keeping Bandits at Bay?

IN THEIR POLICY FORUM "GLOBALIZATION, roving bandits, and marine resources" (17 Mar., p. 1557), F. Berkes and colleagues highlight the serious ecological and management consequences of sequential exploitation of biological resources by mobile agents with no attachment to place. Such "roving bandits" (either legal or illegal) deplete stocks and move on faster than local institutions can be developed to regulate them. Here, we quantify the dynamics of a roving bandit system: the live reef fish trade (LRFT) supplying luxury seafood restaurants, mainly in Hong Kong, with large predatory fish (*1*–*4*).

We compiled annual statistics on the mass of live reef fish imported to Hong Kong from individual source nations (1988–2003; see graph) from the Hong Kong Census and Statistics Department (*5*). Analyzing the start-up dates of the trade from these nations reveals that the LRFT has been spreading away from Hong Kong at an accelerating pace, starting at about 100 km yr^{-1} in the 1970s and reaching over 400 km yr^{-1} in the late 1990s (see map) (*6*). Of 19 exporting nations (*7*), 10 clearly show a pattern of boom and bust. Moreover, booms appear to be increasingly ephemeral, with the time between the start and peak of the trade being significantly shorter for more distant countries (see graph) (*8*). The progressive deterioration of LRFT fisheries in most source nations has also led to what may be termed "fishing down the price list." Analyzing LRFT imports by species (*9*) instead of countries shows that species were depleted serially in order of price (*10*, *11*).



Imports of live reef food fish to Hong Kong over time, excluding countries for which the trade volume is too low to be visible and countries detailed in (*7*). Color-coded by region in ascending chronological order of entry into the LRFT, with minor data gaps extrapolated. The drop in catches in 1999 is a consequence of the global economic downturn that impacted demand for luxury food.

As the accelerating wave with its quickening boom-and-bust pattern spreads out, do local actors have time to react to the threat of roving bandits, or, as

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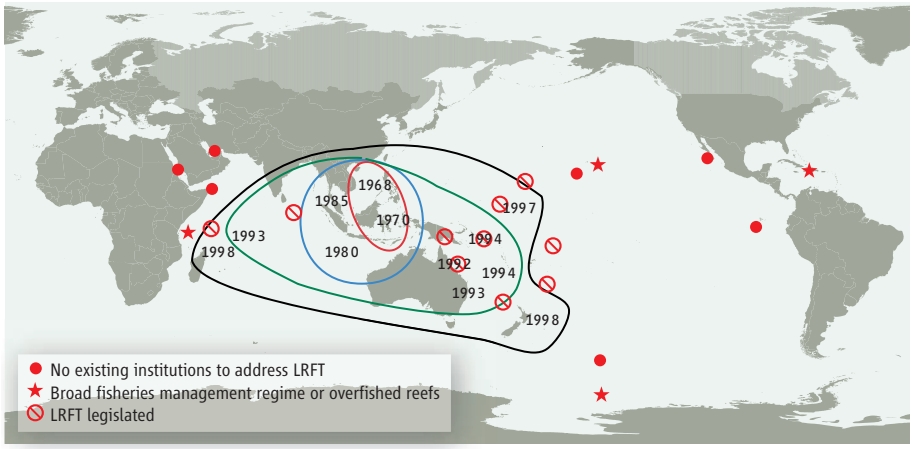

The global spread of the LRFT, showing the start-up year for the trade in several areas. Color contours represent the area covered by the trade before 1970 (red), 1985 (blue), 1995 (green), and present (black).

feared by Berkes *et al.*, are they simply too slow? A surprisingly positive answer comes from the Pacific Ocean, an area that, because of its comparatively healthy and sustainably exploited reefs (*12*), offers perhaps most scope for the expansion of the LRFT. Increasing caution about the trade has led several Pacific nations to start to introduce small-scale trial fisheries and LRFT management plans along the edge of the expanding wave (see map). These efforts are coordinated through the Pacific Regional LRFT Initiative of the Secretariat of the Pacific Community (SPC) (*4*, *13*). But what about areas that are not part of the SPC? Some (e.g., Hawaii) might nevertheless be protected by effective general fisheries regulations, while others (such as the Caribbean and Western Indian Ocean) might simply be ignored because their reefs are already overfished. Of greater concern are areas such as the Red Sea, Persian Gulf, and eastern Pacific, at potentially high risk through a combination of relatively healthy reefs and a lack of effective local institutions or regional coordination (see map).

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5. Data on gross annual mass of marine fish imports carried by air (all imports) and by sea (foreign vessels only) into Hong Kong (provided by the Hong Kong Census and Statistics Department). Hong Kong is the major market for the LRFT, and these imports represent most of the global trade.
6. Quadratic regression of distance from Hong Kong (km) versus start year [for 14 countries, from (*1*, *4*, *14*)]: R^2 = 0.92, $F(1,12) = 71.9$, $P < 0.001$.
7. Excluding Mainland China, Singapore, and Taiwan, which receive large amounts of fish from other countries; Thailand and Bangladesh, which mostly export farmed fish; and the Philippines, due to a major temporal shift from largely unreported, illegally operating vessels to mainly reported air exports (*1*, *14*).
8. Time to peak versus distance from Hong Kong: $F(1,8) = 9.3$, $P = 0.016$, $R^2 = 0.48$. Note that there is no confounding effect of reef area – time to peak versus area [from (*15*)]: $F(1,8) = 0.4$, NS.
9. Data from 1997 to 2002. These include imports by all foreign vessels (including catches that were problematic to assign geographically, such as those from Taiwan and Mainland China) and from voluntary reports by locally registered vessels (collected by the Hong Kong Agriculture, Fisheries and Conservation Department).
10. Time to peak versus 2002 wholesale prices [from (*4*)]: $r = -0.66$, $n = 9$ species, $P = 0.050$.
11. See Supporting Online Material on *Science* Online at www.sciencemag.org/cgi/content/313/5787/612c/DC1.
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Response

SCALES ET AL. PROVIDE AN IMPORTANT ANALYsis of the live reef fish trade. The loss of these local fish resources creates long-term social and economic hardship, while the profits flow from impoverished countries to a luxury market. We advocated addressing this phenomenon on various fronts: reforming markets, using the precautionary principle, establishing property rights, and building multilevel institutions from local to global that can learn from experience. Scales *et al.* argue that some of these policy changes have begun for the live reef fish trade, although we contend that their efficacy in preventing local stock depletion remains to be demonstrated.

A critical issue for coping with "roving bandits" is that local policy responses need to be largely based on lessons learned elsewhere. International agencies such as the Secretariat of the Pacific Community (SPC) can play a critical role in providing good governance and training, and in strengthening local capabilities for monitoring and enforcement. However, the majority of the 22 member nations and territories of the SPC have not yet implemented legislation to regulate the live reef fish trade.

Scales *et al.* attribute the temporary decline in live reef fish imports to Hong Kong in 2000 to a change in demand rather than supply. This observation supports our argument that reforming markets is an important strategy for coping with roving bandits. The regional-scale monitoring of international trade reported by Scales *et al.* is crucial for revealing the market demands for live reef fish that have been stimulated by global trade liberalization and by uneven economic development. Unfortunately, their analysis shows no significant change to market drivers, other than a flexibility to substitute species and locations, characteristic attributes of "roving bandits." Action to date has instead concentrated on harvesting restraints at the local level, encouraged by international agencies such as the SPC. Multilevel action, from the local to the international, is needed to establish institutions that are able to learn from experiences with roving bandits, develop decision-making skill in an environment of uncertainty and complexity, and respond quickly to shifts in demand from global markets.

As well as the trial fisheries and live fish management plans that have been initiated in some places, there are encouraging signs that licensing, monitoring, and enforcing can be effective, at least on a local scale. However, the social inequity arising from exportation of the dwindling coral reef resources of developing tropical nations is a strong argument for banning the international trade of live fish entirely, unless sustainability can be demonstrated. Once those resources are destroyed and forgotten, it is the local people who bear the costs of reduced options for future development.

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Making U.S. Graduate Education More Diverse

INCREASING THE PARTICIPATION OF MINORITY students in science and engineering, at all levels, remains a daunting challenge in the United States despite concerted efforts over the past 30 years ("Diversity remains elusive for flagship NSF program," J. Mervis, News of the Week, 9 June, p. 1454). The issue is more critical than ever before, but we seem to keep trying the same things and expecting different results. Most programs seek to better prepare undergraduates, but the problem is that few are admitted to doctoral programs. The basic problem is therefore admission, not a lack of minority students who have the ability to succeed. If indeed one of the major goals of the Integrative Graduate Education and Research Traineeship program (IGERT) is to increase the number of women and minorities in science, then individual IGERT programs that fail to do that should not be renewed. There is no question that the science that is being done through these IGERT programs is laudable, but if the aim of the program is not being met, investigators should be funded through other programs. I agree that productive faculty often do not have spare time to seek and recruit these students. They rely on the traditional model in which students actively seek participation in graduate research, either on their own or with the assistance of faculty mentors. Such students are self-confident in the pursuit of graduate education in research universities. Although some minority students do fall into this category, the numbers are relatively small. A central, national office to assist in recruiting minority students will no doubt help, but faculty simply have to make the commitment and find the time to actively seek minority students who might not have that self-confidence but who nonetheless are highly qualified. Wherever one finds a successful program, one will always find a faculty member or department head that does this, and we should do more to enable and reward their efforts. After all, it is individual faculty members who ultimately decide who gets admitted to graduate programs.

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Recognizing Computational Science

THERE ARE PRESTIGIOUS INTERNATIONAL awards that recognize the role of theory and experiment in science and mathematics, but there are no awards of a similar stature that explicitly recognize the role of computational science in a scientific field. In my view, this is a serious omission.

In 1945, John von Neumann (*1*) noted that "many branches of both pure and applied mathematics are in great need of computing instruments to break the present stalemate created by the failure of the purely analytical approach to nonlinear problems." In the past few decades, great strides in mathematics and in the applied sciences can be linked to computational science, and perhaps one can debate to what extent these advances are due to terraflop performance rather than human ingenuity in harnessing this power. Advances may be easier to recognize when simulations are supported by controlled experiments (*2*). But for some disciplines (e.g., atmospheric physics, space weather, cosmology), progress is made through passive observation, where "discovery" may be harder to quantify.

Nonetheless, in many different fields of science where great advances are being made, the

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Supporting Online Material for

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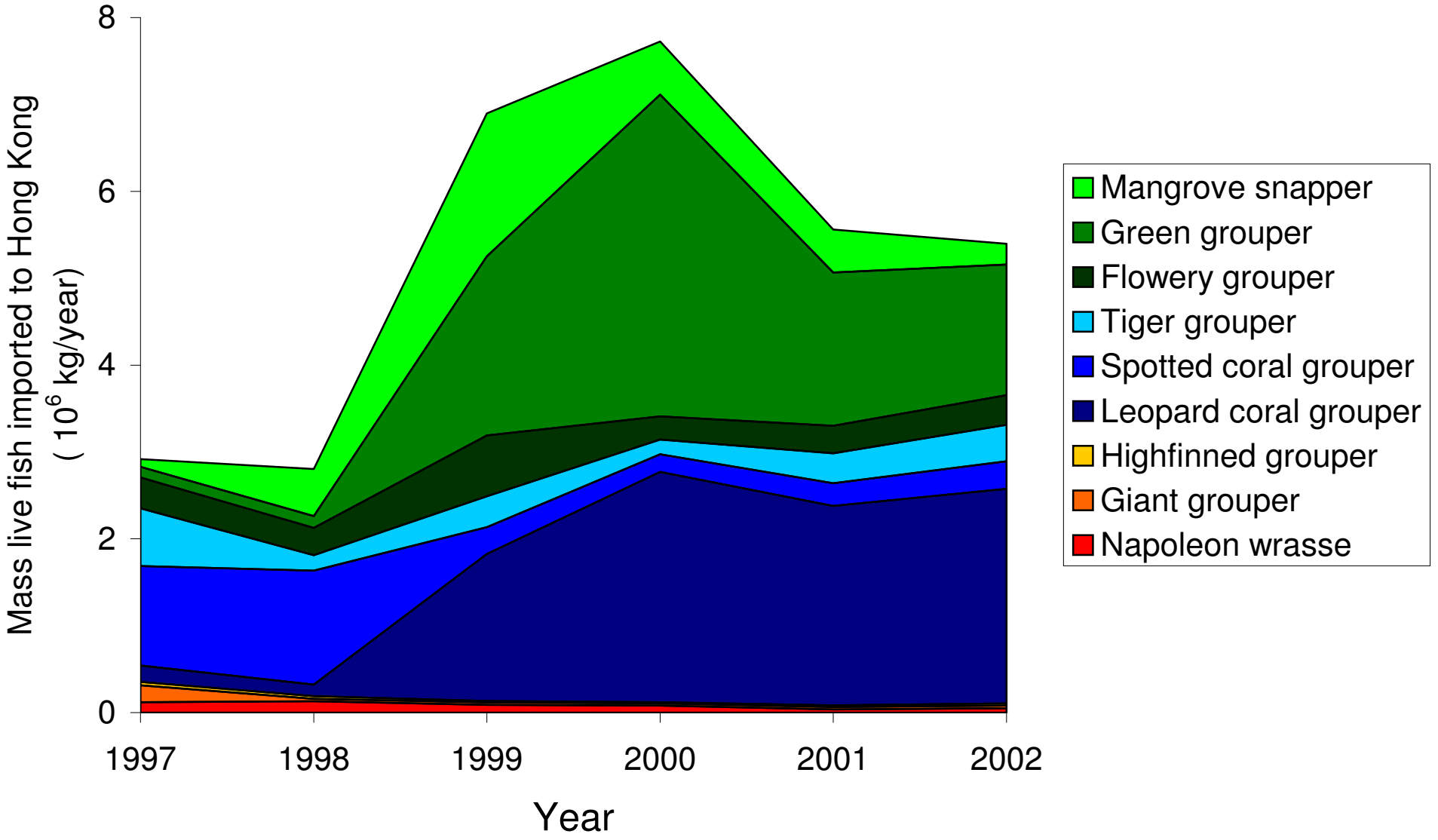
Published 4 August 2006, *Science* 313, 612 (2006)
DOI: 10.1126/science.1129106

This PDF file includes:

Fig. S1. Imports of live reef food fish species to Hong Kong over time, color coded by species in ascending price order (red, high value; blue, middle value; green, low value).


Mass live fish imported to Hong Kong
(10^6 kg/year)
8
6
4
2
0
1997
1998
1999
2000
2001
2002
Year
Mangrove snapper
Green grouper
Flowery grouper
Tiger grouper
Spotted coral grouper
Leopard coral grouper
Highfinned grouper
Giant grouper
Napoleon wrasse