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Promoting alternative livelihoods for conservation backfires when non-monetary benefits of traditional livelihoods are important

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Abstract

Alternative income programs are a common strategy used to reduce resource extraction and improve human welfare but it is unclear whether these programs are successful because they are rarely implemented with evaluation in mind. Taking advantage of a natural experiment in Kiribati, Central Pacific, we test the effect of an agricultural subsidy on fishing, coral reef ecosystem services, and human welfare. We present a standard economic model of household fishing and agricultural production and consumption to demonstrate the logic behind these programs. Contrary to predictions of this model and the program's aims, households actually increased fishing and decreased agricultural labor. To explain these data, we develop an alternative model in which households enjoy fishing; that is, fishing labor provides direct benefits, in addition to providing fish to eat. This model predicts that fishing will increase in response to the agricultural subsidy because increased incomes lead to increased consumption of all goods and leisure, which includes fishing labor. Despite short-run increases in incomes, we expect long-run declines in welfare because increased fishing is linked to declines in coral reef ecosystem services. In order to prevent alternative income programs from essentially subsidizing further resource degradation, non-monetary benefits from traditional livelihoods must be considered.

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Overfishing has radically transformed marine ecosystems and threatens the livelihoods of millions (1,2,3). Marine protected areas (MPAs) have been promoted as a policy to achieve conservation and fisheries management goals, especially in multi-species fisheries, such as coral reefs (4). However, only 9% of coral reef MPAs are successful (e.g. in preventing poaching) (5). Improved implementation and evaluation of incentive-based conservation strategies such as enforcement, conservation payments, and alternative income programs are needed to reduce fishing. While there has been relative success using only enforcement for protected areas generally (6), pure enforcement schemes often provoke conflict, which may undermine conservation efforts (7). Some MPAs and other fisheries management tools are designed to compensate fishermen for their loss in fishing grounds or catch by improving their total catch and profits in the long-run (8). However, short-run and even long-run welfare losses often occur due to the environmental or market setting. For example, MPAs may not improve catch if fish do not move outside the MPA (9) or catches may improve, attracting outside labor, which reduces average benefits (10). Consequently, some alternate form of compensation is needed for conservation strategies to be successful (11, 12).

Integrated conservation-development programs (ICDP) have emerged in the last three decades in response to this need (13). ICDPs attempt to create or enhance alternative incomes as a way to reduce resource extraction and improve local welfare (11, 14). Increasing agricultural productivity is expected to decrease reliance on natural resources and is a typical strategy used in ICDPs (15-17). The majority of the work on agricultural development and natural resources has been on terrestrial environments, particularly tropical forests (18). There are few examples examining the effect of alternative incomes on marine resources (19, e.g. 20-22).

Reviews of ICDPs have found few successes (11, 23-26). The major challenge in understanding how and why ICDPs fail is that few ICDPs are designed with evaluation in mind. Data is rarely collected before and after implementation, and, more importantly, non-random implementation generates a strong selection bias. Rather than randomly selecting treatment and control villages or households so that one can estimate the effect of the treatment, controlling for other changes across time, villages or households are often chosen for political or economic reasons or are self-selected. In the case of self-selection, the treatment group is more likely to reduce resource extraction because it will contain households that are most willing to give up the extractive activity for alternative income. This makes the few reported successes even more tenuous.

Here, we were able to take advantage of a natural experiment in the Republic of Kiribati that had limited selection bias (Fig. 1). In 2003 and 2004, the government of the Republic of Kiribati increased the subsidized buying price of copra, a coconut product, as part of a social welfare program. Given that almost all households in Kiribati engage in fishing and own some land with coconut trees, and that both fishing and copra production do not require significant capital investments, virtually all households were included in the treatment.

In this paper, we first discuss a simple model of the household that represents the standard assumptions that motivate ICDPs. This model predicts that a copra price subsidy should increase labor in copra, decrease labor in fishing, and improve overall welfare. However, this model does not explain our observation of a significant number of households *increasing* fishing labor and *decreasing* copra labor over the time period covering the price subsidy increase. We thus develop an alternative model that simply assumes fishermen may enjoy fishing. This model predicts that if fishing labor has sufficiently large direct benefits (not just through consuming fish) households will increase fishing labor in response to the price subsidy because of a standard income effect. We tested the predictions of this model on data from an economic survey of 286 households conducted in 2007 that collected retrospective data covering the period 2001 to 2006 for a total of 1716 observations (see Table S1, Dataset S1 in Supporting Information). Our results are consistent with the hypothesis that enjoyment of fishing caused the copra subsidy to have a perverse effect on fishing labor. We estimate the effects of an increase in fishing labor on coral reef ecosystem services using data from a detailed fishing survey of 145 households and ecological surveys of 37 reef sites across an extreme fishing gradient (Dataset S2). We show that the copra subsidy had negative effects on the ecosystem and long-run welfare and make recommendations to improve the design of ICDPs when occupations have significant non-monetary benefits.

Uncertain Effects of Integrated Conservation-Development Programs

As of 2001, there were an estimated three hundred or more ICDPs worldwide, supported by hundreds of millions of dollars from governments and international donors (26). Marketing the idea and raising the funds for ICDPs has been far easier than evaluating their success (24). There is little empirical evidence to determine whether alternative income programs are successful, possibly because the programs are assumed to be successful or the implementing agencies do not have the capacity for evaluation, especially when it requires gathering data on both biological and economic outcomes (23, 27, 28).

The effects of alternative income programs aimed at reducing fishing and improving welfare remain mixed but indicate that factors other than the relative wage between fishing and the alternative activity may be important. Alternative income programs associated with MPAs have increased compliance with MPA regulations (20, 22) and have been linked to other measures of MPA success, including coral mortality, perceived resource change, infrastructure, and community empowerment (20). Seaweed farming for export has been reported to increase fishermen's incomes. However, since fishermen rarely gave up fishing entirely and sometimes even invested extra income in new fishing gear (21), the effect on fishing is unclear. Alternative incomes have also been associated with lower perceived quality of life and involvement in conservation activities (22). However, these studies are limited by selection bias and a lack of direct measurement of changes in fishing labor allocation, fish stocks, or associated ecosystem services.

Anthropologists suggest that the enjoyment of fishing explains why fishermen often choose fishing over other jobs with higher wages (29, 30). Attitudinal surveys of fishermen in the Philippines report that fishermen will not give up fishing for other occupations (although they would consider them for supplemental income) because they enjoy the income and lifestyle associated with fishing (20, 31). This attitude is not particular to developing countries. North American fishermen have high levels of job satisfaction that are attributed to factors that represent "self-actualization," suggesting that fishing relates to individuals' need to fulfill rather than merely sustain themselves (32, 33, 29). These attitudes may be associated with other types of traditional livelihoods and explain, in part, why development programs have limited success in rural communities (34, 35).

Expected Outcomes of Alternative Income Programs

Alternative income programs are motivated by the expectation that, under standard economic assumptions, increasing the wage in the alternative income activity should reduce resource extraction and improve welfare. For example, in Kiribati, households decide how to allocate their labor ($\bar{L}$)[*] across copra production ($c = G(L^c)$) and fishing ($f = F(L^f)$) based on the relative shadow wage, which is the product of the output price and the marginal productivity of labor[†]. At the optimum, the household allocates its labor so that the shadow wage in fishing and copra are

[*] Capital is ignored because land, fishing gear, and credit markets are non-existent or incomplete.
[†] The shadow wage is based on production and the price of output, in contrast to a traditional wage that is based on the market return to a unit of labor.

equal ($p^c \partial G / \partial L^c = p^f \, \partial F \big/ \partial L^f$). If a subsidy increases the price of copra (p^c), the marginal productivity of copra labor must decrease, implying that labor in copra (L^c) must increase. Since total labor ($\overline{L}$) is the sum of labor in copra (L^c), labor in fishing (L^f), and leisure (l) and leisure is a normal good (i.e. higher incomes result in increased consumption), then labor in fishing must decrease[‡].

We find that observed household behavior in Kiribati is not consistent with the predictions of this model. A simple comparison of household copra labor, other labor (including fishing), and leisure before (2001) and after (2006) the copra subsidy shows that the standard model only predicts 4.43% of households' responses (Table S2). However, almost half of households' reported no change in labor, which may the result of using recall data. More importantly, 35% of households *increased* other labor and 29% of households *decreased* copra labor. These observations show that the standard model is insufficient to describe the observed behavior.

Enjoyment of Fishing Explains Unexpected Outcome of Alternative Income Program

A parsimonious mechanism by which labor in fishing might increase in response to the copra price increase would be simply if people like to fish. Fishing produces fish but also may provide direct benefits through the act of fishing. In an alternative model that includes fishing as a consumption good, the household problem

[‡] As in many developing country contexts, there are no labor markets or these markets are incomplete so household production is almost totally dependent on household labor.

is to maximize utility from rice (r), fish (f), leisure (l), and fishing labor (L^f) subject to the household's income and labor endowment ($\bar{L}$).

(1) $$\max_{r,f,l,L^c,L^f} u(r, f, l, L^f)$$

(2) $$r + p^f f = p^c G(L^c) + p^f F(L^f) + H(L^o)$$

(3) $$\bar{L} = L^c + L^f + L^o + l, L^c > 0, L^f > 0, L^o > 0, l > 0, r > 0, f > 0$$

Total imputed household income is derived from the value of copra production ($p^c G(L^c)$), fishing ($p^f F(L^f)$), and other labor ($H(L^o)$). In this model, all income is spent on rice and fish and p^f is the local price of fish. We normalize the price of rice to one and focus on an interior solution where households consume some rice, fish, and leisure and participate in copra, fishing, and other activities. Assuming all goods are normal, under this model specification, an increase in the price of copra would increase the consumption of all goods, *including fishing labor*. If both fishing labor and leisure increase, the sum of copra labor and all other labor must decrease.

To test the predictions of our model, we used reduced form econometric models of copra and fishing labor with island- and year-specific copra and fish prices as predictor variables; household demographics, land, and rainfall as controls; and household and island fixed effects. We then predicted changes in the coral reef ecosystem using our estimate of the change in fishing labor due to the subsidy from the econometric model and parameter estimates from ecological models. Ecological models of the relationship between fishing and coral reef ecosystem components were fit to data collected across an extreme fishing gradient in Kiritimati (Fig. 1). We estimated the effects of the copra subsidy on welfare by examining changes in self-reported welfare.

Results

Labor Allocation

The elasticity of fishing labor supply with respect to copra price is 1.54 ($p<0.001$; Table 1), that is, for a 1% change in the copra price, fishing labor increases by 1.54%. Therefore, we conclude that the 31% (weighted mean) increase in the copra price led to a 47% increase in fishing labor. Copra price had no significant effect on copra labor. These results are consistent with the predictions of the alternative model, namely that fishing labor will increase and the sum of copra and other labor will decrease in response to the copra subsidy. Fish price had no effect on fishing labor and a significant positive effect on copra labor ($\beta=1.68$, $p<0.05$; Table 1).

Ecosystem Effects

We conclude that, by increasing fishing labor, the copra subsidy had negative effects on the coral reef ecosystem, which has long-run consequences for welfare because the coral reef provides important ecosystem services such as food and protection from storms. A 47% increase in fishing labor could result in a 24% decrease in total fish biomass (Fig. 2a) and an 8% decrease in herbivorous fish biomass (Fig. 2b). Fishing has indirect effects on reef-builders (coral and crustose coralline algae) and fleshy algae because the consumption of fleshy algae by herbivores helps maintain the dominance of reef-builders since fleshy algae compete with reef-builders for space. Increased fishing, therefore, could result in a 7% decrease in reef-builders (Fig. 2c) and a 13% increase in fleshy algae (Fig. 2d). The estimate of losses in reef-builders is conservative because reef-builders are slower to respond to changes than fleshy algae. On historically over-fished reefs, such as in the Caribbean, sudden and almost complete losses of reef-builders have been observed following disturbances, such as hurricanes (36, 37).

Welfare Consequences

Short-term welfare necessarily improved with an increase in the copra price, although the gain may be off-set by coral reef degradation in the long-run. When asked whether welfare changed over the study period, 40% (95% CI: 33%, 57%) of households reported that welfare improved, 48% (95% CI: 40%, 55%) said that welfare did not change, and 12% (95% CI: 7%, 18%) said that welfare declined over the period. Households that reported declines in welfare typically attributed the decline to idiosyncratic events, such as deaths in the family, aging, and children leaving home. Changes in copra or fishing labor had no significant effect on the probability that a household reported welfare improvements (Δ copra labor: β=-0.05, p=0.800; Δ fishing labor: β=-0.01, p=0.970; Table S3). Increased education, however, increased the probability that households reported welfare improvements (β=0.19, p=0.10; Table S3).

Discussion

We have shown that under standard assumptions, increasing the price of copra should decrease fishing and increase welfare. However, we observed significant numbers of households actually increasing fishing and decreasing copra labor. To explain these observations, we developed an alternative model in which households also get utility from fishing labor, representing the importance of non-monetary benefits associated with fishing that are often cited by anthropologists. This model predicted that households would increase fishing labor, along with consumption of fish, rice, and other leisure, in response to the copra subsidy. Our empirical estimation supports these predictions and shows that on average households increased fishing. We estimate that the 31% increase in the copra price from 2002 to 2006 resulted in a 47% increase in fishing labor. The increase in fishing labor was estimated to have significant negative consequences for the fish stock and reef builders, which provide important goods and services such as food or protection from storms and sea-level rise. In sum, the subsidy not only failed to reduce fishing and protect ecosystem services but actually exacerbated the problem. This suggests that even though the subsidy had a positive effect on welfare, these improvements will not be maintained in the long-run if the fishery and ecosystem decline.

Although there are other mechanisms that could explain an increase in fishing in response to an increase in the copra price, we find little support for these mechanisms and suggest that the role of non-monetary benefits of fishing is the most parsimonious explanation. For instance, under the standard assumptions, an increase in copra price should lead to a decrease in fishing and an increase in consumption of all goods, including fish. This suggests that perhaps general equilibrium effects could lead to an increase in the price of fish, which could draw labor back into fishing. However, this would require the price of fish to increase at a faster rate than the price of copra, which we do not observe (Table S4). We instead see no effect of fish price on fish labor, which seems plausible if fishing labor is responding to an increase in income due to the copra subsidy and not to changes in the wage associated with fishing. Alternatively, an increase in fishing labor in response to an increase in copra price could be observed if rice and/or leisure are inferior goods. In this case, increases in income due to an increase in the copra price would lead to higher consumption of fish relative to rice and/or leisure. Given that rice is imported and fish is produced locally, as well as the observation that eating rice is associated with wealth and status, rice is clearly not an inferior good in Kiribati (38). We also believe that leisure is not an inferior good because time spent with family or friends appears to be highly valued (39). However, as we have already suggested, fishing itself has a leisure component. Another possible explanation for the increase in fishing labor would be a declining fish stock (i.e. declining marginal productivity of fishing labor) that would require more fishing labor to maintain fish consumption levels. Although there is some evidence that the fish stocks in Kiribati are declining, the rate of decline has evidently been slower than the rate of increase in the copra price and is thus unlikely to explain the large increase in fishing labor over a short time scale. Lastly, an increase in the price of copra could increase incomes, enabling people to buy more fishing capital, increasing the marginal productivity of fishing, and drawing labor into fishing. We did not, however, observe any significant changes in fishing capital due to the copra subsidy (β=-0.37, p=0.373; Table S5). Though, we did find evidence of latent demand for fishing capital. Of the 62 households that reported they wanted to improve their income and gave specific examples of how, 38% (95% CI: 28%, 38%) indicated that they wanted to invest in fishing capital; however, most noted that loans were unavailable.

We observed an insignificant relationship between copra price and copra labor. This is consistent with the prediction of the alternative model, namely that the sum of copra and other labor must decrease. With an increase in the copra price, households can earn the same amount of money from copra with less labor or they can even earn more money with the same amount of labor. Rice is the primary good purchased with cash in Kiribati and there is almost no culture of saving (or savings mechanisms). Therefore, some households were evidently allocating just enough labor to copra to purchase rice and may have re-allocated labor into fishing when the copra subsidy allowed them to earn the same amount of cash income in less time; however, other households may have continued to allocate the same amount of labor to copra to keep up with the rising price of rice or to consume more rice overall. Increases in the price of fish had positive effects on copra labor, which is consistent with the expectation that households with more copra labor are net demanders of fish. When the price of fish rises, these households must allocate more labor to copra in order to purchase fish. Rainfall in the two previous years had no significant effect on copra labor, which further supports the prediction that households do not increase copra labor due to an increase in the shadow wage of copra labor.

We do not have any reason to expect that changes, other than the copra price, across time and islands explain the observed changes in fishing labor. Kiribati is a small and homogeneous society that values equality, especially in national policies. The magnitude of increase in copra price was greater in the Line Islands because the government changed its policy to one of uniform prices across islands in 2003; whereas, previously buying prices of copra were lower in the Line Island due to their remoteness. Although population growth over the period from 2000 to 2005 was high in Kiritimati, Line Islands (10% per year), relative to the national average (2% per year), it was also high in N. Tarawa, Gilbert Islands (5% per year). Moreover, the population density on Kiritimati remains lower than on all other islands (12 people/km^2). In addition, we are unaware of any other government programs or policies (e.g. infrastructure development or fishing gear subsidies/supplies) that could explain the observed patterns in labor allocation (40-45). We did, however, include island fixed effects to capture any unmeasured island level factors that may have affected labor.

The limited selection bias, small number of goods, and incomplete labor and resource markets made estimating the effect of the copra subsidy valid and tractable. However, these attributes also limit the generality of the results. Perfect labor markets may buffer responses to alternative income projects because new labor can come in from outside. However, if there were well-functioning labor markets in Kiribati, households with lots of land might hire laborers, which would give land owners more free time that they could possibly use to go fishing. Perfect credit markets may strengthen the negative impact of the copra subsidy by enabling households to invest in fishing gear. With improved credit markets, fishing effort could increase with deleterious effects on the reefs. Lastly, there are a very limited number of goods to purchase or leisure activities in Kiribati. If more options were available, people may substitute other goods or activities for fishing labor as leisure, such as televisions and other mass consumption goods, lessening the negative impact of the copra subsidy.

An additional limitation of the study is the use of recall data. Evaluating alternative income programs is not only challenging because they often have major issues of selection bias but because data is rarely collected over time. Moreover, economic data *and* ecological data must be collected. Although the large percentage of households reporting no changes in at least one type of labor in response to the copra subsidy is inconsistent with our model, suggesting imperfections in the recall data, evidence from island level copra production data suggests that the direction of the changes reported is correct. Using government copra production data over the period 2001-2005 for the four islands surveyed in this study, we found that copra production actually decreased with an increase in the copra price (β=-4.62; p=0.05, Table S6, Dataset S3).

The results of this research suggest that investments in alternative income programs may not always return the “double dividend” to conservation and economic development as commonly thought. Non-monetary benefits associated with fishing or other livelihoods may play a significant role and small differences in wages between alternative incomes and fishing may not be sufficient to draw labor out of fishing. Households are likely to respond differently to these programs not only based on their demographic attributes and capital endowments but based on preferences. Here, we show how a preference for fishing actually causes an alternative income program to have the perverse effect of increasing fishing. In cases where the non-monetary benefits of traditional livelihoods are high, ICDPs need to provide alternative income sources that are similar to the traditional livelihood but have low impact (e.g. catch-and-release sport fishing), make available additional consumption goods, or develop community work programs to produce public or common resource goods.

Methods

Household Data

To evaluate the effect of the copra price on fishing and welfare, we collected retrospective data (2001-2006) from 286 households on four islands in May and June 2007. The survey instrument was developed with input from officers from the Ministry of Finance and Ministry of Fisheries and pre-tested on 85 households on two islands in December 2006. Households within islands were selected randomly with sample sizes proportional to the island population. After obtaining oral consent, surveys of heads of households were conducted by one of the authors (SMW) and a trained field assistant with translation by local Fisheries Assistants. These research methods were approved by the University of California- San Diego Institutional Review Board.

Ecological Data

We used one degree resolution daily rainfall estimates from the Global Precipitation Climatology Project to control for natural changes in copra productivity (46). Daily rainfall for the one degree cell associated with each island summed over the two previous years was used in analyses because copra production lags droughts by two years (47, 48).

We conducted ecological and fishing surveys in Kiritimati during July and August 2007 at 37 reef sites and with 145 households, respectively, to estimate the effect of changes in fishing labor on coral reef ecosystem services using a space for time model that took advantage of the fact that the majority of people live in the northern part of the island and reefs along the unpopulated coastline are virtually unfished since few households own canoes or automobiles (49). We argue that the location of fishing effort is determined exogenously because the government planned the location of villages and people have limited mobility relative to the extent of the reef, which permits the use or standard regression methods.

Statistical Analyses

To test the predictions of our economic model, we considered reduced form models of copra and fishing labor:

(4) $$\ln(L_{it}^{c}) = \alpha_i^0 + \alpha^1 \ln(p_t^c) + \alpha^2 \ln(p_t^f) + Z_i + I_t + \varepsilon_{it}$$

(5) $$\ln(L_{it}^{f}) = \beta_i^0 + \beta^1 \ln(p_t^c) + \beta^2 \ln(p_t^f) + Z_i + I_t + \varepsilon_{it}$$

where island- and year-specific prices for copra, p_t^c, and fish, p_t^f, adjusted for inflation, predict labor allocation. Household demographics, land, and island-specific rainfall D_{it}, are represented in the constant terms, $\alpha_i^0 = \left(\alpha^5 + \alpha^6 D_{it}\right)$ and $\beta_i^0 = \left(\beta^5 + \beta^6 D_{it}\right)$. The responses of copra labor to copra price and fish price are α^1 and α^2, respectively, while β^1 and β^2 are the responses of fishing labor to copra price and fish price, respectively[¶]. Household fixed effects, Z_i, and island fixed effects, I_t, are included to control for fixed unobservable heterogeneity across households and islands. Models were estimated using clustered standard errors, where clusters were village-years[‖], and probability weighted $w_i = (N_i / N)/(n_i / n)$ data, where N is the population across islands, N_i is the population within island i, n is the sample across islands, and n_i is the sample within island i (50).

The relationship between fishing effort (standardized for gear type) and ecological variables was estimated using ordinary least squares. The parameter estimates from these models were then used to estimate the effect of the change in fishing labor due to the copra subsidy, estimated from the econometric model, on the ecosystem.

[¶] Results are insensitive to controlling for fishing capital.
[‖] Clustering by village-year allowed for a large number of clusters (greater than 50), which are required for the use of statistical methods based on asymptotic theory (51).

Changes in welfare were assessed by asking the discrete choice question "Since 2001, has household welfare improved, remained the same, or declined?" The proportion of households in each category and the 95% confidence intervals were estimated, adjusting for clustering by village-years and weighting with sampling weights described above.

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References

1. Pauly D, Christensen V, Dalsgaard J, Froese R, Torres F (1998) Fishing Down Marine Food Webs. *Science* 279:860-863.

2. Jackson JBC, et al. (2001) Historical overfishing and the recent collapse of coastal ecosystems. *Science* 293: 629-638.

3. Smith MD, et al. (2010) Sustainability and Global Seafood. *Science* 327:784-786.

4. Gaines SD, White C, Carr M.H, Palumbi SR (2010) Designing marine reserve networks for both conservation and fisheries management. *Proc Natl Acad Sci USA*. doi: 10.1073/pnas.0906473107

5. Mora C, Andrefouet S, Costello MJ, Kranenburg C, Rollo A, Veron J, Gaston K J, Myers RA (2006) Coral reefs and the global network of marine protected areas. *Science* 312: 1750-1751.

6. Bruner AG, Gullison RE, Rice RE, da Fonseca GAB (2001) Effectiveness of parks in protecting tropical biodiversity. *Science* 291: 125-128.

7. Ferraro PJ, Kramer RA (1997) in *Last stand: protected areas and the defense of tropical biodiversity*, eds Kramer R, van Schaik C, Johnson J (Oxford University Press, New York), pp 187-211.

8. Sanchirico JN, Malvadkar U, Hastings A, Wilen JE (2005) No-take zones as optimal fishery management. *Ecol Appl* 16: 1643-1659.

9. Sanchirico JN, Wilen JE (2001) Dynamics of spatial exploitation: a metapopulation approach. *Natural Res Modeling* 14: 391-418.

10. Muller J, Albers HJ (2004) Enforcement, payments, and development projects near protected areas: how the market setting determines what works where. *Resource Energy Econ* 26: 185-204.

11. Wells MP, Brandon KE, Hannah L (1992) *People and parks: linking protected area management with local communities* (The World Bank, WWF, and USAID, Washington, D.C.), pp 99.

12. Tisdell CA (1995) Issues in biodiversity conservation including the role of local communities. *Environ Conserv* 22: 216-222.

13. Berkes F (2007) Community-based conservation in a globalized world. *Proc Natl Acad Sci USA* 104:15188-15193.

14. Worah S (2000) International History of ICDPs. *Proceedings of Integrated Conservation and Development Projects Lessons Learned Workshop, June 12-13, 2000* (UNDP/World Bank/WWF, Hanoi)

15. OECD (1996) *Shaping the 21st Century: the Contribution of Development Cooperation (*Organisation for Economic Cooperation and Development, Paris), pp 20.

16. Wilkie DS, Godoy RA (2000) Economics of bushmeat *Science* 287: 975-976.

17. Bennett EL (2002) Is There a Link between Wild Meat and Food Security? *Conserv Biol* 16: 590-592.

18. Oates JF (1999) *Myth and Reality in the Rain Forest: How Conservation Strategies are Failing in West Africa* (University of California Press, Berkeley), pp 310

19. Wilcox, E.S. (1994) *Lessons from the Field: Marine Integrated Conservation and Development* (World Wildlife Fund, Washington, D.C.),

20. Pollnac RB, Crawford BR, Gorospe MLG (2001) Discovering factors that influence the success of community-based marine protected areas in the Visayas, Philippines. *Ocean Coast Manage* 44: 683-710.

21. Sievanen L, Crawford B, Pollnac R, Lowe C (2005) Weeding through assumptions of livelihood approaches in ICM: seaweed farming in the Philippines and Indonesia. *Ocean Coast Manage* 48: 297-313.

22. Thiele MT, Pollnac RB, Christy P (2005) Relationships between coastal tourism and ICM sustainability in the Central Visayas region of the Philippines. *Ocean Coast Manage* 48: 378-392.

23. Smith D, Hughes R, Swiderska K (1998) Review of Lessons Learnt from DFID-supported Biodiversity and Livelihoods Development Projects. Unpublished report for the UK Department for International Development. Internet: http://www.iied.org/blg

24. Wells, M., S. Guggenheim, A. Khan, W. Wardojo, and P. Jepson. (1999.) *Investing in Biodiversity: A Review of Indonesia's Integrated Conservation and Development Projects.*World Bank, Washington, D.C.

25. UNDP (2000) *Proceedings of the Integrated Conservation and Development Projects Lessons Learned Workshop* (UNDP/World Bank/WWF, Hanoi), pp 50.

26. Hughes R, Flintan F (2001) Integrating Conservation and Development Experience: A Review and Bibliography of the ICDP Literature (International Institute for Environment and Development, London), pp 24.

27. Kremen C, Merenlender AD, Murphy DD (1994) Ecological monitoring: a vital need for integrated conservation and development projects in the tropics. *Conserv Biol* 8: 388-397.

28. Larson P, Freudenberger M, Wyckoff-Baird B (1997) *Lessons from the Field: A Review of World Wildlife Fund's Experience with Integrated Conservation and Development Projects 1985-1996*. (WWF, Washington, D.C.)

29. Pollnac RB, Poggie Jr MLG (1988) The structure of job satisfaction among New England fishermen and its application to fisheries management policy. *Am Anthropol* 90: 888-901.

30. Gatewood JB, McKay B (1990) Comparison of job satisfaction in six New Jersey fisheries: implications for management. *Hum Organ* 49: 14-25.

31. Coastal Resources Center. (2000) Coastal Resources Management Project II 1999 Results: Increasing Conservation and Sustainable Use of Coastal Resources. Coastal Management Report #2222. (University of Rhode Island, Coastal Resources Center. Narragansett, Rhode Island USA), pp 48.

32. Smith, CL (1981) Satisfaction bonus from salmon fishing: implications for economic evaluation. *Land Econ* 57: 181-196.

33. Apostle RL, Kasdan L, Hanson A (1985) Work satisfaction and community attachment among fishermen in southwest Nova Scotia. *Can. J. Fish. Aquat. Sci.* 42: 256-267.

34. Uphoff NT, Esman MJ, Krishna A (1998) Reasons for success (Kumarian Press, West Hartford, CT), pp 252.

35. Bebbington A (2000) Reecountering Development: Livelihood transitions and Place Transformations In the Andes. *Ann Assoc Am Geogr*: 90, 495-519.

36. Knowlton N (1992) Thresholds and multiple stable states in coral reef community dynamics. *Am Zool* 32: 674-682.

37. Hughes TP (1994) Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science* 265: 1547-1551.

38. Thomas FR (2002) Self-reliance in Kiribati: contrasting views of agricultural and fisheries production. *Geogr J* 168: 163-177.

39. Borovnik M (2005) Seafarers' "maritime culture" and the "I-Kiribati way of life": the formation of flexible identities? *Singapore J Trop Geo* 26: 132-150.

40. Asian Development Bank (2002) Asian Development Outlook 2002. (Oxford University Press, Hong Kong), pp. 225.

41. Asian Development Bank (2003) Asian Development Outlook 2003. (Oxford University Press, Hong Kong), pp. 304.

42. Asian Development Bank (2004) Asian Development Outlook 2004. (Oxford University Press, Hong Kong), pp. 299.

43. Asian Development Bank (2005) Asian Development Outlook 2005. (Oxford University Press, Hong Kong), pp. 321.

44. Asian Development Bank (2006) Asian Development Outlook 2006. (Oxford University Press, Hong Kong), pp. 333.

45. Asian Development Bank (2007) Asian Development Outlook 2007. (Oxford University Press, Hong Kong), pp. 388.

46. Huffman GJ, et al. (2001) Global precipitation at one-degree daily resolution from multisatellite observations, *J. Hydrometeor.* 2**:** 36-50

47. NRC (1951) Handbook for Atoll Research (Pacific Science Board, National Research Council, Washington, D.C.)

48. Catala RLA (1957) Report on the Gilbert Islands: Some Aspects of Human Ecology. *Atoll Res. Bull.* 59:1-187.

49. Walsh, S (2009) Ecosystem-scale effects of nutrients and fishing on coral reefs. In Linking Coral Reef Health and Human Welfare, Walsh, S (Proquest, Ann Arbor), pp. 1-144.

50. MaCurdy T (2007) in *Handbook of Econometrics*, *5*, eds Heckmen J, Leamer E (North Holland Publishing Co, Amsterdam), pp 4060-4167.

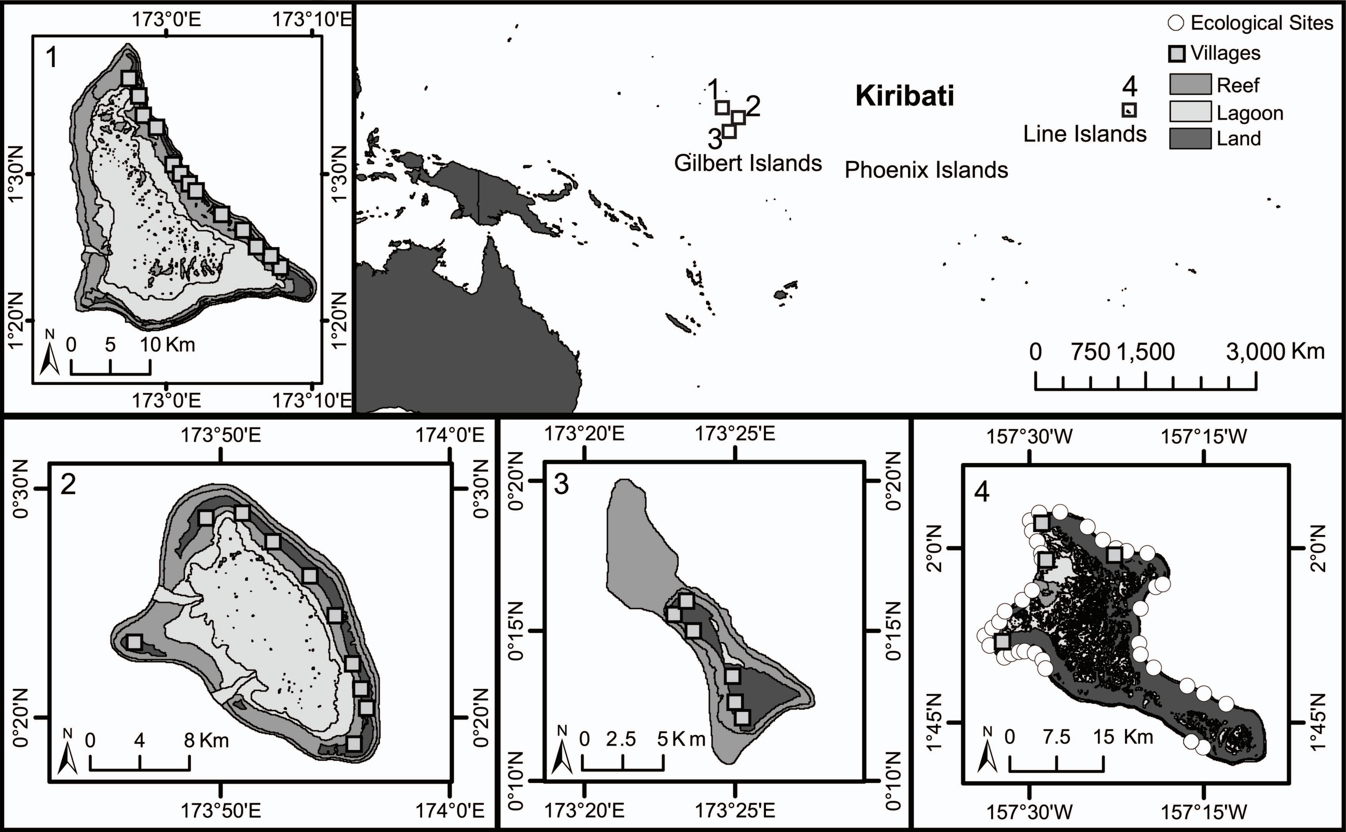
51. Angrist JD, Lavy L (2002) The Effect of High School Matriculation Awards: Evidence from Randomized Trials. Working paper, Massachusetts Institute of Technology.

Figure Legends

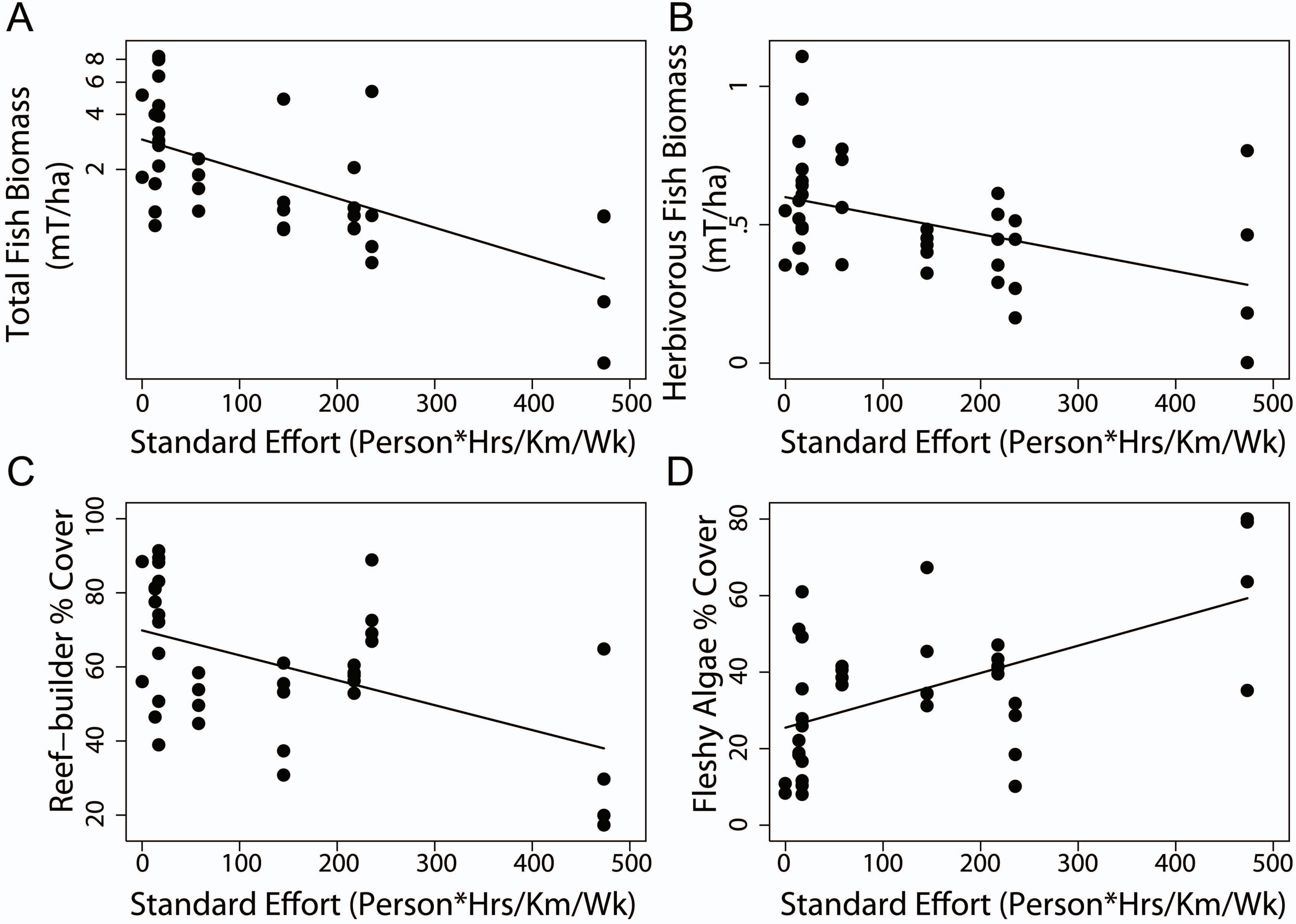
Fig. 1. The Republic of Kiribati is comprised of three island chains, the Gilbert, Phoenix, and Line Islands. Economic surveys of 286 households were conducted in all villages (squares) on four islands (A. N. Tarawa, B. Abemama, C. Kuria, D. Kiritimati). Detailed fishing surveys of an additional 145 households were conducted in the four villages of Kiritimati. Ecological surveys were conducted at 37 sites on the

fore reef along an extreme fishing gradient in Kiritimati. All islands are low lying atolls primarily covered with coconut trees and surrounded by coral reefs.

Fig. 2. Estimates of the effect of fishing on ecological variables from ecological surveys (n=37) and fishing surveys (n=145). An estimated 47% increase in fishing labor due to the copra subsidy will result in a) a 24% decrease in total fish ($F_{1,35}$=26.21, $p<0.0001$, R^2=0.43), b) a 8% decrease in herbivores ($F_{1,35}$=8.99, $p<0.01$, R^2=0.20), c) a 7% decrease in reef-builders (coral and crustose coralline algae) ($F_{1,35}$=12.15, $p<0.05$, R^2=0.26), and d) a 13% increase in algae ($F_{1,35}$=15.69, $p<0.001$, R^2=0.31).



Ecological Sites
Villages
Reef
Lagoon
Land
Kiribati
Gilbert Islands
Phoenix Islands
Line Islands
1
2
3
4
0 750 1,500 3,000 Km
173°0'E
173°10'E
1°30'N
1°20'N
0 5 10 Km
173°50'E
174°0'E
0°30'N
0°20'N
0 4 8 Km
173°20'E
173°25'E
0°20'N
0°15'N
0°10'N
0 2.5 5 Km
157°30'W
157°15'W
2°0'N
1°45'N
0 7.5 15 Km
N



A
Total Fish Biomass (mT/ha)
2
4
6 8
0
100
200
300
400
500
Standard Effort (Person*Hrs/Km/Wk)
B
Herbivorous Fish Biomass (mT/ha)
0
.5
1
0
100
200
300
400
500
Standard Effort (Person*Hrs/Km/Wk)
C
Reef–builder % Cover
20
40
60
80
100
0
100
200
300
400
500
Standard Effort (Person*Hrs/Km/Wk)
D
Fleshy Algae % Cover
0
20
40
60
80
0
100
200
300
400
500
Standard Effort (Person*Hrs/Km/Wk)

Table 1. Fixed effects (household, island) ordinary least squares estimate of labor (†p<0.10, * p <0.05, ** p<0.01, ***p<0.001).

	Fishing Labor		Copra Labor	
Explanatory variable	*β*	*Robust SE*	*β*	*Robust SE*
Ln(Copra price)	1.54***	0.34	0.68	0.60
Ln(Fish price)	-0.46	0.63	1.68*	0.80
Land	-0.04	0.03	-0.13	0.10
No. of household members	0.05†	0.03	-0.08*	0.04
No. of males aged 15-60	0.18†	0.10	-0.07	0.09
No. educated above primary	-0.02	0.08	0.30†	0.17
$Rain_{t-1} + Rain_{t-2}$	-0.00*	0.00	0.00	0.00
Constant	-0.21	0.46	-2.57	0.60
N		1627		1682
Within R^2		0.05		0.13

Table S1. Descriptive statistics

Variable	[units]	Mean	S.D.	N
Fishing Labor	[persons*hrs/yr]	0.52	0.65	1655
Copra Labor	[persons*hrs/yr]	0.60	1.16	1713
Other Labor	[person*hrs]	0.19	0.55	1709
Copra Price	[2001 AUD/kg]	0.51	0.07	1716
Fish Price	[2001 AUD/kg]	0.73	0.13	1716
Household Land	[acres]	5.93	12.41	1713
Fishing Capital	[count]	0.48	0.85	1713
Household Members	[count]	6.92	4.02	1713
Males aged 15-60	[count]	2.14	1.69	1712
Educated > primary	[count]	2.14	1.69	1685
Rain (t_1+t_2)	[mm/yr]	3148.25	1454.58	1716
Income Satisfaction	[1=yes, 0=no]	0.76	0.43	276
Want Alternative Income	[1=yes, 0=no]	0.56	0.50	101
Welfare Improved	[1=yes, 0=no]	0.40	0.49	280

Note: hours of labor are normalized so that 40 hrs/wk for 50 weeks/yr=1.

Table S2. The percentage of households by changes in copra labor, other labor, and leisure between 2001 and 2006.

Case	Changes in Labor	% Households
1.	$L^c < 0, L^o < 0, l > 0$	19.19
2.	$L^c < 0, L^o > 0, l < 0$	3.69
3.	$L^c < 0, L^o > 0, l > 0$	4.06
4.	$L^c < 0, L^o > 0, l = 0$	0
5.	$L^c < 0, L^o = 0, l > 0$	2.21
Subtotal		29.15
6.	$L^c > 0, L^o < 0, l > 0$	4.43
7.	$L^c > 0, L^o > 0, l < 0$	12.54
8.	$L^c > 0, L^o < 0, l < 0$	3.32
9.	$L^c > 0, L^o < 0, l = 0$	0
10.	$L^c > 0, L^o = 0, l < 0$	5.17
Subtotal		25.47
11.	$L^c = 0, L^o > 0, l < 0$	14.76
12.	$L^c = 0, L^o < 0, l > 0$	12.18
13.	$L^c = 0, L^o = 0, l = 0$	18.45
Subtotal		45.39
TOTAL		100.00

Table S3. Logit estimate of self-reported welfare improvement over the period 2001-2006.

Explanatory variable	*β*	*Robust SE*	*z*	*Significance*
Δ Copra labor	-0.05	0.19	-0.25	0.800
Δ Fish labor	-0.01	0.36	-0.04	0.970
Δ No. of household members	0.08	0.05	1.48	0.139
Δ No. of males aged 15-60	-0.26	0.17	-1.53	0.127
Δ No. educated above primary	0.19	0.12	1.66	0.098
Constant	-0.41	0.16	-2.62	0.009
N				263
Psuedo R^2				0.01

Table S4. Percentage Change in Copra and Fish Prices

Year	Gilbert Islands		Line Islands	
	Copra	Fish	Copra	Fish
2001	-	-	-	-
2002	-5	-4	-5	-6
2003	9	<1	17	-1
2004	21	<1	21	-9
2005	0	5	0	4
2006	2	5	2	5

Table S5. Fixed effects (household, island) ordinary least squares estimate of ln(fishing capital).

Explanatory variable	*β*	*Robust SE*	*t*	*Significance*
Ln(Copra price)	-0.37	0.41	-0.89	0.373
Ln(Fish price)	-1.24	0.99	-1.26	0.210
No. of household members	0.06	0.03	2.14	0.033
No. of males aged 15-60	-0.05	0.09	-0.59	0.557
No. educated above primary	0.14	0.13	1.13	0.261
Constant	-4.34	2.29	-1.90	0.059
N				1685
Within R^2				0.01

Table S6. Fixed effects (island) ordinary least squares estimate of copra production by island.

Explanatory variable	*β*	*SE*	*t*	*Significance*
Copra price	-4.62	2.16	-2.14	0.052
Fish price	0.84	3.85	0.22	0.830
$Rain_{t-1}$ + $rain_{t-2}$	0.00	0.00	2.03	0.064
Constant	2.03	2.33	0.87	0.400
N				20
Within R^2				0.29