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Industry-funded fishing license reduction good for both profits and conservation

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Abstract

For many commercial fisheries, reductions in fishing effort would likely result in higher long-term catches and improved incomes per fisherman. But fishing licenses are perceived as though they were property rights, which can imply relatively high costs for publicly funded buyback programmes to reduce fishing effort. Instead of the public buying out fishing licenses, it can make good business sense for license holders to expect the public to pay for protection against new licenses, and to proceed under this protection to finance buybacks of licenses themselves. The short-run costs of such an investment are outweighed by long-term gains in annual incomes and the transfer value of licenses at the time of individual retirement, especially in fisheries that are severely overfished.

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Introduction

There have been widespread calls for global reduction in fishing fleet sizes and fishing effort, owing to instances of severe over-fishing and slow or dramatic collapse of fisheries (Mullon *et al.* 2005). Yet, despite apparently clear legal mandates to prevent over-fishing, most management agencies have been slow to respond to these calls. Control of fishing effort is not just a matter of identifying an optimal effort level; it also involves regulating fishing effort so as to prevent this level from being exceeded. Simply reducing the effort by a license holder without reducing the number of licenses, can lead to significant impoverishment in terms of a reduction in income per license holder. Hence, long-term effort reduction typically needs to include reductions in numbers of licenses.

In most jurisdictions, fishing licenses are treated essentially as property rights, for which fishermen are entitled to financial compensation in the form of buyback programmes when license numbers need to be reduced (Weninger and McConnell 2000). It has typically been seen as a public responsibility to pay for such buybacks, although industry-funded buyback programmes have been suggested (Clark *et al.* 2005a,b). Publicly funded programmes are typically very costly, slow to gain political approval, and fraught with difficulties including: (i) buying out only the least efficient license holders; (ii) failure to prevent effort from seeping back into fisheries (Holland *et al.* 1999); and (iii) increasing license prices as fishermen anticipate increased incomes following license reduction (Clark *et al.* 2005a).

License reduction programmes may be implemented far more quickly if they were conducted not by public agencies, but by the commercial fishing industry as a business investment. The current paper first argues that 'contract' agreements between industry and management agencies are necessary to make investment worthwhile. Then it discusses gains that fishermen might expect from such investments; alternative investment strategies for such investments, and presents methods for calculating cost-benefit ratios over time. Finally, an example from the west Florida shrimp (*Penaeus* spp.) fishery is used to show that industry investment in license buybacks is a wise choice even if effort reduction does not result in increased total catch because the stock(s) were not overfished in the first place.

Industry–government agreements to protect fisher investments

As licenses and fishing efforts are typically managed by public agencies, there would be little incentive for commercial fishermen to make investments in license reduction programmes (Hilborn *et al.* 2005; Grafton *et al.* 2006). Investment to buy out competitors and to rebuild stock size so as to increase catch rates would only be attractive where there are clear guarantees from government to protect the value of that investment. Such guarantees, preferably in the form of a binding contract with government, would need to have at least the four key elements discussed next. Note that taken together, these elements amount to an agreement to treat the existing commercial fishing licenses as the property of the individuals who hold them (rather than as an annual fishing privilege to be renewed at public discretion). In subsequent sections of this paper, licenses will be treated as fully transferable catch rights, with fair market values that can be appraised by the same methods used for any other small business.

1. *Agreement not to issue any new licenses and to prevent increases in fishing power when remaining licenses are transferred.* This agreement would be necessary to protect the individual investor from having any gains accrue to people who did not participate in the investment. It is common for new fishers that enter a fishery via the purchase of an existing license to put that license on a vessel with greater fishing power. As for new license entrants, such increases in fishing power can defeat the objective of decreasing fishing mortality rate so as to allow stock rebuilding.
2. *Agreement to prevent expression of 'latent effort' by remaining license holders.* Fishing industries seldom operate at full capital capacity. Without deliberate action to prevent remaining license holders, after a buyback, from each exerting more fishing effort, license reductions may simply result in increased effort per license holder and so prevent total effort from decreasing. This would prevent stock sizes from rebuilding just as if new entrants and/or increases in fishing power were allowed.
3. *Enforcement of equitable sharing of buyback costs.* Investment in a buyback programme must be shared equitably over all license holders, including new entrants who buy licenses later in time, otherwise the existence of 'free riders' would make it both unfair and less economical for the other fishermen to invest. This means that government must agree to collect buyback investment fees, via landing or annual license taxes, from all fishers according to some mutually acceptable cost-sharing formula.
4. *Contingency plans for recovering investments under alternative stock recovery outcomes.* Stock assessments and dynamic models are not reliable in

providing accurate assessments of current fishing impact or stock recovery dynamics under reduced fishing mortality (Walters and Martell 2004). Uncertainty about the benefit from buyback investments can be reduced by providing a clear plan as to how gains in catch resulting from the effort reduction are to be allocated among the remaining license holders (e.g. by individual quotas or by assured access to shares of allowable effort in competitive situations). Also, by providing a clear plan to allow more fishing effort per license if it is found that reduction in fishing mortality rate does not result in increases in stock size [i.e. the stock(s) were not overfished in the first place].

Causes of increased income under effort reduction

There are at least four ways for individual license holders investing in buyback programmes to benefit from reducing the number of fishing licenses. Most fishermen know that reduced competition would lead to improved catch per effort (CPUE) and net income. But this intuition is likely to be based on thinking about causes that would have to be prevented in order to achieve conservation (reduced fishing mortality rate) goals.

First, reducing fishing mortality rate when total effort is reduced is likely to lead to increases in total stock size. On average, higher stock sizes typically result in higher CPUE (and hence lower cost of fishing); if through no other mechanism than reducing the number of low-yield gear sets (Walters and Martell 2004).

Second, reduction in total catch may lead to increased value per unit landed, provided the fishery represents a substantial share of a regional or global market for a product that is specialized enough to command a distinct consumer demand. Fisheries for shrimp rarely show strong price elasticity in local markets owing to the fact that the markets for shrimp are usually global in nature. However, other high-valued species that are restricted in geographical range and are unique fisheries (e.g. Pacific halibut, *Hippoglossus stenolepis*) are subject to strong price elasticity. In the analyses that follow, this possible benefit of reduced catch is not included in the calculations in order to fairly evaluate industry-funded buyback programmes with no price increases.

Third, fishermen can reasonably expect to work more efficiently when there are fewer spatial competitors. Spatial competition can involve simple 'exploitation-competition' where fishermen lose time in searching for fish aggregations that have already been taken by competitors, or more complex 'interference-competition' for the most productive fishing sites (Walters and Martell 2004). Unfortunately, such increases in fishing power or catchability (proportion of stock taken by each unit of effort in a given period) must be prevented by the regulatory agency if total fishing mortality rates are to be reduced so as to achieve financial gains owing to increased stock size or fishing efficiency.

Fourth, fishermen typically assume that a reduction in the number of licenses will mean more fishing time for remaining individual license holders (e.g. longer fishing seasons and/or more places open to the remaining license holders). As noted before, this potential source of improved income must be prevented if fishing mortality rates are to be reduced; at least for long enough to determine if there is a reduction in the total mortality rate that results in an increase in stock(s) abundance.

Options for financing buybacks

If the very stringent conditions for the protection of license holders' investment outlined before are met, then there are two main strategic options for actually carrying out a buyback programme. The first option is a 'pay-as-you-go' system that involves an incremental license purchase plan based on annual funds from license fees or landing taxes. The second option is a 'single purchase' system that involves the purchase of a large number of licenses immediately using borrowed money amortized over a fixed time horizon of 25–40 years (i.e. a small business mortgage).

In the 'pay-as-you-go' system, the largest incremental reductions in license numbers would be in the first few years of the programme. Initially, fees or taxes are captured from the largest number of existing license holders and when license prices are lowest. Then, over time, the annual funding would decline, and license prices would increase owing to increasing revenues per license and development of expectations by license holders for further increase in the value of their holdings (Clark *et al.* 2005a,b). Hence, while this approach would avoid the cost of borrowing money, it ultimately might be more costly to achieve the same overall effort reduction in comparison to a plan which removes a large number of licenses initially while license prices are still small.

The 'single purchase' system has the obvious advantages of: (i) immediately reducing effort so as to achieve a reduction in fishing mortality and growth in stock size as quickly as possible; (ii) buying back licenses at the lowest possible price; and (iii) minimizing the annual cost to remaining license holders by amortizing the repayment over a long period of time. It has the disadvantage of adding potentially quite large interest charges to the total buyback cost, unless an interest-free or very low interest public loan is provided as a cost-sharing contribution to the programme.

With a substantial buyback (e.g. when 50% or more of the fleet is to be bought out), the 'single purchase' system suffers an additional disadvantage. This stems from the fact that there may be fewer than the percentage of the license holders who will want to part with their licenses voluntarily at the assessed fair market value for a license. In that event, it would be necessary to employ some 'fair' method for deciding which license holders would be required to sell, either by some proportional reduction or even through a lottery system.

Models for assessing trade-offs over time

Comparison of financial performance to alternative buyback strategies requires at least three dynamic model components for the prediction of: (i) stock response to reduced fishing mortality rate F; (ii) changes in catch per effort (or per license) with changes in stock size; and (iii) changes in the fair market value (FMV) of licenses with changes in catch per license (i.e. the value of an individual license at the time of retirement). In some cases, it may be prudent to also model changes in prices and fishing costs, especially, as they relate to changes in stock size and in energy costs for fishing.

Stock responses to reduced *F*

Stock size responses to reduced F are likely to occur on two distinct time-scales associated with growth of existing fish (short-term) and future recruitment (long-term). In cases where severe growth in over-fishing has occurred, rapid yield per recruit effects are likely to happen on scales of 1–5 years, owing to build up of larger, older animals in response to reduced F. If there has been severe over-fishing, slower recruitment responses will begin after a delay of at least as long as the minimum age at first capture, and may take decades to be fully expressed. Considering the complexity of these responses as fishermen will see them over time, it is generally safest to use age- or size-structured models to project the stock rebuilding pattern, rather than some simple model such as a surplus production model that may give optimistic projections because of ignoring time delays in recruitment responses. A key decision point when considering investing in buyback programmes is the anticipated gains associated with increases in yield per recruit over the short-term relative to anticipated gains in future recruitment associated with increases in stock abundance.

For the West Florida shrimp fishery example described next, where response time in growth are short (order of months rather than years), we ignored yield per recruit effects and used a simple, continuous recruitment-mortality model for biomass B_t of the form

$$dB_t/dt = R_t - (M + F_t)B_t, \qquad (1)$$

with recruitment and fishing rates R_t and F_t assumed piece-wise constant over a 6-month time step. We assumed recruitment rate during each time step to vary with stock size at the end of the previous period according to a Beverton–Holt recruitment relationship of the form

$$R_t = aB_{t-1}/[1 + bB_{t-1}], \qquad (2)$$

where a is the maximum juvenile survival rate and b is the density-dependent term. Parameters for the recruitment model are derived from leading management parameters (F^*); which corresponds to F_{MSY} and (C^*) which corresponds to the maximum sustainable yield (MSY). We adopted this management-oriented approach because it reduces confounding in the estimates of the leading parameters (Martell and Walters in press). We assumed natural mortality rate, $M = 2.0$, and $F_t = qE_t$ (E_t = effort) and estimated model parameters by fitting the models to observed catch (Fig. 1) (Florida or National Marine Fisheries Service, NMFS) and effort data.

Changes in catch per effort with stock size

Fishermen should generally not expect proportional increases in catch per effort with increases in stock size. Catch per effort is 'hyperstable' in most fisheries

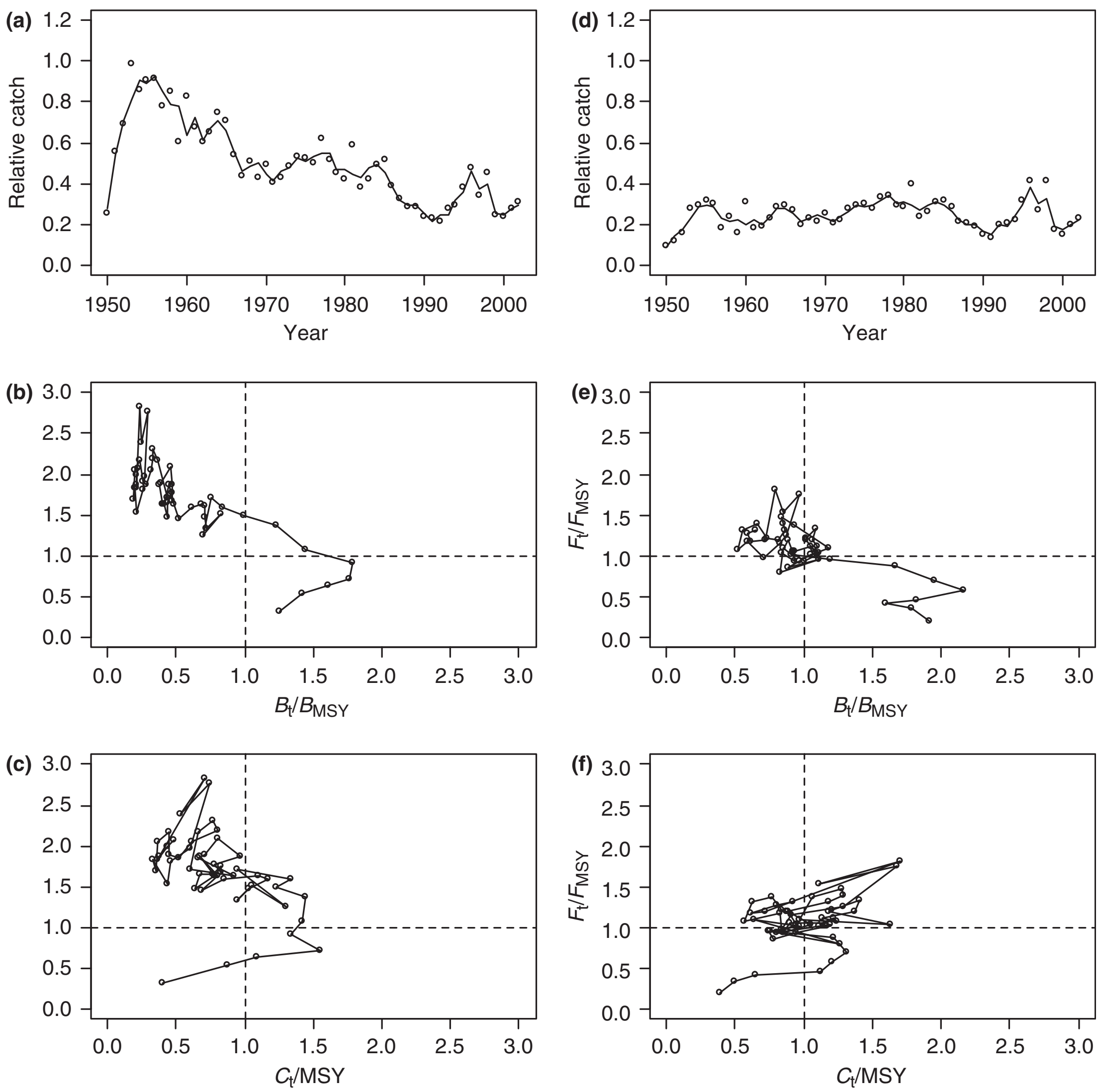

Figure 1 Observed (circles) and predicted catches (lines) from the Florida catch series (left column, panel a) and the National Marine Fisheries Service catch series (right column, panel d). Panels (b) and (e) show the biomass history and fishing mortality history relative to estimates of F_{MSY} and B_{MSY} from the stock assessment models and panels (c) and (f) show the history relative to estimates of maximum sustainable yield (MSY) for each case. The intersection of the horizontal and vertical dashed lines corresponds to optimal fishing based on MSY reference points.

(Harley *et al.* 2001), mainly owing to partitioning of fishing time between search for fish aggregations and exploitation of these aggregations (Walters and Martell 2004, p. 217). It is common in fisheries models to assume (as we do before for model fitting in the West Florida shrimp fishery example) that fishing mortality rate is proportional to effort (i.e. $F_t = qE_t$), where catchability q is the fishing mortality rate per unit effort; this assumption implies that catch per effort is proportional to biomass (i.e. CPUE = qB_t). But if there is likely to be hyperstability in catch per effort, a better assumption (to avoid overly optimistic predictions of improvement in catch per effort as stock increases) is

$$F_t = q_o E_t / (1 + q_o h B_t), \tag{3}$$

implying CPUE = $q_o B_t/(1 + q_o h B_t)$; here q_o represents maximum catchability at low stock sizes, and the 'handling time' h represents the proportion of a unit of fishing time needed to exploit each aggregation encountered (Walters and Martell 2004).

Changes in FMV of licenses

The FMV of an average fishing license has two key impacts in predictions of whether license holders should invest in buybacks. First, it determines how many licenses can be retired for a given total investment (i.e. how costly it would be to reduce effort). But equally important, it is a key indicator for license holders about how much more valuable their licenses are likely to become over the long-term, especially for individuals who view eventual license sale as their 'pension plan' (primary source of retirement income).

Fishing is a business (usually small), and there is no reason not to apply the same methods that are routinely used to estimate sale values of other businesses to appraise fishing licenses. Such methods range from complex analyses of expected revenue and cost streams over time so as to produce estimates of net present value of the business as an asset, to simple statistical models that predict FMV from observed sale prices as a simple multiple of gross annual income (or gross annual revenue multiple; Desmond and Marcello 1987; Lokey and Masson 1987; Finley and Hays 1988; Kuriloff and Hemphill 1988). The basic idea here is that the value is some multiple of the amount of income that the business generates. The statistical models are appealing because they require fewer assumptions about future cost and income streams. They have the added advantage that they are able to provide reasonable estimates of value even when revenues are erratic, which fits the profile of many fishing businesses. Essentially, this approach uses the simple relationship

$$FMV_t = kG_t, \tag{4}$$

where G_t is the gross annual income; for various types of more or less risky businesses, k can range from less than 1.0 to around 6.0 (see http://www.bizcomps.com). There is not enough empirical experience with market sales of fishing licenses under limited license management programmes to provide a range of estimates of k for commercial fisheries, but it seems reasonable to plan on fisheries being about as valuable as other small businesses and to use k values of order 2–5 for initial investment planning.

In situations where voluntary license sales are large enough, at least some licenses would have to be chosen for retirement by lottery. In this case, much more complicated appraisals would likely have to be carried out by current license holders who may lose if a lottery is used to reduce the number of licenses. Considering the current perception of fisheries as risky businesses by investors, it is doubtful that such analyses would result in acceptable (e.g. in court settlements) FMV estimates far larger than the range of kG_t values that would result from using k estimates from other risky businesses.

Case example: West Florida shrimp fishery

The West Florida shrimp trawl fishery developed shortly after the Second World War, and reached peak fleet sizes of 1000+ vessels. The distribution of fishing effort ranges widely over the continental shelf and targets three main species: pink shrimp (*Farfatepenaeus duorarum*), brown shrimp (*Farfatepenaeus aztecus*), and white shrmp (*Panaeus setiferus*). In the early days of the fishery, fishing effort was distributed even more widely, ranging across the Gulf of Mexico to the Campeche bank off Mexico to the coast of Texas. Development of competing fleets in other states and Mexico led to contraction of activities to mainly just waters off Florida. We present two alternative catch histories for this fishery that represent contrasting examples for investment strategies. In the first case, we refer to the catch history as the Florida catch which includes landings from a broader geographic area in the 1950s and 1960s. In the second case, we refer to the catch history as the NMFS catch which represents landings from the Florida region only. The Florida catch series is an example of an overfished fishery and the NMFC catch series is an example of a sustainable fishery.

In the last decade, yields were relatively stable with an annual catch of 6000–7000 mt with a landed value worth US$ 27 million, taken by a relatively stable fleet of around 850 vessels. There have been no annual quotas and no effort restrictions in this fishery; there is a license system in place but with no limited access (i.e. this is essentially an open access fishery). This situation apparently represents a bionomic equilibrium where the average gross annual income of roughly $32 000 just covers operating, depreciation/replacement, and skipper plus crew salary costs.

We fitted stock assessment models, based on the population dynamics in Equations (1) and (2), to the historical catch series (Florida and NMFS) conditioned on the same fishing effort series (details of the assessment model are outlined in the Appendix). Results from the assessment models indicate that the current landings are roughly 55% and 94% of

Table 1 Estimates of key parameters and reference points from the stock assessment models using the Florida and National Marine Fisheries Service (NMFS) catch series.

Parameter	Florida catch	NMFS catch
MSY	0.557	0.242
F_{msy}	0.591	0.92
B_{msy}	0.924	0.263
B_0	2.164	0.648
F_{2002}	1.127	1.127
B_{2002}	0.262	0.187
Biomass status (B_{2002}/B_{MSY})	0.277	0.711
Fishing rate status (F_{2002}/F_{MSY})	1.907	1.224
Catch status (C_{2002}/MSY)	0.553	0.938

MSY, maximum sustainable yield.

MSY for the Florida and NMFS catch series, respectively. Current estimates of fishing mortality rates are $1.9 \times F_{MSY}$ and $1.2 \times F_{MSY}$ (Table 1). Thus, there would be considerable economic benefit in reducing fishing effort by about half to 20%. The stock assessment models were also used to forecast biomass and catch responses to alternative future effort patterns associated with two alternative buyback programmes assuming that the industry–government protection measures described earlier are in place. The forecasts also include calculations for landing taxes and or mortgage payments, the number of fishing licenses retired, and the net income per license for each year of the forecast. We also compare alternative buyback programmes to a status quo option where the number of fishing vessels remains at 850 with no annual total allowable catches or effort restrictions.

'Pay-as-you-go' system

Consider first a very pessimistic economic scenario in which fishermen are unable or unwilling to seek a mortgage, are unable to tolerate landing taxes exceeding 10% of landed value to put toward a pay-as-you-go buyback programme, and find that prospective license sellers are unwilling to sell for less than five times their gross income ($k = 5$ in $\text{FMV}_t = kG_t$ model for market value). Under this scenario, license numbers would decline slowly, with a maximum of only 17 licenses retired per year, with that number dropping considerably over time to about 11 licenses per year after 20 years for the Florida catch series (Fig. 2b). This is owing to increasing FMV_t associated with improving gross incomes G_t (Fig. 2c). At a tax rate of 10%, it would take roughly 36 years to complete the buyback and reduce the fleet to the optimum size of 410 vessels (Fig. 2b). After 20 years, an individual license holder would have invested (been taxed) \$72 000, or a total of around \$49 million for the remaining fleet of 567 vessels. However, average net income per license (gross income minus the buyback tax) would increase to about \$50 000 under the most optimistic assumptions about stock recovery, with each license having a retirement fund value (FMV_{20}, assuming $k = 5$) of around \$250 000 (Table 2). For comparison, putting the same amount of money as the landing taxes each year into a retirement fund with an average annual interest growth rate of 6% would result in a total retirement fund after 20 years of around \$134 000; hence, growth in stock size would (optimistically) make quite a difference to the potential retirement value of a license held by a younger individual. The 20-year discounted net gain in value (NGV), assuming a discount rate of 7% is roughly \$50 930, which is the difference between the NPV under the buyback scenario and that under the status quo (Table 2).

If relatively minor reductions in fleet size are required to achieve the target fishing mortality rate that will optimize long-term yield (e.g. the NMFS catch series), the earning potential in a buyback programme is less in comparison to an over-capitalized fleet. In the NMFS catch series, the optimal fleet size is 644 vessels and the net income per license holder is roughly \$45 000 per year, 20 years post-buyback. The discounted net gain in value after 20 years is roughly \$23 946 (Table 2).

'Single purchase' system

Under the single purchase buyback programme, an initial payment of nearly \$70 million is required to reduce the fleet size from 850 to 410 vessels in order to reduce fishing mortality rate to F_{MSY} levels in the Florida series case. In this example (Fig. 2 and Table 2), we assume interest rate of 8.5%, amortized over 35 years, which corresponds to annual payments of \$6.33 million (or \$15 433 per license holder) to service the initial \$70 million loan. Initially, this is a huge financial burden that decreases the annual net income by over \$17 000 in the first few years after the buyback programme. After 20 years, the total financial investment in the

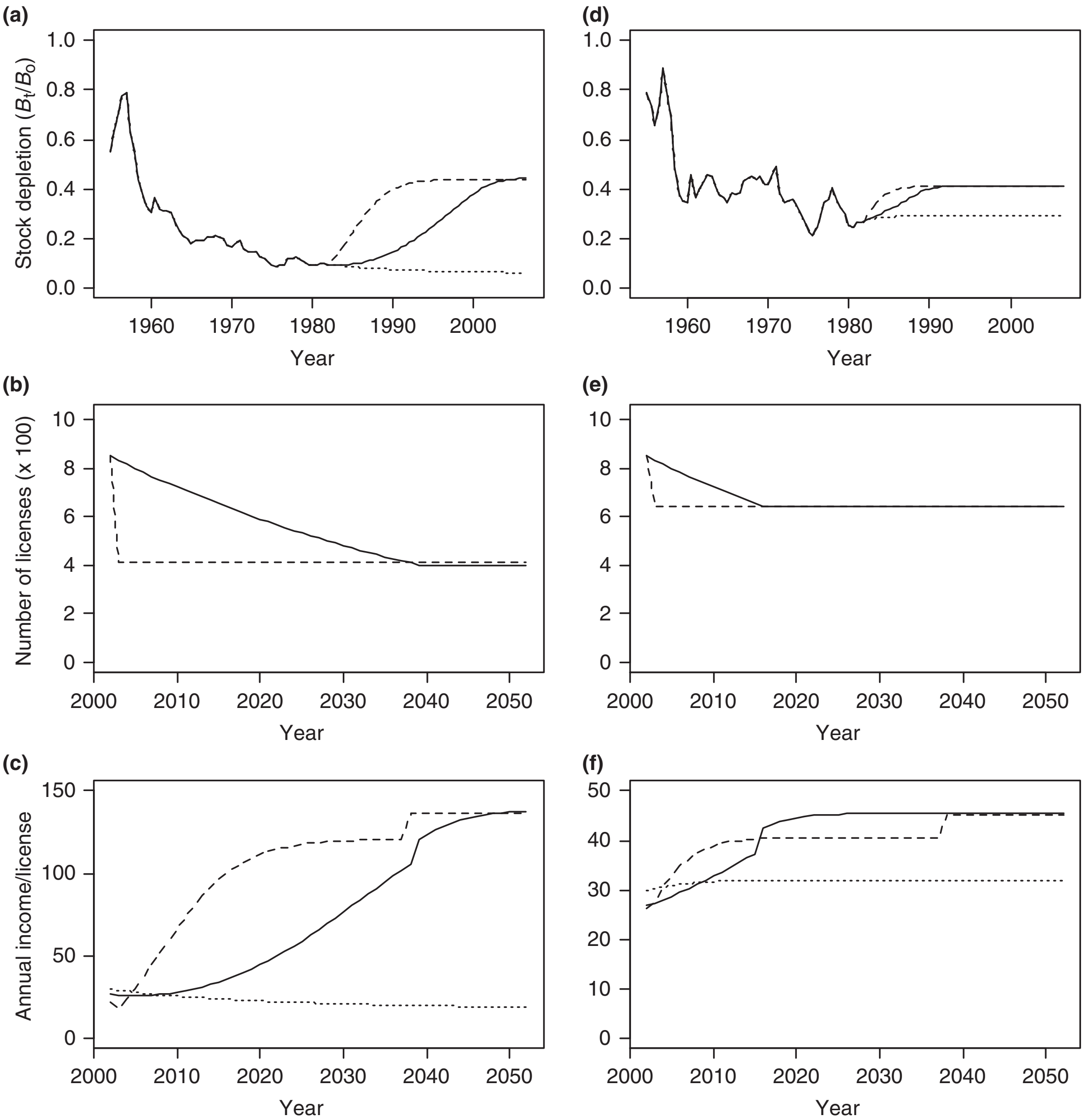

Figure 2 Predicted changes in relative depletion (a, d), number of licenses operating (b, e) and, annual income/license (c, f) for the 'pay-as-you-go' buyback programme (solid lines), 'single purchase' programme (dashed lines), and status quo or no buyback programme (dotted lines) for the Florida catch series (left column) and National Marine Fisheries Service catch series (right column) from 2002 to 2052.

buyback programme is just over $308 000 per license holder; however, the projected annual income is just over $114 000, and the estimated license retirement value would increase to $573 980 (Table 2). In comparison to the status quo of 850 vessels, this represents nearly a $400 000 discounted net gain in value (Table 2). An equivalent investment with annual contributions equal to the mortgage payments would have to return 5.4% per year to match the retirement value of $573 980.

Suppose, however, that license holders were able to negotiate a low interest rate government loan of say 1%. There are a number of good reasons alluded to in previous sections of this paper why governments should be willing to subsidize a mortgage. With a 1% interest rate, the corresponding annual payments are approximately $5900 per license holder per year, and the net income 20 years after the buyback is roughly $123 000 per year with a license retirement value of $615 000. To equal this growth in value, a retirement fund with annual

Table 2 Per license value and the number of vessels operating for the Florida and National Marine Fisheries Service catch series under alternative buyback options compared with no buyback option (status quo). Net income is defined here as the landed value minus the cost of servicing the buyback option, FMV (fair market value) is five times the net value, NPV is the discounted net present value assuming a discount rate of 7%, and NGV is the net gain in discounted value (i.e. difference between the NPV under a buyback scenario and NPV under the status quo).

	Florida series			NMFS series		
	Pay-as-you-go	Single purchase	Status quo	Pay-as-you-go	Single purchase	Status quo
1-year post-buyback						
Vessels operating (numbers)	833	410	850	833	644	850
Net income ($)	26 337	17 946	29 117	27 365	27 573	30 254
FMV ($)	131 686	89 729	145 584	136 825	137 866	151 269
NPV ($)	51 415	39 101	56 990	52 386	52 061	58 064
NGV ($)	5576	17 889	NA	5679	6003	NA
10 years post-buyback						
Vessels operating (numbers)	695	410	850	695	644	850
Net income ($)	30 183	80 459	24 877	34 600	39 724	31 815
FMV ($)	150 917	402 294	124 383	172 998	198 620	159 073
NPV ($)	216 796	336 843	219 891	239 940	270 700	248 719
NGV ($)	3096	116 951	NA	8779	21 981	NA
20 years post-buyback						
Vessels operating (numbers)	567	410	850	641	644	850
Net income ($)	50 082	114 796	22 235	45 029	40 609	31 993
FMV ($)	250 409	573 980	111 174	225 144	203 046	159 966
NPV ($)	354 534	700 458	303 604	386 697	414 867	362 751
NGV ($)	50 930	396 853	NA	23 946	52 116	NA

NA, not applicable.

contributions of $5900 per year would have to grow at a rate of 13.2% per year.

For the NMFS case, a single purchase buyback would reduce the number of vessels from 850 to 644, with a total purchase price of $33 million. Corresponding annual payments are approximately $4600 per license holder per year, which is roughly 15% of the total income in the first year, and roughly 10% of the total income in year 20. Relative to the status quo, the annual income increases from $32 000 to $40 000 per year (a 21% increase) and would more than cover the cost of loan repayment. However, the discounted net gain in value is approximately double ($52 000; Table 2) in comparison to a pay-as-you-go system.

Scenarios like these show that for very short-lived and productive stocks like shrimp, the main beneficiaries of an industry-based buyback programme would be younger fishermen who plan for a fairly long fishing career and are concerned about eventually having a reasonable nest egg for retirement. But younger fishermen are also likely to be the least able to afford the annual tax or mortgage payments that loom large as proportions of total income for some years, until stock sizes have substantially increased. For this case, less extreme scenarios (more realistic mortgage interest rates and amortization periods, more modest tax rates) generally imply either severe reduction in gains in long-term incomes, or impractically severe impact on immediate incomes.

Note that in calculating the net gains in this paper, the operating costs of fishing (fuel, depreciation, wages, and so on) were not taken into account. By this, we are assuming that per vessel operating costs in a reduced fleet are the same as in the original fleet. This is a strong assumption, which is most likely to make our estimated gains conservative because in general the more biomass there is in the ocean, the lower will be the cost of fishing, everything being equal. Hence, the scenarios that allow rebuilding will lead to a lower per vessel operating cost.

The FMV prediction parameter k obviously has a heavy impact on the attractiveness of investment scenarios. If it were lower than 5, say 2, the initial tax or mortgage burden on remaining fishers would be much lower, many more licenses could be purchased for the same investment (for instance, $k = 2$ would imply needing only a $28 million mortgage to reduced the fleet to 410 vessels), and stock rebuilding would be much more rapid. But persistently low k values would also mean much lower retirement values for licenses.

Interestingly, high uncertainty about stock recovery and eventual income per license holder (Fig. 2d,f) does not imply that investment is a bad gamble. Even under the most conservative recovery projection, there would be a quite substantial increase in long-term income and license value.

Discussion

The shrimp fishery example shows that it certainly can make good business sense for license holders who take a long view of their fishing future to invest in buyback programmes, particularly if government assistance is provided in the form of low-interest mortgages with long amortization periods. Mortgage-based programmes appear to be much more desirable from a stock-rebuilding and long-term economic perspective in comparison to pay-as-you-go programme. This is especially true if the fishery is severely depleted because expected short-term gains are much greater following an immediate reduction in fishing mortality. Whereas, the pay-as-you-go programme delays the stock rebuilding process because there are only marginal reductions in fishing effort from year to year. It may also make sense for governments to offer such mortgages as an 'in-kind' contribution to promoting safer and more productive fisheries. In cases like the shrimp fishery, there may also be considerable benefits to other fisheries and marine conservation interests, through reduction in bycatch and benthic habitat damage caused by trawling. This raises the interesting question of whether those other competing interests would be willing investors in the effort reduction.

Considering that fishermen are highly heterogeneous, with some not willing to give up immediate income for long-term gains from better management, it is really difficult to see how widespread consensus could be reached about whether and how to enforce an equitable distribution of buyback costs over an entire fishing fleet. If a 'democratic' choice based on majority vote is to be the basis of deciding whether to proceed with a buyback, it is quite probable that license holders with the long-term view will lose.

What should governments do in the likely event that there is not a clear consensus among license holders to proceed with a buyback programme that would require mandatory participation and payment by all license holders? In requiring all license holders to help pay for the programme, then retiring the licenses that are purchased, governments would essentially be exerting powers of eminent domain. There is growing precedent in North America for using such powers to benefit particular economic interests (in this case, the remaining license holders), with only vague justification about public benefit. But there is also growing concern about the abuse of such powers. A key question for further research is whether there are economic incentive schemes that might bypass the issue entirely, in favour of investment/payment plans that are broadly acceptable to both fishermen who want to invest for the long-term and fishermen who could be induced to leave.

This paper has not considered the property rights alternative of converting fishing licenses to individual transferable quotas (ITQ), then encouraging stock rebuilding through purchase and retirement of some quota holdings. This alternative presumes accurate enough stock assessments to determine how much quota would have to be retired in order to achieve low enough fishing mortality rates that would allow stock recovery. Much less precise (and less costly) assessments are needed to estimate effort reductions needed to achieve fishing mortality rate reductions (Martell and Walters 2002). The ITQ alternative is likely to look much less attractive relative to the proposal in this paper if the additional costs of accurate assessments (i.e. annual fisheries independent surveys over a broad geographical region) were included in the annual calculations of fishing cost.

Resistance to buyback programmes might not be that difficult in practice as there are many examples of concentration of ownership in ITQ fisheries or license stacking (i.e. diversifying the fishing portfolio with several different species quotas). Concentrating the quota into few hands does nothing to reduce fishing mortality, but it does reflect that some fishing industries are willing to invest in order to increase profit margins through the incentive of catching more fish with only marginal increases in operating costs. Similar arguments about investing in future quota could be used in fisheries managed under ITQ, but all the quota holders would have to view their share as future fishing opportunities and be willing to retire some quota holdings or reduce the overall total allowable catch in order to allow stock recovery. Similarly, improvements in fishing technology makes good economic sense, but would call for further reductions in fishing capital and additional investment in buyback programmes.

The deterministic scenarios presented here are intended to represent two contrasting scenarios where there are small and large incentives to invest in buyback programmes. Such scenarios could also be extended to better characterize investment risk by incorporating additional stochastic components representing variation in stock projections, or better characterize the uncertainty in the current status of the resource. Such additions to the models for assessing trade-offs over time would result in a range of projected future market values. A volatile investment would be represented by a stock with high recruitment variation; high investment returns with strong recruitment events and large short-term losses with recruitment failures. A relatively stable investment would be represented by stocks that show little variation in recruitment.

Considering the severe temporal trade-offs and high uncertainties about future benefits associated with buyback investment choices, and the difficulty of justifying public intervention to force such choices on license holders, it is certainly not appropriate to view buyback programmes by fishers as a win–win option for reducing fishing effort and over-capacity in general. Rather, we should see these very difficult decision problems as a warning for the future. The widespread current practice by governments of delaying decisions on needed effort reductions is likely to make the choices progressively more difficult to make with time.

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Appendix: Assessment model and reference points

The observed data consist of the total removals (C_t) and the fishing effort (E_t), and the distribution for the instantaneous natural mortality rate (M) is assumed to have a mean of 2.0 and a standard deviation of 0.2. Estimated parameters consist of the maximum sustainable yield (C^*), the fishing mortality rate corresponding to MSY (F^*), a vector of annual recruitment deviations (w_t), and a vector of annual deviations in the instantaneous natural mortality rate (v_t). In each case, a total of 109 parameters were estimated. The initial biomass (B_t) was initialized using $B_t = C_t/F_t$ for $t = 1950$. Note that for both the Florida catch series and the NMFS catch series we assume the same catchability coefficients ($q = 1$); therefore, the model results are scaled such that the same fishing mortality is assumed for both catch series and the estimated biomass is on a relative scale.

Estimated parameters:

$$\theta = \{C^*, F^*, M, w_t, v_t\}. \qquad (A.1)$$

Derived variables and reference points based on Equations (1) and (2):

$$a = \frac{(F^* + M)^2}{M}, \qquad (A.2)$$

$$b = \frac{F^*(a - M - F^*)^2}{C^*(F^* + M)}, \qquad (A.3)$$

$$R_0 = (a - M)/b, \qquad (A.4)$$

$$B_{\mathrm{MSY}} = C^*/F^*, \qquad (A.5)$$

$$B_0 = R_0/M. \qquad (A.6)$$

Residuals:

$$\varepsilon_t = \ln(C_t) - \ln\left(F_t\left[\frac{R_t}{Z_t} + \frac{\left(B_t - \frac{R_t}{Z_t}\right)(1 - \exp(-Z_t))}{Z_t}\right]\right), \qquad (A.7)$$

$$v_t = \ln(M_t) - \ln(M), \qquad (A.8)$$

$$w_t = \ln(R_t) - \ln\left(\frac{aB_t}{1 + bB_t}\right). \qquad (A.9)$$

Objective function:

$$\ell(\theta) = \sum_t \varepsilon_t^2 + \sum_t v_t^2 + \sum_t w_t^2 + \ln(\sigma_M) + \frac{(M - 2.0)^2}{2\sigma_M^2} \qquad (A.10)$$