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Conservation that's more than skin-deep: alligator farming

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Abstract Wildlife farming is a contentious conservation measure. In Louisiana alligator farming has generated significant conservation gains. This case study is used to test several assumptions employed in debates about wildlife farming. These include whether farming 'floods' the market to depress prices and deter poaching, whether it encourages wild harvest and whether it can compete against wild harvest. Data from over three decades is used to model harvest behaviour with OLS and SUR models. This shows strong separation between the market between farmed and wild alligator skins. Immense rises in farmed output have not caused prices to collapse, however poaching has collapsed. This highlights that farming can have important non-price effects on poaching. Assumptions that are commonly used to debate wildlife farming are not supported in this example. Such assumptions, including open-access of the wildlife, inert and exogenous wildlife managers and excluding indirect benefits of wildlife farming tend to bias policy away from farming. Using these assumptions makes it harder to identify cases where wildlife farming could assist conservation objectives.

Keywords Alligator · Wildlife-farming · Conservation · Sustainable use · Poaching · Black-market

Introduction

Wildlife farming is sometimes proposed as a solution to conservation problems like poaching or human–wildlife conflicts (Bulte and Damania 2005). It is however a contentious and hence rarely employed measure (Nogueira and Nogueria-Filho 2011). This reluctance to employ it may mean opportunities to improve the status of species are forgone. It is important that this option is evaluated properly.

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Policy decisions should be based on robust economic reasoning and empirical examples. One such example is the sustainable use programme for the American alligator (*Alligator mississippiensis*) in Louisiana. This means it can also be used to test the validity of many assumptions about the economics of wildlife farming. In this paper wildlife farming is used in the wider sense, and includes ranching, which is raising wild-sourced stock in captivity (Nogueira and Nogueria-Filho 2011).

Alligators have been the subject of a sustainable use programme since the early 1970s in Louisiana (Joanen and McNease 1987; Elsey and Kinler 2004). The data from this programme has been collated annually and as such, it is a rare example of such a long duration study. There are a range of issues that can be addressed with this example.

The first issue applies to the supply-side of the market. One perception is that an increase in farmed skin-output will cause prices to fall and this will crowd out (reduce) wild-harvests. Poaching is part of the wild harvest. Any crowding-out will thus reduce poaching and this will have a positive conservation effect.

The second issue is whether farmed output encourages an increase in wild harvests. Many conservationists are concerned that farmed output of wildlife may increase illegal wild harvests. There are two paths this could take. The first is that it could increase demand by reducing any stigma effects that are associated with a ban (Bulte and Damania 2005). The second path is by expediting laundering. Laundering occurs when the products of the illegal wild harvest are introduced into the legal market as if they were legal (Bulte and Damania 2005). Assuming customers or enforcement agencies are unwilling or unable to identify the illegal parts, the legal trade acts as a cover for illegal. This means that even if there is no increase in demand for poached parts, consumers may still purchase more poached parts by mistake.

The third issue raised with wildlife farming is its competitiveness. Wildlife farms require a level of capital and ongoing costs (such as food) that hunters do not. This may mean that wild harvests have significantly lower costs than farming. Hence it is sometimes questioned whether farms can be competitive against the wild given farming costs are higher (cf. Damania and Bulte 2007, p. 467).

The three identified issues generate three separate hypotheses. The first is that wild harvest is partly dependent on farmed output and that this relationship is negative. The second is that wild harvest is partly dependent on farmed output and that this relationship is positive. Some of this wild harvest will come from increased poaching. Assuming legal hunters and poachers are employing the same technology, then behaviour of poachers should mimic the actions of legal hunters. The response of legal hunters will thus resemble the responses of poachers. Deliberate mimicking occurred with alligators in the 1960s in the US (Thorbjarnarson and Wang 2010).

The third hypothesis is that farmed output is partly dependent on wild harvests and this relationship is negative. In the extreme case, wild output will drive farmed output to zero. If neither wild nor farmed sellers are price takers (as would occur in a Cournot market), this third hypothesis implies that wild and farmed output are endogenous and determined simultaneously. The absence of endogeneity in output would imply that producers are price takers.

The main characteristics of this market need to be described before any formal analysis is undertaken. Alligators are a large reptile whose hide produces valuable leather. Widespread commercial hunting was underway by the late nineteenth century and the wild population plummeted (Thorbjarnarson and Wang 2010). In Louisiana an average of 64,000 alligators between 1880 and 1933 were harvested annually (Joanen and McNease 1987). As the large European market recovered after World War II, the population collapse continued. The annual harvest rate averaged around 18,000 animals from 1939 to 1960 (Joanen and McNease 1987).

This decline in wild populations prompted Louisiana and Florida to ban hunting completely in 1961 and 1962 respectively. Nonetheless illegal hunting to supply markets in other states continued until the Lacey Act was strengthened in 1969 (Thorbjarnarson and Wang 2010). The reduction in hunting pressure and readily available habitat led to an early population recovery.

By the 1970s the policy problem had shifted away from managing low population densities to managing increasing densities (Joanen and McNease 1987). The increase in alligator populations began generating more human-wildlife conflicts (Thorbjarnarson and Wang 2010). To ameliorate concerns a new management regime including harvest was initiated in 1972. This program employs economic incentives to maintain popular support for alligators and sustain their recovery and habitat. The unusual aspect of this scheme is that it includes harvest of alligators in the wild, alongside those from captive-sources (farms with integral breeding stock and ranching). Many other sustainable use programmes are exclusively one or the other.

The wild harvest is generally restricted to a 30 day season centred on September (Elsey and Kinler 2004). The number of alligators that can be taken is controlled by hunting tags, issued by the Louisiana Department of Wildlife and Fisheries (DWF). The number of tags issued is linked to the habitat type (degraded wetlands get fewer tags) and specific to geographic areas. These assessments are very labour-intensive (Elsey and Kinler 2004). The overall number of tags issued is proportionate to the wild population of alligators. As wild alligator populations have increased, the number of tags issued has also increased. Hunters however, typically use 90–95 % of the tags issued in a season (Elsey and Kinler 2004).

The second hunting restriction is on size. Only alligators longer than 4 ft (1.2 m) can be taken (Joanen and McNease 1987). Hunters however prefer to harvest alligators larger than this minimum. Hence in the period 1999–2009 a small number of bonus tags (10 % of the regular quota) were issued for smaller alligators (4–5 ft) to rebalance age distributions (Elsey and Kinler 2004). Alligator meat sales have been permitted since 1979 and this helps buffer the revenue of hunters against the skin-price volatility (Joanen and McNease 1987).

In summary, the wild harvest of alligators has three important aspects. The first is that it is undertaken by a large number of small harvesters (hunters). The second is that the supply decisions are output based. The Louisiana DWF decides what the limit on harvest will be. Hunters decide how much of the harvest to take up. The third is that wild harvests occur late in the year and after much of the farmed output has occurred.

Alligator farming has gone through three phases. The original farms were small and often operated as a hobby rather than a commercial enterprise (Elsey and Kinler 2004). The farms were true farms in the sense that eggs came from adult breeding animals held in captivity. Phase two coincided with the placement of alligators on Appendix II of CITES, which regained access to export markets for skins (Joanen and McNease 1987). This led to an expansion of exports and commensurate rise in farming operations. This led to farms becoming larger and more commercially focused. The third phase was the introduction of ranching in 1986 (Elsey and Kinler 2004). Eggs were taken from nests in the wild under a permitting system run by the Louisiana DWF. The hatched offspring take one to two years to reach a size suitable for harvest (Elsey personal communication).

The ranching phase led to rapid growth in the industry. This was spurred by the record high skin prices of the late 1980s (Elsey and Kinler 2004). Meat production from farmed alligators started in 1980 but is a much smaller element of revenue than the wild alligator industry. Skin prices then fell in the wake of the 1990–1991 global recession (Elsey and Kinler 2004). This led to a reduction in farm numbers, but of a larger average size in the 1990s. Farmed output then stabilised. The switch from farms with integral breeding stocks to ranches was not universal because ranches have one disadvantage.

An important disadvantage to ranching is the cost of returning some juveniles to the wild. This cost comes in the form of the foregone revenue of these alligators. This policy is a deliberate mechanism to tie together the conservation and farming via a regulation. This is not however, required of farms that have their own breeding stock. By 2010, over 820,000 juvenile alligators have been released (Elsey and Kinler 2004). In 2005 this egg-collection and release buffered the natural population against the elevated nest-mortality caused by Hurricanes Katrina and Rita (Elsey and Kinler 2006).

The farmed output of skins has several important traits. First, like the case of wild harvest the supply decision centres on output. It is based on eggs the farm holds. The ranched output comes from eggs that are collected under quantity permits about two years earlier. Second, output from farms largely precedes the wild output. It occurs continuously rather than being postponed to September. The third point is that the increase in farmed output has been huge (Fig. 1). The output of skins also has a high correlation with total length (Fig. 2). Nonetheless this is not associated with any commensurate declines in wild output or prices (Fig. 3).

Farmed skins and wild skins also diverge in their traits. Farmed skins come from much smaller animals (3–4 ft long) than the wild skins, which come from much larger animals (averaging 7 ft or more). The price per foot of hide also differs between the two, with wild skins typically having a premium until quality improvements in farmed leather overtook this (Fig. 4). This premium is derived from the size of the wild leather rather than its innate quality. As an aside alligator skin prices can be measured in two ways. One is based on length per foot, and the other is the belly-width in centimetres. These measures are nearly perfectly correlated.

The farmed skins are used for small leather goods like watch wrist-straps. The wild skins are used for larger leather goods, like hand bags (Elsey personal communication). The higher prices of the larger leather goods contributed to the wild-leather premium.

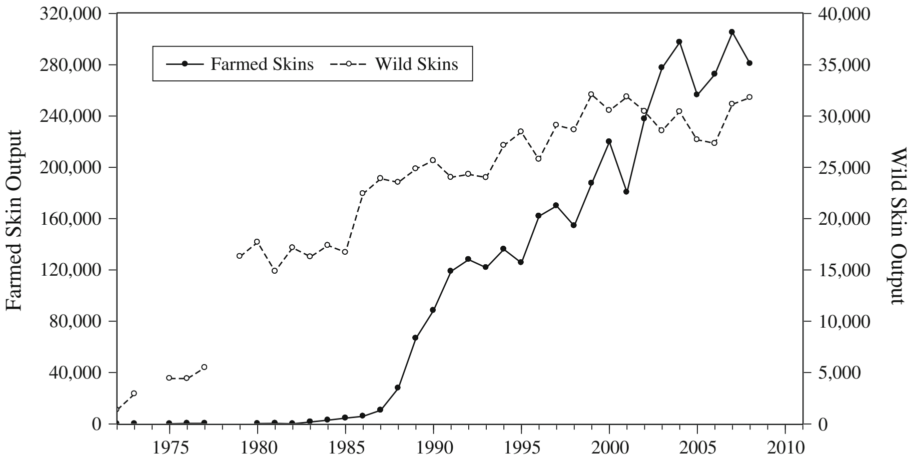

Fig. 1 Alligator skin output–actual skins

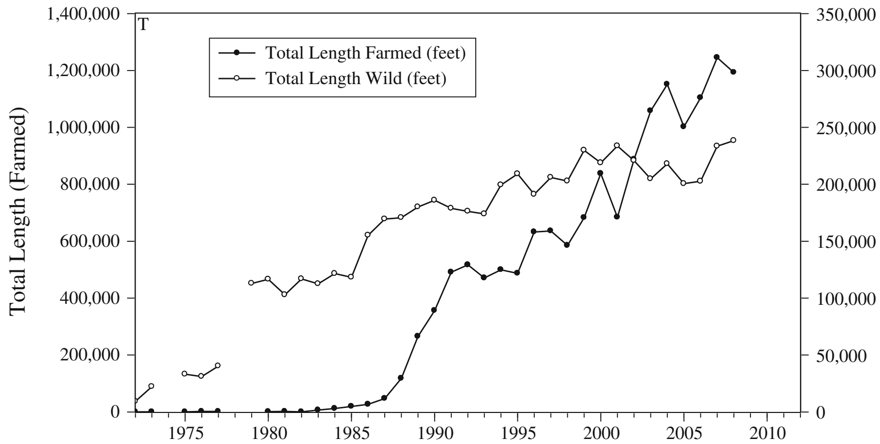

Fig. 2 Alligator skin output–total output length measure

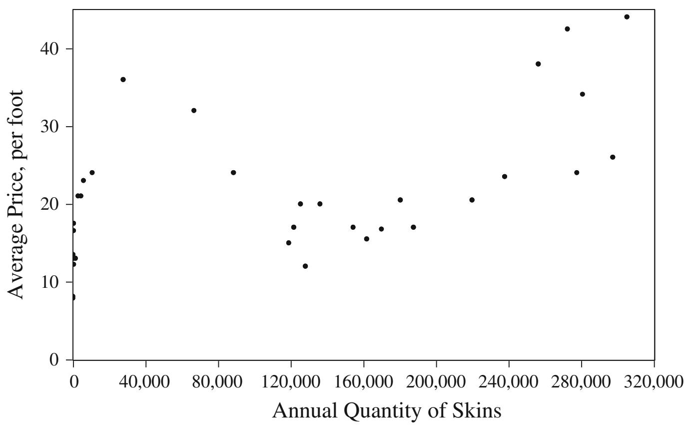

Fig. 3 Farmed prices versus farmed output

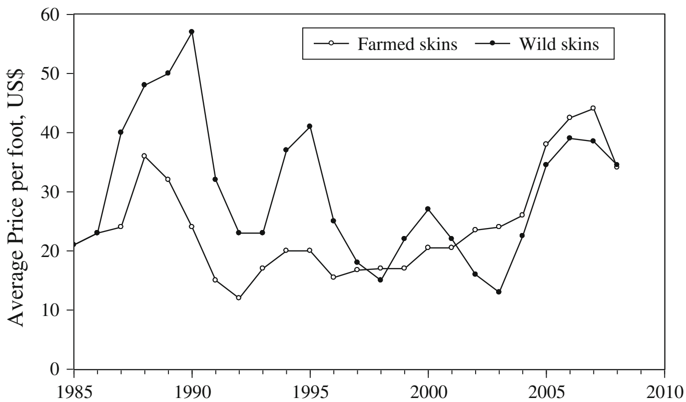

Fig. 4 Prices of farmed and wild skins

Hence the leather from the two sources has traits that the final market values differently. It cannot be assumed that these are products that are close substitutes.

Methodology

The statistical modelling began by examining the data to infer an appropriate functional form for the equations. The statistical software EViews 7.1 was employed for analysis. Parsimonious models were then generated and tested for the presence of endogenous variables. The motivation for parsimony was that the number of observations was not great given its annual nature. Redundant variables would have a large impact on the degrees of freedom. The results of ordinary least squares (OLS) and seemingly unrelated regressions (SUR) models are presented in the end.

Harvest data for the period 1972–2008 was employed. The global financial crisis in 2008 produced a catastrophic shock from 2009 onwards and the following structural break in the series is immense. Data from 2010 onwards has not been released. The data is reported at an annual frequency. It should be noted that the wild alligator hunting-season is about one month long hence it is not continuous.

The data contains four market parameters. These are the quantity of skins produced from the two sources (wild and farmed) and the average price per foot of skin for the two. These were tested for unit roots employing the Augmented Dickey–Fuller tests. These supported the presence of unit roots in the variables that were eliminated by using first differences. The Johansen test rejected the presence of cointegration between these variables. This eliminated the error-correction model and supports the inference the two markets for alligator skins have no long-term relationship. A differenced-functional form is therefore an appropriate specification.

There are two dependent variables. These are the skins produced by farms and the skins produced by hunting. The prices of the skins are required by economic theory to be included as explanatory variables. These would also be endogenous under Cournot imperfect competition assumptions. It is also possible that wild skin output is endogenous to farmed, and vice versa if producers are responding to output-levels in the other market. There are several environmental and other production variables that may also serve as explanatory variables.

Alligators are a wild resource and even the farms are dependent on wild-sourced eggs. The Louisiana wetlands are the source of these outputs. These wetlands are subject to two kinds of environmental perturbations. These are hurricanes and droughts. In the sample period the largest disturbance came from Hurricanes Katrina and Rita in 2005 (Elsey and Kinler 2006). These were represented as the dummy variable Katrina. The Palmer Drought Severity Index for Louisiana was sourced from the US National Oceanic and Atmospheric Administration as the drought variable. Given this index is measured as a deviation from a norm, it was not differenced.

The production of skins requires additional inputs. For farmed skins the number of eggs on the farms is an essential input while the actual number of farms affects the scale of output. For wild skins the number of hunters is also a potential explanatory variable.

The economic output of skins is also influenced by exogenous factors. The Louisiana DWF is one such agent that influences wild harvest through the hunting tags they issue and enforcement of harvest regulations. The number of hunting tags issued each season is another possible explanatory variable.

Skins from both wild and farmed sources are exported in significant numbers. Hence external trading conditions may also exert an effect on harvest decisions. This could be done via the US terms-of-trade, exchange rates or foreign incomes (Joanen and McNease 1987). The total level of US exports measured in US dollars was used as a proxy for this exogenous parameter to reduce the number of variables for parsimony. Competition from other regions may also affect output decisions of farms and hunters. The output of alligator skins from Florida and the export figures for Nile crocodile skins from Zimbabwe were also tested. The Nile crocodile export figures were sourced from CITES.

Many of the variables above would not have a contemporaneous effect on harvest levels. For instance, the numbers of eggs collected or hatched in one year do not become part of that year's output. It takes time for these juveniles to mature to a point where harvest is economic. Environmental perturbations could also spill over into following seasons. Recovery from some of these events may take time. This creates a modelling problem for parsimony. If these lags are distributed over several years then the degrees of freedom in the model will suffer. Hence lag-lengths were carefully considered on the basis of their likely effect, then tested for sensitivity.

For instance, the lag length for alligator egg collection was selected as two years, given it takes one to two years for farmed alligators to reach a size suitable for harvest. This was tested for sensitivity by varying this length to one to three years. The two year lag received the strongest support. This lag fortunately matched the production cycle for skins. This was the only lag length retained, which minimised the impact of the degrees of freedom in the models.

Parsimonious models using OLS were generated for the two types of output. Each equation was then tested for the presence of endogenous variables. The Hausman test was employed to test variables for endogeneity. This is a two step process that first estimates residuals from a reduced form equation then second, tests their significance in a structural equation. For the farmed output, prices of farmed skins and output of wild skins were tested. For wild output the prices of wild skins and output of farmed skins was tested. In all cases endogeneity was rejected. This result supports the inference that the producers in these skin markets are price takers and lack market-power.

The closely related nature of the two products (farmed and wild skins) then motivated the final model for this analysis. This was a seemingly unrelated regression methodology. This estimates a system using generalised least squares for the two equations, linked via their contemporaneous residuals. The use of GLS also makes the estimation technique robust against heteroscedasticity.

Results

In terms of the OLS model (Table 1) for the output of wild skins, the final model had four variables with statistical significance. Changes to prices had a positive effect on output as did the number of hunting tags issued by the Louisiana DWF. While the numbers of hunters was eventually omitted from this model, this variable does match the number of tags issued closely. Hence, the number of hunters can be inferred from the number of tags. Hurricane Katrina had a major effect on the 2005 season, producing a large drop in output. The effect of Katrina had not dissipated by 2006 and the inclusion of a lag in this variable also eliminated autocorrelation in the model.

The proxy for foreign demand for wild skins (US exports) was insignificant but its inclusion improved the model selection tests. The rationale for using the following year's export levels is one of timing. Wild skins are harvested late in the year. The carcasses are

Table 1 OLS regression results

Variables	Farmed		Wild	
	Model 1	Model 2	Model 3	Model 4
Dependent variable	D (Qf)	D (Qf)	D (Qw)	D (Qw)
Explanatory variables				
D (Pi)	501.500 (712.294)	514.887 (698.602)	23.608 (14.282)	27.582** (12.610)
D ($eggs_{t-2}$)	0.102 (0.066)	0.085 (0.0742)	–	–
D (farms)	768.866*** (228.104)	797.924*** (198.356)	–	–
D (tag)	–	–	0.894*** (0.052)	0.893*** (0.0498)
D (US exports)	0.110** (0.042)	0.125** (0.046)	–	–
D (US $exports_{t+1}$)	–	–	0.001 (0.001)	0.002 (0.001)
D (ZW skins)	0.568 (0.375)	–	−0.013 (0.0128)	–
Katrina	−62,184.940*** (8,629.006)	−62,230.520*** (8,758.323)	−4,078.773*** (653.693)	−4,242.387*** (612.129)
$Katrina_{t-1}$	–	–	2,959.485*** (742.187)	2,724.004*** (662.661)
PDSI	−631.004 (857.333)	–	−2.465 (0.013)	–
R^2	0.374	0.321	0.936	0.934
Adjusted R^2	0.210	0.212	0.920	0.924

Coefficients listed first, with standard errors in brackets underneath

Coefficients that have significance at 10 % are *, at 5 % are **, and at 1 % are *** transported by refrigerated trucks before then being skinned, a process assisted with compressed air and pressure washers to reduce damage to the hides (Elsey and Kinler 2004). The skins then have to be soaked, limed, delimed and bated, then pickled before they can be tanned. They are then tanned, dried, finished and sold. For animals shot over September the export sales align more closely to the following year's exports.

Droughts as measured by the PDSI did not have a statistically significant effect. The effect of droughts may also been mediated the number of tags issued by the Louisiana DWF. This variable was eventually omitted. The skin output from Florida and Zimbabwe were not significant either. It does not appear that Louisiana producers are well informed enough to take anticipate and adjust their output plans for output elsewhere.

The final OLS model (Table 1) for farmed output was corrected for autocorrelation using the Newey-West procedure. This had the effect of changing the statistical significance of the numbers of eggs collected. A two year lag is a consequence of farmed alligators being harvested in their second year after they were hatched. This lag also had the highest significance compared to contemporaneous or single year lags of eggs collected. The foreign demand proxy measured by US exports and Hurricane Katrina also had expected effects. Prices however did not have a statistically significant effect and are included for economic theory reasons alone. The number of farms also had an expected and significant positive effect on farmed output.

The SUR approach models all equations in the system and is able to use more information than a single equation estimation approach. The coefficients and their signs in the SUR are very similar to the OLS equations (Table 2). There is however an improvement in the power of the statistical tests as a consequence of the better information. Several variables increased their statistical significance. The Portmanteau test for high order autocorrelation rejects its presence in the system. The only variable in the final SUR model to lack statistical significance is the farmed prices.

Discussion

The absence of a price effect in farmed output was not anticipated. The inertia in the production of farmed skins may account for this. There is basically a two year production time-horizon for farmed alligator skins starting from when eggs are hatched. Production plans cannot be easily varied in response to price movements. The second is that farms sustain their profits by managing their costs. This has been done by economies of scale (the average size of farms has increased), better technology and reductions in the mortality rate in hatchlings and juveniles (Elsey and Kinler 2004).

The surprising result of this analysis is that none of the common perceptions of wildlife farming hold. In terms of the first hypothesis, immense increases in farmed output have not led to price decreases for either farmed or wild output. In terms of the second hypothesis, there has not been an increase in poaching. That the output in both of these markets is not endogenous with each other also contradicts all three hypotheses.

In terms of the hypothesis that poaching would increase under the cover of farming, the last major skin poaching case in Louisiana occurred in 1976 (Joanen and McNease 1987). Wildlife farming is able to influence illegal activity by other means than flooding the market to depress prices. The observed reduction in poaching has been generated by the cooperation between producers, buyers and conservation authorities on a sustainable-use solution (Hutton and Webb 2003).

Table 2 SUR model

Variables	Farmed		Wild	
	Model 1	Model 2	Model 3	Model 4
Dependent variable	D (Qf)	D (Qf)	D (Qw)	D (Qw)
Explanatory variables				
D (Pi)	496.057 (692.411)	504.230 (703.789)	23.107* (12.516)	26.189** (11.508)
D ($eggs_{t-2}$)	0.109** (0.045)	0.094** (0.045)	–	–
D (Farms)	709.382* (396.862)	732.669** (396.841)	–	–
D (tag)	–	–	0.889*** (0.045)	0.887*** (0.045)
D (US exports)	0.099** (0.043)	0.112** (0.043)	–	–
D (US $exports_{t+1}$)	–	–	0.002 (0.001)	0.002* (0.001)
D (ZW skins)	0.598 (0.363)	–	−0.011 (0.011)	–
Katrina	−61,052.240*** (20,239.820)	−60,514.970*** (21,025.040)	−4,152.134*** (574.695)	−4,288.140*** (561.703)
$Katrina_{t-1}$	–	–	2,780.174*** (648.932)	2,594.237*** (603.171)
PDSI	−801.967 (1,726.248)	–	−5.482 (47.537)	–
R^2	0.371	0.317	0.936	0.934
Adjusted R^2	0.207	0.208	0.920	0.924

Coefficients listed first, with standard errors in brackets underneath

Coefficients that have significance at 10 % are *, at 5 % are **, and at 1 % are ***

It is notable that the reductions in poaching have not come about by falling prices. This may appear surprising as most economic models of wildlife farming presume that farming will change prices and hence poaching levels (Bulte and Damania 2005; Damania and Bulte 2007; Abbott and van Kooten 2011). Nonetheless, originally it was the non-price effects of alligator farming that were expected to change poaching levels. As early as the mid-1970s the steady supply combined with uniform size and quality was seen as how wild harvests would be affected by farming (Hutton and Webb 2003). Farmed wildlife products thus compete against wild (and poached) on a number of dimensions. These include prices, the quality of the product, the security and volume of supply, and its legal status.

It is also important to identify improvements to harvest-policy when farming is implemented. The commercial use of alligators was not a replication of the flawed earlier-era hunting programmes. The egg-collecting programme is one major point of difference. This approach is more ecologically-informed. Egg collection shifts the burden of the harvest on to cohorts with high natural mortality. Long term ecological studies show that alligator populations can sustain high annual take of eggs (Rice et al. 1999). Hunting of large adults may also contribute to population recovery as this reduces the predation pressure (cannibalism) on younger alligators (Rootes and Chabreck 1993).

The wild output of skins is largely explained by the quotas set by the Louisiana DWF and the price movements of those skins. For instance, the 2009 season saw prices collapse as a consequence of the 2008 global financial crisis. This led to a massive decline in hunting effort and most hunting tags were not used. The output of hunters is thus driven by the quotas they are allocated and the prices for wild skins. The hypothesis that farmed output increases wild output is not supported. No interaction was detected and the quotas above determine most of the wild output.

Hunting has no discernible effect on farmed output in this case. It has been argued that hunting costs are much lower than farming and hence, will out-compete farms. Nonetheless, farming is obviously viable and has grown substantially. Part of the reason is that hunting costs are actually a small part of the total costs of producing hides. For instance, in Venezuela caiman hunters receive less than 2 % of the final export price of skins (Thorbjarnarson and Velasco 1999). Hunters in Louisiana receive a larger percentage (5–15 %) but this is still, a minor part of the final export price (Plott personal communication). The cost advantage of hunting is a poor basis to out-compete farmed skins. The other reason is that the two types of hides cater to different markets.

This case shows that the buyers may perceive differences in the products which generate market segmentation. Farmed and wild skins have different traits. Correlated growth in the two market segments is not in fact, evidence farmed goods are contributing to the demand for wild. Rather the trend will be the product of external factors. Some of these external factors may not even be shared by the two segments. For instance, in this case the tags issued by the Louisiana DWF had a strong influence on the wild skin market, but none on the farmed market. This has an important policy implication. Suppressing demand for farmed parts will not reduce demand for wild because the external factors driving this growth are being ignored. It is misleading to infer that because the two market segments are growing this is caused by growth in one.

The implication of this segmentation is that the two markets for wild and farmed can coexist because they are not catering to the same group of customers. This may account for the persistence of bear poaching in China despite the bear-bile farms having a crowding-out effect. Some crowding-out via lower prices has occurred (Mills et al. 1995). This is not sufficient to eliminate the poached supply because a market segment that prefers wild bear-bladders persists (Liu et al. 2011).

The two producer groups also exhibit no market power. This is reflected in the statistical results. Prices and outputs are not endogenous as would be the case if they had market power. Likewise the statistical results for skin prices manifest no market power. There are also many sellers in the market as is the case in competitive markets with price-taking sellers. By 1990 there were 1,900 hunters and 80 farms producing hides. The actual trade in alligator leather is also not one where hides are sold directly to consumers. Rather it is a mediated trade, where dealers buy up hides for sale to tanneries (Joanen and McNease 1987).

This lack of market power is reinforced by the external-trade variable. Alligator skins are largely an export product. External trading conditions matter for the performance of this industry. When export markets go into recession, as happened in the 1997–1998 Asian crisis, then demand and prices drop. Output tends to change to match this.

Non-price effects are sometimes employed as arguments against wildlife farming. Two such common instances are laundering and stigma effects (Bulte and Damania 2005). Laundering occurs when poached products enter the market by infiltrating the legal stream. Legal trade is sometimes claimed to reduce the stigma attached to consuming wildlife products (Fischer 2004).

Laundering has not been an issue for alligator skins (Hutton and Webb 2003). Wild skins can be distinguished from farmed on the basis of quality (number of flaws) and size in the first instance. The second is that the tanneries have a preference for legal products. Tanneries were forced to close or switch to poached skins in the 1960s when the legal supply diminished (Thorbjarnarson and Wang 2010). A legal and reliable flow of skins was preferable to an erratic illegal supply and the risk the trade would be shut down. These effects were reinforced by the CITES tagging system developed for crocodile skins (Hutton and Webb 2003). By the early 1990s the global trade in classic skins (crocodiles and alligators) had been insulated from laundering (Hutton and Webb 2003).

Stigma effects have been proposed as a means by which legal trade could inadvertently inflate demand for illegal parts (Fischer 2004; Bulte and Damania 2005). The claim is that by making trade in wildlife parts legal, the stigma attached to buying illegal may fall. Fischer (2004) formalised this model by positing a type of consumer that was influenced by the stigma attached to the wildlife product. There appears to be no straightforward way to detect shifts in stigma for alligator skins in both the ban and trade periods. One possibility is that because alligators are often perceived as a pest or a menace and lack charisma, a stigma effect did not occur (Joanen and McNease 1987).

Economic models of over-harvest often assume that wild populations will be an open-access resource. This changes the behaviour of harvesters from rent-maximisers to rent-dissipaters (Gordon 1954). In effect this assumption embeds over-harvesting into the model. This condition was not met in this example. The farmed alligators had effective property rights enforced by farm owner. The system of public property rights to wild alligators was also well defined and featured high compliance with hunters (Joanen and McNease 1987; Elsey and Kinler 2004). The assumptions of open access and authorities either unwilling or unable to respond to over-harvest (including illegal) do not hold. Employing these assumptions in policy-deliberations creates a bias against wildlife farming.

Alligator farming has two notable direct effects on alligator conservation. The first is by providing manufacturers with a steady supply of quality skins there is less incentive for them to resort to poached products (Hutton and Webb 2003). This is consistent with the lack of poaching in this market. The second is the return of hatchlings back into the wild. The latter is a deliberate intervention created to link farming back to wild populations

(Elsey and Kinler 2004). Given that alligators can sustain large egg harvests it may however, have little discernible effect. Nonetheless it emphasises that wildlife authorities are not a passive or exogenous to the market but an important agent directly involved in management.

Alligator farming has also generated a number of indirect benefits to wild alligator conservation. The first is via habitat protection. Alligators have two notable nesting traits. One is that they have a lower breeding frequency than other crocodilians (Thorbjarnarson 1996). This is linked to habitat. Seasonal wetlands are preferred (Subalusky et al. 2009). The economic motive to preserve these for alligators improves breeding frequency. This is allied to the second trait. Females exhibit nest-fidelity and prefer sites they have used in the past (Elsey et al. 2008). Protecting habitat maintains these nesting sites.

The economic value has generated a management benefit also. The wild alligator population is perceived to be an economic resource. This increases the willingness of the government to actively manage the animals (Thorbjarnarson and Wang 2010). The political will to sustain and protect alligator populations is easier to obtain in light of the palpable economic returns they generate.

Wildlife farming also has limitations. In the case of crocodilians it took longer to resolve the laundering problem with caimans than classic hides (Hutton and Webb 2003). Farming has not generated like recoveries for endangered crocodilians that also suffer from significant habitat loss (Thorbjarnarson and Wang 2010). In contrast to ranching, actual farming using captive breeding stock produces fewer incentives to preserve wild populations. Regulations may be able to offset this by creating linkages similar to the release of juvenile alligators in Louisiana. Another problem is it may pull conservation effort away from species that have little commercial value (Thorbjarnarson and Wang 2010). Policy makers need to be aware of and evaluate these risks as well.

Conclusion

Louisiana alligators provide over three decades of harvest data from farms and the wild. The analysis reveals a more complex market than might be supposed. The two products show persistent segmentation rather than being close-substitutes that are sold in the same market. The correlation in growth is spurious as the two markets have different trajectories and some unique factors. This is also why farming and wild harvest is able to coexist. Nonetheless, alligator farming has contributed to the suppression of poaching by competing on non-price dimensions, and to habitat protection. This case highlights the danger that the economic theory employed to analyse wildlife markets may be flawed.

The motivation for this research was to examine the assumptions often employed in debates about wildlife farming. This particular case highlights that much of this debate is oversimplified. The assumptions used tend to be restrictive and they also tend to create pessimism towards wildlife farming. If the analysis assumes that wildlife farming only affects wild harvests via the price mechanism, that open-access to wild stocks will prevail, that the regulatory authority is inert and exerts no influence on harvest levels and there are no additional ways for farming to create conservation benefits then predictions of conservation failure are more likely. Relaxing these assumptions may identify other cases where wildlife farming could be used as part of the management strategy.

The lack of many examples of wildlife farming being used for conservation ends also hinders conclusions. It is difficult to test assumptions when so few examples exist. It is also difficult to identify the factors that will make wildlife farming succeed with the lack of empirical examples and nascent state of the theory. The success of alligators does not mean that carte blanche approval should be given to wildlife farming. Rather it highlights the divergence between economic theory and actual practice. Assumptions about the economics of wildlife should not be accepted so readily without empirical corroboration.

In summary, a narrow set of assumptions has guided much of the policy debate around wildlife farming. Many of these assumptions also tend to yield pessimistic outcomes about farming. The Louisiana alligator case however does not support many of these assumptions. This is an example where commercial use has contributed to reductions in poaching, and is not unique amongst the crocodilians. The risk at the moment is that opportunities to achieve conservation gains are being overlooked. If wildlife farming is able to contribute to the conservation of some threatened species such instances need to be identified in an objective way.

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