To fish or not to fish? Resource degradation and income diversification in Benin

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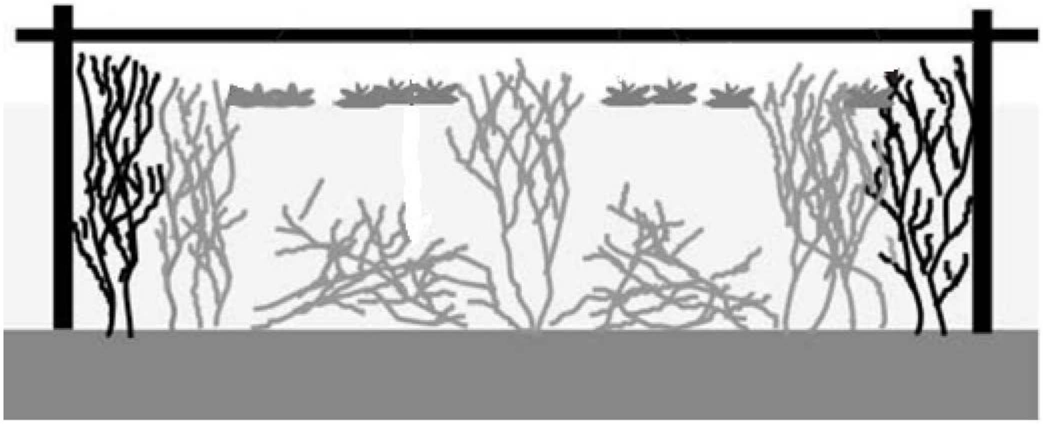
Online Appendix

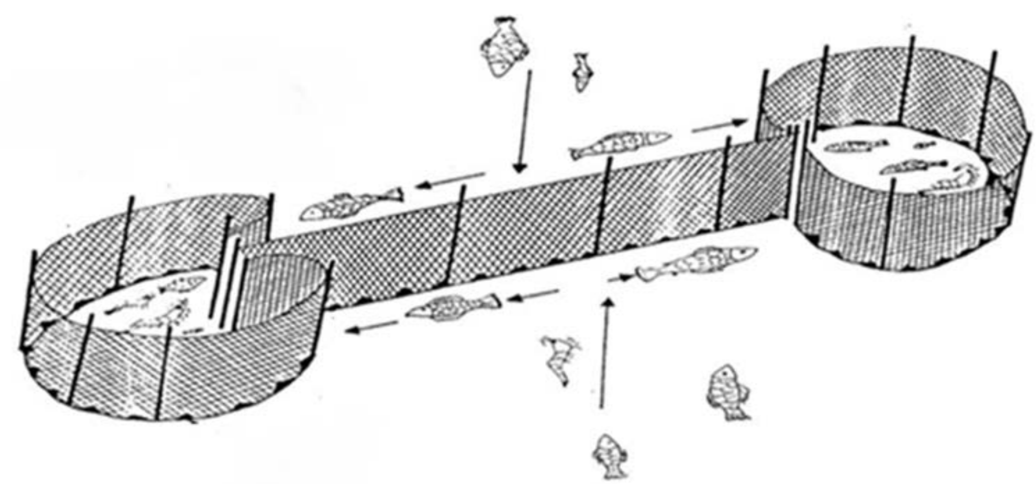
1. Figures

Panel A: Acadja



Notes: The acadja resembles a fishing pond. It is constructed by placing wooden branches in the lake and fencing them with fishing nets (USAID, 2007). The nets protect fish against predators and food is provided abundantly by algae and other micro-organisms which grow on the immersed parts of the branches. The acadja became a popular fishing instrument because of its high yield. From 1981-1996 the number of acadja in Benin's coastal lakes increased by more than 1500 per cent (USAID, 2007). In 2010, they covered about 35 per cent of Lake Nokoué's water surface (Niyonkuru and Lalèyè, 2010). As mangrove wood is used to construct the acadja, the popularity of the fishing instrument has led to a decrease of mangrove cover, with serious implications for the productivity and diversity of coastal ecosystems (USAID, 2007). With the disappearance of mangrove cover, several fish species lost their natural habitat and the shores of the lakes have become vulnerable to erosion and silting (Amoussou, 2004; Gnohossou, 2006; Pliya, 1980). The high concentration of acadja further causes an accumulation of mud and silt in the lakes, reducing oxygen levels and hindering water circulation (Amoussou, 2004; Gnohossou, 2006).

Panel B: Konou



Notes: The konou is a fixed fishing installation with fine-mesh nets. Contrary to the acadja, it is not closed by nets, but nets of several meters are set in such a way that fish get trapped. Its fine-mesh nets also trap young fish and fish eggs, thereby reducing the reproductive potential of the fisheries stock (USAID, 2007). In addition, the konou is a direct source of conflict: in order to make use of the water current to trap fish, the nets are usually set out close to narrow channels thereby catching basically all fish entering the lake and leaving few resources for fishermen further downstream.

Figure A1. *Productive, but damaging fishing instruments*

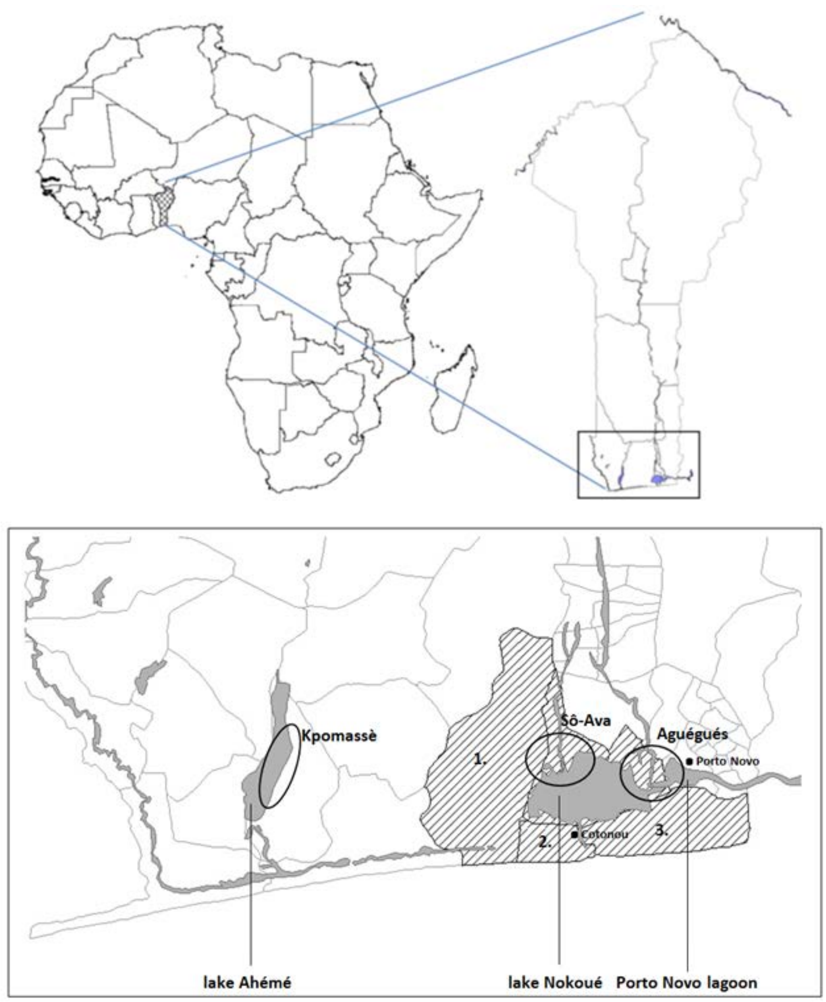


Figure A2. *Location of the sampling area when expanding the analysis to the villages included in Benin's 2006 fisheries census*

Notes: Our sample area comprises three communes (Kpomassè, Sô-Ava and Aguégués), located at the three main lakes of Benin (Lake Ahémé, Lake Nokoué and Porto Novo lagoon). When expanding our sample to include all communes located at Lake Nokoué, we include fishermen living in Sô-Ava, Aguégués, Abomey-Calavi (1.), Littoral (2.) and Sèmè-Podji (3.).

2. Tables

Table A1. *Resource degradation, fishing revenues and the non-fisheries sector*

Panel A: Correlation between village-level self-reported degradation and daily fishing revenues in 2009		
Ahémé	-0.26	***
Nokoué	-0.11	**
Porto Novo	-0.13	***
Panel B: Correlation between village-level self-reported degradation and the village-share of individuals who entered the non-fisheries sector between 2002 – 2009		
Petty trade	0.21	***
Agriculture & livestock keeping	0.39	***
Other self-employment outside fisheries sector	0.28	***
Wage-employment	0.39	***

Notes: *** p<0.01, ** p<0.05, * p<0.1; The data in this table comes from a survey module on the evolution of economic activities over the period 2002-2009; The level of self-reported degradation for each lake and village is reported in table 1 of the main manuscript.

Table A2. *Literacy by years of schooling*

	able to read a small note	able to write numbers
no schooling	2.66%	8.94%
1-2 years	18.92%	48.65%
2-5 years	68.83%	94.81%
> 5 years	96.88%	97.66%

Notes: The shares are calculated for 1,297 individuals of the economically active population

Table A3. *Descriptive statistics, by lake*

	Ahémé	Nokoué	Porto-Novo
Age	35.6	35.8	35.2
Share of women	44.6%	49.8%	46.5%
Literacy	22.6%	11.2%	15.2%
Ethnicity			
Goun	3.3%	0.0%	73.5%
Houedah	79.7%	1.0%	0.0%
Tofin	0.8%	98.5%	14.6%
Other	16.2%	0.5%	11.9%
Share of Voodoo-adherents	74.9%	28.6%	3.4%
Household size	3.9	4.9	5.7
Dependency ratio	27.6%	30.7%	65.1%
Village population size	1,276	2,303	1,600
Distance to nearest town (km.)	15.7	5.6	7.7
Asset ownership			
acadja / konou	0.0%	76.6%	89.6%
non-motorized canoe	43.9%	95.8%	93.1%
outboard motor	1.0%	29.0%	13.9%
generator	7.3%	21.5%	9.1%
television	12.7%	16.4%	13.5%
radio	73.5%	69.1%	64.9%
mobile phone	49.4%	64.1%	71.0%
Access to credit			
bank account	7.8%	6.8%	3.7%
tontines (ROSCA)	83.6%	84.4%	80.4%
No. of observations	390	412	495

Notes: The descriptive statistics in this table represent averages by lake for the economically active population. The nearest towns to Lake Ahémé, Lake Nokoué and Porto-Novo lagoon are Ouidah, Abomey-Calavi and Porto-Novo, respectively. Further information on asset ownership and access to credit can be found in section 4.3 of this appendix.

Table A4. *Determinants of income diversification*

Dependent variable:	No IV *(Eq. 1)* no. of income sources	Herfindahl index	IV *(Eq. 2 and 3)* 1st stage Degradation	2nd stage no. of income sources	2nd stage Herfindahl index
	(1)	(2)	(3)	(4)	(5)
log distance to influx of water			0.064***		
			(0.013)		
Nokoué	0.787	0.032	-0.570***	3.694***	3.577***
	(0.507)	(0.298)	(0.108)	(0.620)	(1.332)
Porto Novo	-0.263	-0.159	-0.205***	1.653***	1.482**
	(0.365)	(0.214)	(0.080)	(0.388)	(0.669)
log age	0.672***	0.300***	0.001	0.288***	0.294***
	(0.107)	(0.061)	(0.014)	(0.104)	(0.094)
female	-0.096	-0.033	0.012	0.160**	-0.097
	(0.080)	(0.047)	(0.008)	(0.079)	(0.068)
literate	0.403***	0.143**	0.005	0.273**	0.093
	(0.121)	(0.070)	(0.017)	(0.127)	(0.108)
Goun	-0.198	-0.138	0.065	-0.452**	-0.438*
	(0.186)	(0.107)	(0.045)	(0.203)	(0.262)
Houedah	-0.647***	-0.210*	0.027	-0.605***	-0.342**
	(0.188)	(0.109)	(0.028)	(0.173)	(0.156)
Tofin	-0.529**	-0.289*	0.249***	-1.372***	-1.506***
	(0.248)	(0.150)	(0.059)	(0.316)	(0.549)
Voodoo	-0.078	-0.142	0.018	-0.129	-0.229
	(0.167)	(0.091)	(0.024)	(0.134)	(0.143)
household size	-0.035	-0.023	-0.015***	0.068***	0.045
	(0.026)	(0.016)	(0.005)	(0.026)	(0.035)
dependency ratio	0.235***	0.132***	0.052***	-0.077	-0.093
	(0.064)	(0.035)	(0.015)	(0.089)	(0.109)
log village population size	-0.581***	-0.441***	0.131***	-0.870***	-0.971***
	(0.136)	(0.086)	(0.023)	(0.123)	(0.226)
log distance to nearest city	0.178	-0.203	0.023	0.481	0.028
	(0.362)	(0.203)	(0.068)	(0.332)	(0.385)
ownership acadja / konou	-0.236	-0.137	-0.008	-0.341	-0.107
	(0.188)	(0.114)	(0.040)	(0.217)	(0.223)
degradation	0.750***	0.561***		4.080***	5.263***
	(0.259)	(0.151)		(0.672)	(1.656)
Observations	1,220	1,220	1,220	1,220	1,220
F-test of excluded instruments			23.78***		

Notes: *** p<0.01, ** p<0.05, * p<0.1. The determinants of the number of income sources outside the fisheries sector were estimated using an (IV) ordered probit model, while the determinants of the Herfindahl index were estimated using a (IV) tobit model. The robust standard errors are adjusted for clustering by household and are reported in parentheses. Columns 1-2 present the estimates without IV (equation (1)) while columns 3-5 present the IV-estimates (equations (2) and (3)).

Table A5. *Determinants of the number of income sources outside the fisheries sector, marginal effects.*

No. of income sources outside the fisheries sector:	0	1	2	3
degradation	-1.219***	0.376***	0.335***	0.508
	(0.148)	(0.145)	(0.063)	(0.324)
log age	-0.086***	0.027	0.024*	0.036**
	(0.033)	(0.021)	(0.013)	(0.015)
female	-0.048*	0.015	0.013	0.020***
	(0.025)	(0.014)	(0.009)	(0.007)
literate	-0.082**	0.025	0.022	0.034**
	(0.040)	(0.022)	(0.015)	(0.015)
Goun	0.135**	-0.042	-0.037*	-0.056
	(0.061)	(0.030)	(0.020)	(0.036)
Houedah	0.181***	-0.056	-0.050**	-0.075***
	(0.056)	(0.042)	(0.025)	(0.029)
Tofin	0.410***	-0.126*	-0.113***	-0.171*
	(0.087)	(0.065)	(0.035)	(0.101)
Voodoo	0.039	-0.012	-0.011	-0.016
	(0.040)	(0.014)	(0.012)	(0.018)
household size	-0.020***	0.006	0.006**	0.008
	(0.008)	(0.004)	(0.003)	(0.006)
dependency ratio	0.023	-0.007	-0.006	-0.010
	(0.026)	(0.007)	(0.007)	(0.014)
Nokoué	-1.104***	0.340**	0.303***	0.460*
	(0.155)	(0.157)	(0.075)	(0.273)
Porto Novo	-0.494***	0.152**	0.136***	0.206
	(0.108)	(0.075)	(0.041)	(0.127)
log village population size	0.260***	-0.080*	-0.071***	-0.108**
	(0.038)	(0.046)	(0.025)	(0.052)
log distance to nearest city	-0.144	0.044	0.039	0.060
	(0.100)	(0.041)	(0.030)	(0.048)
ownership acadja / konou	0.102	-0.031	-0.028	-0.042*
	(0.067)	(0.032)	(0.023)	(0.025)
Observations	1,220	1,220	1,220	1,220

Notes: *** p<0.01 ** p<0.05 * p<0.1 The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources. The robust standard errors are adjusted for clustering by household and are reported in parentheses.

Table A6. *Determinants of the Herfindahl index, marginal effects.*

degradation	1.582**
	(0.621)
log age	0.088***
	(0.029)
female	-0.029
	(0.021)
literate	0.028
	(0.032)
Goun	-0.132
	(0.083)
Houedah	-0.103**
	(0.050)
Tofin	-0.453**
	(0.195)
Voodoo	-0.069
	(0.044)
household size	0.013
	(0.011)
dependency ratio	-0.028
	(0.035)
Nokoué	1.075**
	(0.476)
Porto Novo	0.445*
	(0.229)
log village population size	-0.292***
	(0.086)
log distance to nearest city	0.009
	(0.116)
ownership acadja / konou	-0.032
	(0.067)
Observations	1,220

Notes: *** p<0.01 ** p<0.05 * p<0.1 The coefficients represent marginal effects calculated after an IV tobit regression on the determinants of the Herfindahl index. The robust standard errors are adjusted for clustering by household and are reported in parentheses.

Table A7. *Determinants of income diversification, marginal effects - looking at the ownership of acadja and konou separately*

Panel A: Number of income sources outside the fisheries sector

	0	1	2	3
degradation	-1.333***	0.321*	0.323***	0.688*
	(0.129)	(0.166)	(0.100)	(0.376)
literacy	-0.068*	0.016	0.017	0.035**
	(0.039)	(0.017)	(0.014)	(0.016)
ownership acadja	-0.052	0.013	0.013	0.027
	(0.077)	(0.016)	(0.017)	(0.047)
ownership konou	0.227***	-0.055	-0.055	-0.117**
	(0.081)	(0.044)	(0.034)	(0.054)
ownership acadja and konou	0.137*	-0.033	-0.033	-0.071*
	(0.076)	(0.033)	(0.027)	(0.037)
observations	1,220	1,220	1,220	1,220

Panel B: Herfindahl index

degradation	1.925**
	(0.805)
literacy	0.024
	(0.036)
ownership acadja	0.124
	(0.118)
ownership konou	-0.175
	(0.116)
ownership acadja and konou	-0.087
	(0.087)
observations	1,220

Notes: *** p<0.01, ** p<0.05, * p<0.1. The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources (Panel A) and an IV Tobit regression on the determinants of the Herfindahl index (Panel B). Robust standard errors are adjusted for clustering by household and are reported in parentheses. In Panel A, columns represent the number of income sources. The coefficients in Panel A (Panel B) were estimated with the same specification as in table A5 (table A6), now controlling separately for the ownership of acadja and konou (the reference category being individuals who do not own acadja or konou).

Table A8. *Marginal effect of degradation on income diversification - with and without controlling for the ownership of acadja / konou*

Panel A: Number of income sources outside the fisheries sector

Controlling for ownership acadja / Konou ?	0	1	2	3
Yes	-1.219***	0.376***	0.335***	0.508
	(0.148)	(0.145)	(0.063)	(0.324)
No	-1.222***	0.384***	0.336***	0.502
	(0.149)	(0.142)	(0.062)	(0.318)
observations	1,220	1,220	1,220	1,220

Panel B: Herfindahl index

Controlling for ownership acadja / Konou ?	
Yes	1.582**
	(0.621)
No	1.560**
	(0.607)
observations	1,220

Notes: *** p<0.01, ** p<0.05, * p<0.1. The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources (Panel A) and an IV tobit regression on the determinants of the Herfindahl index (Panel B). Robust standard errors are adjusted for clustering by household and are reported in parentheses. In Panel A, columns represent the number of income sources. The coefficients in Panel A (Panel B) were estimated with the same specification as in table A5 (table A6).

3. Alternative specifications

3.1. Individual-level information on degradation

We exploit the fact that we have individual-level information on degradation. Specifically, we estimate equation (1) using individual-level self-reported degradation as a measure for natural resource degradation. Doing so allows us to add village fixed effects and therefore to check the sensitivity of our results to omitted variables at the village-level. Table A9 reports the results of two regressions, one with and one without village fixed effects. In both specifications we find that individuals who indicated a decreasing fishing stock are more likely to have an income source outside the fisheries sector. Moreover, the size of the degradation effect is highly comparable across specifications (11 vs 13 per cent). From specification A to B, the pseudo R2-value strongly increases from 0.09 to 0.20, indicating that omitted variables at the village-level explain quite some additional variation in the number of income sources. The estimated degradation effect however barely changes, providing evidence that it is largely insensitive to such omitted variables.

Table A9. *Using individual-level degradation, with and without including village FE*

Panel A: without village FE

No. of income sources outside the fisheries sector:	0	1	2	3
Degradation	-0.106***	0.077***	0.023***	0.005**
	(0.027)	(0.019)	(0.007)	(0.002)
Literacy	-0.153***	0.110***	0.035***	0.008***
	(0.028)	(0.019)	(0.009)	(0.003)
Ownership acadja / konou	0.191***	-0.135***	-0.045***	-0.011***
	(0.032)	(0.020)	(0.010)	(0.004)
Observations	1,220	1,220	1,220	1,220

Panel B: with village FE

No. Of income sources outside the fisheries sector:	0	1	2	3
Degradation	-0.132***	0.098***	0.027***	0.007**
	(0.032)	(0.024)	(0.008)	(0.003)
Literacy	-0.106***	0.079***	0.022***	0.005**
	(0.035)	(0.026)	(0.008)	(0.002)
Ownership acadja / konou	0.110**	-0.082**	-0.023**	-0.006*
	(0.046)	(0.035)	(0.010)	(0.003)
Observations	1,220	1,220	1,220	1,220

Notes: *** p<0.01 ** p<0.05 * p<0.1 The coefficients represent marginal effects calculated after an ordered probit regression on the determinants of the number of income sources. The robust standard errors are adjusted for clustering by household and are reported in parentheses. We use individual-level self-reported degradation as a measure for natural resource degradation. In Panel B we estimate the same specification as in Panel A, but we include village fixed effects. In every specification we control for the following covariates: age, gender, literacy, ethnicity, religion, household size, dependency ratio, lake, village population size, distance to the nearest city and ownership of acadja / konou. The pseudo R^2 – values for the two specifications are respectively 0.12 and 0.27.

Although the use of individual-level self-reported degradation allows us to control for omitted variables at the village level, there are two main reasons why we prefer the use of the village-level aggregate. First, the individual-level measure may suffer more strongly from endogeneity as it is related to individual characteristics which may both influence perceived degradation and income diversification. For instance, full-time fishers may be better informed about the evolution of the fishing stock and may hence report higher levels of degradation. The opposite might hold for fishers who have diversified their income, leading to a negative relationship between income diversification and degradation. Aggregating self-reported degradation at the village level is therefore likely to give a more accurate representation of the actual level of degradation. Second, as our instrumental variable is specified at the village level, we cannot include village-fixed effects in the IV-approach.

3.2. Bio-index based on physicochemical parameters

As a second sensitivity check we construct an alternative measure for natural resource degradation, using a bio-index. The index was constructed by Gnohossou (2006) who studied the impact of water pollution on aquatic fauna at Lake Nokoué. In order to study this relationship, Gnohossou (2006) focused on 33 different types of aquatic vertebrates. He justifies this approach mentioning three main points: 1) aquatic vertebrates play an important role in the food chain as they constitute the main source of food for fish in the lake; 2) they facilitate organic matter degradation and thus play a key role in the ecological functioning of aquatic ecosystems; 3) due to the specific development stages of aquatic invertebrates, they allow study of acute types of pollution even after the toxic substances which caused it are no longer measurable in the water.

First, he installed 79 different measuring stations across Lake Nokoué, for which he collected physicochemical parameters of water quality: temperature, depth, salinity, transparency and oxygen levels. These parameters were used in a factor analysis to calculate a pollution gradient for each measuring station. A pollution-sensitivity score was then calculated for all types of aquatic vertebrates based on their presence at the different measuring stations throughout the year. To take into account seasonal variations, measurements took place both during the rainy season and the dry season. Finally, a bio-index was calculated at the level of the measuring station by taking a weighted sum of the pollution-sensitivity scores of the present aquatic vertebrates. The index ranges from 1 (very polluted water) to 5 (water of high quality).

Thirty-four of the 79 measuring stations in Gnohossou's (2006) study are located within our sample area. Using the GPS locations of these stations, we calculate a village-level bio-index for the six villages in our sample which are located at Lake Nokoué. In ArcGIS, we calculate the average score for the measuring stations within a 4 km buffer around each village. We recoded the index such that a higher score relates to higher levels of degradation. Specifically, we recoded any value x of the index in the following way $x \Rightarrow 5-(x-1)$. For instance, if $x=2.9$ in the original index, it equals 3.1 in the recoded index. The village-level bio-index ranges from 2.1 to 2.4 with a standard deviation of 0.09.

Table A10 presents the marginal effects calculated after estimating equation (3) using the bio-index as a measure for natural resource degradation. The results indicate that a 0.1 unit increase in the bio-index increases the likelihood of having an income source outside the fishing sector by 12.66 pre cent. Literate fishermen are found to be 19 per cent more likely to have an income source outside the fishing sector

Table A10. *Using the bio-index*

No. Of income sources outside the fisheries sector	0	1	2	3
Degradation	-1.266**	0.937**	0.206*	0.123
	(0.605)	(0.445)	(0.114)	(0.077)
Literacy	-0.185***	0.137***	0.030**	0.018*
	(0.068)	(0.051)	(0.013)	(0.010)
Ownership acadja / konou	0.231***	-0.171***	-0.038***	-0.022**
	(0.056)	(0.042)	(0.013)	(0.010)
Observations	357	357	357	357

Notes: *** p<0.01 ** p<0.05 * p<0.1 The coefficients represent marginal effects which were calculated after an IV ordered probit regression on the determinants of the number of income sources. As a measure for degradation, the village-level bio-index was used. Columns represent the number of income sources. We additionally control for the following covariates: age, gender, literacy, religion, village population size, household size, dependency ratio, distance to the nearest city and ownership of acadja / konou.

Our two measures of degradation differ across several dimensions. Self-reported degradation relates to the perceived change of the fish stock for respondents on the three lakes, while the bio-index relates to the measured water quality at a certain point in time, for Lake Nokoué only. Illustrative of these differences is the correlation coefficient between the two measures, which only amounts to 0.09 (***). On the other hand, the correlation coefficient is significant, and positive, which is in line with our claim that "self-reported degradation is higher in areas where the lake is more shallow - making it more prone to silting, low oxygen levels, poor water circulation and higher levels of salinity". It is also in line with the analysis presented by Gnohossou (2006), who studied the relation between his index of water quality and the presence of crustacean and micro-organism that constitute the feed of fish species caught by the fishermen (to establish this feed, he investigated the stomach content of 754 fish from 22 different species).

Although this evidence is from one point in time, and therefore does not reveal anything about the evolution of the fish stock over time, it is very plausible to assume that "areas of low water quality have not only a lower fish density but also more fish stock reduction", because the variation in water quality captured by Ghonossou's index is very much prone to factors that change over time, in particular the increased population of human settlement. As such, Gnohossou (2006) finds the highest levels of pollution nearby the fastest growing and most dense settlement on the water, i.e. Ganvié.

3.3. Representativeness of the sample

As a third sensitivity check we address the concern that our sample may not be representative. To do so, we use information from Benin's 2006 fisheries census. The census includes rather crude information on income diversification but has the advantage of a large coverage. This allows us to expand our analysis to 109 villages and 10,850 individuals located in the five communes which border Lake Nokoué – the lake for which the bio-index is available.

As a dependent variable, we construct an indicator variable which takes the value 0 if an individual is a full-time fisher, while it is equal to 1 if this is not the case. We use Gnohossou's

(2006) index to create a commune-level bio-index in ArcGIS. For each commune, we identify the 10 closest measuring stations and use their average score as a commune-level bio-index. As with the village-level index, we recoded the bio-index such that a higher score relates to higher levels of degradation. The commune-level bio-index ranges from 1.2 to 2.4 with a standard deviation of 0.25.

We estimate an IV probit model, using the average distance from the 10 measuring stations to the closest influx of water as an instrument for degradation. The results in table A11 confirm our baseline findings. A 0.1 unit increase in the bio-index increases the likelihood of having a diversified income with 12.69 percentage points. Furthermore, literate individuals are 29.2 per cent more likely to diversify their income away from the fishing sector, while individuals who own acadja or konou are 22 per cent less likely to have a diversified income.

Table A11. *Expansion of the analysis using Benin's 2006 fisheries census*

IV:	1st stage	2nd stage
Dependent variable:	degradation	ID
	(1)	(2)
Log distance to influx of water	0.247***	
	(0.007)	
Log age	0.027***	0.264***
	(0.005)	(0.064)
Female	-0.007	-0.522
	(0.012)	(0.349)
Literate	0.031***	0.292***
	(0.004)	(0.037)
Goun	-0.365***	-0.225**
	(0.009)	(0.111)
Tofin	-0.037***	-0.798***
	(0.012)	(0.108)
Houédah	-0.040	-0.833**
	(0.025)	(0.348)
Aïzo	0.113***	0.464***
	(0.012)	(0.090)
Wémè	-0.486***	1.157***
	(0.008)	(0.123)
Xwla	-0.004	-0.506***
	(0.007)	(0.083)
Voodoo	0.049***	-0.264***
	(0.003)	(0.047)
Total no. Of children	-0.002***	-0.016**
	(0.001)	(0.008)
No. Of dependent children	-0.001**	0.013
	(0.001)	(0.009)
Log village population size	0.045***	-0.122***
	(0.003)	(0.025)
Log distance to nearest city	0.197***	-0.233***
	(0.004)	(0.060)
Ownership acadja / konou	0.001	-0.220***
	(0.003)	(0.034)
Degradation		1.269***
		(0.167)
Observations	10,850	10,850

Notes: *** p<0.01, ** p<0.05, * p<0.1. Using data from Benin's 2006 fisheries census, this table expands the analysis to 109 villages in the five communes bordering Lake Nokoué. The coefficients represent marginal effects calculated after an IV probit model. ID is a dummy variable which takes the value 0 if an individual is a full-time fisher and 1 otherwise. We include the six largest ethnicities in the regression, while the 10 remaining smaller ethnicities form the base category. The first stage estimates the determinants of the commune-level bio-index using the distance to the closest influx of water as an instrument; the second stage looks at the determinants of fishing full time.

4. Robustness checks

4.1. Household-level analysis

We study income diversification at the individual level because the financial spheres of husband and wife in Benin are largely disconnected. Expenditure decisions are based on individual budgets rather than a common one (LeMay-Boucher and Dagnelie, 2012). As a first robustness check, we repeat the analysis at the household level. The results in table A12 indicate that a 10 per cent increase in village-level self-reported degradation is associated with an increase of 1.3 income sources at the household level.

Table A12. *Income diversification at the HH-level*

IV:	1st stage	2nd stage
Dependent variable:	degradation	no. of HH income sources
	(1)	(2)
Log distance to influx of water	0.049***	
	(0.011)	
Nokoué	-0.592***	9.997***
	(0.104)	(3.810)
Porto-novo	-0.218***	3.910**
	(0.082)	(1.892)
Log age of HH head	-0.049**	0.968**
	(0.023)	(0.471)
HH head is female	0.048**	-0.724
	(0.023)	(0.461)
HH head is literate	-0.024	0.811**
	(0.024)	(0.347)
HH head is Goun	0.090*	-1.355
	(0.054)	(0.852)
HH head is Houédah	0.006	-0.917*
	(0.028)	(0.549)
HH head is Tofin	0.248***	-3.849**
	(0.062)	(1.511)
HH head is Voodoo adherent	0.022	-0.654
	(0.025)	(0.466)
Household size	-0.002	0.214***
	(0.005)	(0.081)
Dependency ratio	0.034**	-0.622***
	(0.014)	(0.217)
Log village population size	0.114***	-2.316***
	(0.021)	(0.608)
Log distance to nearest city	0.025	0.445
	(0.062)	(0.952)
Ownership acadja / konou	-0.050	0.093
	(0.031)	(0.587)
Degradation		13.350***
		(4.595)
Observations	418	418

Notes: *** p<0.01, ** p<0.05, * p<0.1. The robust standard errors are adjusted for clustering by household and are reported in parentheses. The coefficients were estimated using a 2SLS regression.

4.2. Estimating the degradation effect separately for men and women

About 47 per cent of our sample observation are women. In Benin's coastal fisheries, the actual fishing is reserved for men (with the exception of setting traps for crabs and looking for oysters), while women operate as small or intermediate traders of fish, or process the catch (by smoking or drying it). In their role as fishmongers and processors, women may also see their revenues being threatened by the degradation of the fisheries stock, and thus be pushed to diversify their activity portfolio. As a second robustness check, we estimate the degradation effect separately for men and women. The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources. The results indicate that the degradation effect holds both for men and for women. When running the same specification on the full sample (men and women) with an interaction term between degradation and gender, the results indicate that the gender difference in the degradation effect is statistically insignificant.

Table A13. *Estimating the degradation effect separately for men and women*

No. of income sources outside the fisheries sector	0	1	2	3
Women *(567 obs.)*	-1.202***	0.433**	0.336***	0.433
	(0.180)	(0.177)	(0.073)	(0.361)
Men *(653 obs.)*	-1.239***	0.344**	0.334***	0.561
	(0.176)	(0.149)	(0.087)	(0.374)

Notes: *** p<0.01, ** p<0.05, * p<0.1 The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources. The robust standard errors are adjusted for clustering by household and are reported in parentheses. We ran two regressions, one on the female sample and one on the male sample. We additionally control for the following covariates: age, literacy, lake, village population size, ethnicity, household size, dependency ratio, distance to the nearest city and ownership of acadja / konou.

4.3. Controlling for access to credit and asset ownership

The level of income diversification may be affected by an individual's access to credit. As a third robustness check, we include two measures to control for access to credit. The first one is an indicator variable which takes the value 1 if an individual has a bank account (this is the case for about 6 per cent of the sample). The second is an indicator variable which takes the value of 1 if an individual is involved in a 'tontine', i.e. ROSCA or Rotating Savings and Credit Association (this is the case for about 80 per cent of the sample).

The coefficients reported in table A14 are marginal effects calculated after an IV ordered probit estimation on the determinants of the number of income sources. The estimates do not show a strong correlation between access to credit and income diversification. Having a bank account or being involved in a ‘tontine’ is not significantly related to the number of income sources. The estimated marginal effects of self-reported degradation on income diversification are hardly affected by additionally controlling for access to credit, which suggests that access to credit does not dramatically alter the relationship between degradation and income diversification.

Although these results are interesting, we do not include them in the baseline analysis for two main reasons. First, and most importantly, access to credit is endogenous: those who have a more diversified income, or use highly productive fishing gear, may have a higher income, which could facilitate their access to credit – especially when some kind of collateral is necessary. Therefore it is not clear in which direction this relationship goes. Second, we do not have information on access to credit for the full sample; adding these variables therefore significantly reduces our sample size (from 1,220 to 862 observations).

Table A14. *Controlling for access to credit*

	No. of income sources outside the fisheries sector	0	1	2	3
A)	Degradation	-1.029***	0.479***	0.300***	0.250
		(0.277)	(0.075)	(0.099)	(0.257)
B)	Degradation	-1.038***	0.477***	0.301***	0.259
		(0.267)	(0.079)	(0.094)	(0.258)
	Bank account	-0.060	0.028	0.017	0.015
		(0.059)	(0.035)	(0.018)	(0.013)
C)	Degradation	-1.058***	0.472***	0.306***	0.280
		(0.242)	(0.086)	(0.084)	(0.253)
	Bank account	-0.062	0.028	0.018	0.016
		(0.059)	(0.033)	(0.018)	(0.014)
	Tontines	-0.028	0.012	0.008	0.007
		(0.043)	(0.021)	(0.012)	(0.011)
	Observations	862	862	862	862

Notes: *** p<0.01, ** p<0.05, * p<0.1 The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources. The robust standard errors are adjusted for clustering by household and are reported in parentheses. We estimate three different specifications (A, B, C), gradually adding two variables which capture access to credit (having a bank account and being involved in a tontine). In every specification we additionally control for the following covariates: age, gender, literacy, ethnicity, religion, household size, dependency ratio, lake, village population size, distance to the nearest city and ownership of acadja / konou.

Since wealth plays a role in the acquirement of fishing methods, and may thus both directly and indirectly affect diversification, we further explore this variable by controlling for the ownership of six assets: outboard motor, mobile phone, non-motorized canoe, generator, radio and TV (table A3 presents summary statistics on the ownership of these assets at the three lakes). The coefficients in table A15 represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources. The results indicate that ownership of the above assets is not significantly related to income diversification. Furthermore, the degradation effect barely changes when additionally controlling for asset ownership of different kinds.

Table A15. *Additionally controlling for the ownership of different assets*

	No. of income sources outside the fisheries sector:	0	1	2	3
A)	Degradation	-1.219***	0.376***	0.335***	0.508
		(0.148)	(0.145)	(0.063)	(0.324)
B)	Degradation	-1.205***	0.412***	0.341***	0.453
		(0.166)	(0.137)	(0.055)	(0.310)
	Owns outboard motor	-0.007	0.002	0.002	0.003
		(0.059)	(0.021)	(0.017)	(0.022)
	Owns mobile phone	0.051	-0.017	-0.014	-0.019
		(0.035)	(0.013)	(0.010)	(0.019)
	Owns non-motorized canoe	0.018	-0.006	-0.005	-0.007
		(0.038)	(0.014)	(0.011)	(0.014)
	Owns generator	-0.072	0.025	0.020	0.027
		(0.062)	(0.022)	(0.017)	(0.030)
	Owns radio	-0.036	0.012	0.010	0.013
		(0.035)	(0.014)	(0.010)	(0.015)
	Owns tv	-0.029	0.010	0.008	0.011
		(0.060)	(0.020)	(0.017)	(0.025)
	Observations	1,220	1,220	1,220	1,220

Notes: *** p<0.01, ** p<0.05, * p<0.1 The coefficients represent marginal effects calculated after an IV ordered probit regression on the determinants of the number of income sources. The robust standard errors are adjusted for clustering by household and are reported in parentheses. We estimate two different specifications (A, B). In specification B we control for the ownership of 6 different assets. In every specification we control for the following covariates: age, gender, literacy, ethnicity, religion, household size, dependency ratio, lake, village population size, distance to the nearest city and ownership of acadja / konou.

4.4. Heckman selection model

As our analysis only covers economically active individuals, we use a Heckman selection model to investigate if our findings are influenced by selection bias. The selection equation in the model estimates the determinants of being economically active, and the outcome equation estimates the determinants of the number of income sources among the economically active sample.

To satisfy the exclusion restriction, we use an indicator variable which takes the value 1 if an individual is between 15 and 25 years of age and 0 otherwise. Individuals in this age category are more likely to attend school and hence less likely to be economically active. The table below shows that those in the age cohort 15-25 on average have 3.62 years of schooling, while those who are older on average have less than 1 year of education. Furthermore, only 39 per cent of those within the 15-25 age cohort are economically active compared to 85 per cent of those who are older.

Table A16. *Summary statistics on age cohort 15-25*

Aged 15-25 ?	Years of schooling	% economically active
Yes	3.62	0.39
No	0.99 ***	0.85 ***

Notes: *** p<0.01 ** p<0.05 * p<0.1. The significance levels were obtained from a t-test.

Conditional on being economically active, we do not expect this age group to strongly influence the level of income diversification. Table A17 presents the results of the Heckman selection model. In Columns 1 and 2, we first estimate the determinants of the number of income sources with and without controlling for the 15-25 age cohort. The results imply that belonging to this age cohort does not have a significant impact on the number of income sources an individual has. In Column 3, we estimate the determinants of being economically active, i.e. the Heckman selection equation. The results indicate that individuals in the 15-25 age cohort are 76 per cent less likely to be economically active. Finally, in Column 4 we estimate the Heckman outcome equation. The estimated coefficient on degradation is practically unchanged with respect to those estimated in Columns 1 and 2 (although it loses some significance). Importantly, we find that the correlation between the error terms of the selection and outcome equation is low and statistically insignificant, indicating that our results are not influenced by selection bias.

Table A17. *Heckman selection model*

Estimation method	Ordered Probit	Ordered Probit	Heckman	
Dependent variable:	No. of income sources	No. of income sources	Economically active	No. of income sources
	(1)	(2)	(3)	(4)
Degradation	0.750***	0.746***	0.464*	0.767*
	(0.259)	(0.260)	(0.257)	(0.414)
Log age	0.672***	0.492***	0.765***	0.723
	(0.107)	(0.171)	(0.206)	(0.914)
Female	-0.096	-0.110	-0.155**	-0.099
	(0.080)	(0.082)	(0.077)	(0.090)
Literate	0.403***	0.396***	-0.609***	0.379
	(0.121)	(0.121)	(0.097)	(0.503)
Goun	-0.198	-0.216	-0.109	-0.197
	(0.186)	(0.187)	(0.143)	(0.189)
Houedah	-0.647***	-0.635***	-0.292	-0.656***
	(0.188)	(0.189)	(0.210)	(0.225)
Tofin	-0.529**	-0.534**	0.520**	-0.518
	(0.248)	(0.250)	(0.212)	(0.341)
Voodoo	-0.078	-0.082	0.094	-0.075
	(0.167)	(0.168)	(0.142)	(0.170)
Household size	-0.035	-0.033	-0.064**	-0.037
	(0.026)	(0.026)	(0.027)	(0.052)
Dependency ratio	0.235***	0.233***	-0.652***	0.203
	(0.064)	(0.065)	(0.063)	(0.606)
Nokoué	0.787	0.812	-0.995**	0.756
	(0.507)	(0.506)	(0.505)	(0.797)
Porto novo	-0.263	-0.237	-0.346	-0.275
	(0.365)	(0.366)	(0.369)	(0.426)
Log village population size	-0.581***	-0.590***	-0.322***	-0.588***
	(0.136)	(0.136)	(0.108)	(0.181)
Log distance to nearest city	0.178	0.184	-0.193	0.170
	(0.362)	(0.361)	(0.386)	(0.388)
Ownership acadja / konou	-0.236	-0.248	0.267	-0.223
	(0.188)	(0.192)	(0.165)	(0.313)
Age cohort 15-25		-0.208	-0.761***	
		(0.159)	(0.186)	
Observations	1,220	1,220	1,873	1,220
Athanrho			0.113	
			(2,17)	
Rho			0.112	
			(2,14)	

Notes: *** p<0.01, ** p<0.05, * p<0.1; The selection equation (Column 3) measures the determinants of being economically active, while the outcome equation (Column 4) measures the determinants of the number of income sources for the economically active sample. As an exclusion restriction, we use an indicator variable which takes the value 1 if an individual belongs to the 15-25 age-cohort and 0 otherwise. Columns 1 and 2 estimate the determinants of the number of income sources with and without including this indicator variable. The Heckman model was estimated with the stata-command ‘cmp’ which allows us to estimate the outcome equation with an ordered probit model (Roodman, 2009). The (athan)rho variables indicate that the correlation between the error terms of the selection and outcome equations is low and statistically insignificant, i.e. our results are not influenced by selection bias.

4.5.Using different estimation methods

We assume that there is an upper bound to the number of income sources from which a person can derive income. We therefore opt for an ordered probit model to estimate the determinants of the number of income sources in the baseline estimation. As a robustness check we use a Poisson model for count data, which has two important differences: first, the values of the outcome have a cardinal rather than just ordinal meaning (i.e. 2 income sources are considered to be twice as much as 1 income source; 4 double as much as 2, etc.). Second, the Poisson model does not assume a natural upper bound to the outcome variable (Verbeek, 2008).

With respect to the Herfindahl index, we use a tobit model in the baseline estimation as the index is continuous, but its range is constrained. The tobit model is particularly useful in our case, where the dependent variable is 0 for a substantial part of the population but positive for the rest of the population (Verbeek, 2008). Angrist and Pischke (2009: 102-107) argue, however, that there is a case for estimating Linear Probability Models instead of using nonlinear models such as tobit. As a robustness check, we compare the 2SLS estimate to the marginal effect calculated after estimation with an IV tobit model.

The IV results in table A18 show that using different estimation methods yields qualitatively similar marginal effects of degradation on income diversification.

Table A18. *The degradation effect when using different estimation methods*

Panel A: No. of income sources outside the fisheries sector	0	1	2	3
1. IV Ordered Probit	-1.219*** (0.148)	0.376*** (0.145)	0.335*** (0.063)	0.508 (0.324)
2. IV Poisson	1.677*** (0.464)			
Panel B : Herfindahl index				
1. IV Tobit	1.582** (0.621)			
2. 2SLS	0.923*** (0.259)			

Notes: *** p<0.01 ** p<0.05 * p<0.1 The coefficients represent marginal effects of degradation on income diversification calculated with different estimation methods. For specification 1 in Panel A, the columns represent the number of income sources. The robust standard errors are adjusted for clustering by household and are reported in parentheses. In every specification we control for the following covariates: age, gender, literacy, ethnicity, religion, household size, dependency ratio, lake, village population size, distance to the nearest city and ownership of acadja / konou.

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