REFERENCES

Abusin, S. 2005. The impact of fishing on fish diversity in Jebel Aulia Reservoir. Unpublished MSc thesis, University of Khartoum, Khartoum.

Adam, A.B. 1986. Distribution and abundance of fish in Jebel Aulia Reservoir – White Nile. *Sudan Journal of Science*, 2:161-176.

Akpalu, W. 2008a. Individual discount rate and regulatory compliance in a developing country fishery. *Journal of Environment and Development Economics*, 13(5):591-606.

Akpalu, W. 2008b. Determinants of non-compliance with light attraction regulation among inshore fishers in Ghana. CEEPA discussion paper no. 40. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Akpalu, W. 2009. A dynamic model of mesh size regulatory compliance in fisheries. Working Paper Number 123, Farmingdale State College.

Akpalu, W. 2011. Fisher skills and compliance with effort-limiting fishing regulations in a developing country: The case of Ghana. *International Journal of Social Economics*, 38(8): 666-675.

Ali, M. T. 2000. Recent trends and current status of aquatic ecosystems and their management in Sudan. *Unpublished research paper,* Fisheries Research centre, Khartoum.

Allan. J. D.; Abell, R. Hogan, Z.; Revenga, C.; Taylor, BW; & Welcomme, R.L. 2005. Overfishing of inland waters. *BioScience*, 55(12). p.1041. Available at: http://www.jstor.org/stable/4099537.

Anderson, L. G. 1989. Enforcement issues in selecting fisheries management policy. *Marine Resource Economics,* 6(2): 261-277.

Andrew, N., Bene, C., Hall, S. Allison, E., Heck, S. & Ratner, B. 2007. Diagnosis and management of small-scale fisheries in developing countries. *Fish and Fisheries*, 8: 227-240.

Atta-mills, J. Alder, J. Sumaila, U.R. 2004. The decline of a regional fishing nation: the case of Ghana and West Africa. *Natural Resource Forum*: 13-21.

Becker, G. 1968. Crime and punishment: An economic approach. *Journal of Political Economy*, 76(2): 169-217.

Bender, R. Augustin, T. & Blettner, M. 2005. Generating survival times to simulate Cox Proportional Hazards Models. *Journal of Statistics in Medicine*, 24(11): 1713-1723.

Bodenhorn, H. & Price, G. 2009. Crime and body weight in the nineteenth century: was there a relation between brawn, employment opportunities and crime? *Workings paper* 15099 Cambridge.(online) from http://www.nber.org/papers/w15099 (accessed:2011-10-24).

Charles, A.T. Mazany, R.L., & Cross, M. L. 1999. The economics of illegal fishing: a behavioural mode. *Marine Resource Economics*, 14(2): 95-110.

Cameron, A. & Trivedi, P.K. 2009. *Micro econometrics using Stata***.** Indiana University, Bloomington, Indiana.

Cameron, A. & Trivedi, P.K. 2005. *Micro-econometrics: Methods and applications*. Cambridge University Press, New York.

Chiang, A. 1984. *Fundamental methods of mathematical economics*, 3rd ed. McGraw Hill, Singapore.

Clark, C.W. 1990. *Mathematical Bio-economics: The optimal management of renewable resources*. 2nd ed, John Wily & Sons, New York.

Cox, D.R. 1972. Regression models and life tables with discussion. *Journal of the Royal Statistical Society*, 34:187-220.

Davis, M.L. 1988. Time and Punishment: An intertemporal model of crime. *Journal of Political Economy*, 96(2): 383-390.

Department of Fisheries. 2004. Unpublished research report on: Information base on Jebel Aulia fisheries. Khartoum. Access from Ministry of Agriculture, Animal Wealth and Water Resources.

Eggert, H. & Ellegård, A. 2003**.** Fishery control and regulation compliance: a case for co-management in Swedish commercial fisheries'. *Marine Policy*, 27:525–533.

Eggert, H. & Lokina, R. 2010. Regulatory compliance in Lake Victoria fisheries. *Journal of Environment and Development Economics*,15(02):197-217.

Fisheries Research Centre. 1985. Unpublished technical report on: Stock assessment studies on Jebel Aulia Reservoir. Prepared by Ahmed, A. Khartoum.

Fisheries Research Centre 1985. *Fisheries report on*: *The project of assessment of Jebel Aulia reservoir fisheries*. Author: Rahman, A.E. Khartoum, pp. 1-23.

Faisal, A.A. 2007. Biological studies on age, growth and population dynamic of fishes in Jebel Aulia Reservoir. Unpublished MSc thesis: University of Juba, Sudan.

FAO (Food and Agriculture Organization). 1993. *Sudan fisheries: An assessment of the situation and proposal for future, with emphasis given on Inland Fisheries*. Everett, G. V. *FAO Fisheries circular no 901:88 pp*.

FAO (Food and Agriculture Organization). 1999a. *Review of the state of world fishery resources: inland fisheries.* FAO Fisheries Circular 942. FAO: 58. Rome, Italy.

FAO (Food and Agriculture Organization). 2003. *Review of the state of world fishery resources: inland fisheries*. FAO Fisheries Circular 942 Rev.1. FAO: pp. 60. Rome, Italy.

FAO (Food and Agriculture Organization). 2000. *Manual on estimation of selectivity for gillnets and long lines gear in abundance surveys*. FAO Fisheries Technical paper no. 397, p. 84. Rome, Italy.

FAO (Food and Agriculture Organization). 1991. *Source book for inland fisheries resources of Africa*, *Vol. 3*, CIFA Technical Paper.18/3. Rome, Italy.

FAO (Food and Agriculture Organization). 1999b. *Assistance in fishery management in Sudan.* Working paper, TCP/SUD/6611.

FAO (Food and Agriculture Organization). 2006. *Year book fishery and aquaculture statistics,* [Online] available: www.fao.org (accessed: 2011-10-24).

FAO (Food and Agriculture Organization). 2008. Sudan fishery country profile, FID/CP/SUD, [Online] available: www.fao.org (accessed: 2011-10-24).

FAO (Food and Agriculture Organization). 2009. *The state of world fisheries and aquaculture', (SOFIA)*, 2008. FAO: pp.196. Rome, Italy.

FAO (Food and Agriculture Organization). 2003. Major dilemmas in southern Africa, freshwater fisheries, synthesis report – management – co-management – no management. Authors: Lansen, E.J; Kolding, J; Overå, R; Nielsen, J R& van Zwieten, PA.M. FAO *Fisheries technical paper* 426/1. Rome, Italy.

FAO (Food and Agriculture Organization). 1994. Status of fish stocks and fisheries of thirteen medium-sized African reservoirs. *CIFA Technical paper* 26: 107P .Rome.

Furlong, W.J. 1991. The deterrent effect of regulatory enforcement in the fishery. *Land Economics*, 67(1): 116-129.

Green, W.H. 2003. *Econometric Analysis*, 5th ed. Prentice Hall, Upper Saddle River, NJ.

Gezelius, SS. 2003. *Regulation and compliance in the Atlantic fisheries: state/ society relation in the management of natural resource*. University of Oslo: Kluwer Academic Publishers.

Hamid, A. Mwiturubani, D. & Osiro, D. 2009. *Nature and extent of environmental crime in Sudan, Situation report*. Published by Institute for Security Studies, Pretoria.

Hamid, U.Y. 2000. *Environmental impacts of surge industry waste water on White Nile area*, Unpublished MSc Thesis, University of Khartoum, Khartoum.

Hanna, S. 1998. Co-management in small-scale fisheries: creating effective links among stakeholders. Proceedings of the International CBNRM Workshop, Plenary Presentation, Washington D.C., USA, 10-14 May 1998. Washington.

Hardin, G. 1968. The tragedy of the common. *Journal of Science*, 8:162-1243.

Hatcher, A. & Pascoe, S. 2006. Non-compliance with fishery regulation in *Knowledge base in fisheries management, Developments in aquaculture and fisheries science,* 355:454. Elsevier, Amsterdam.

Hatcher, A. & Gordon, D. 2005. Future investigation into the factors affecting compliance with U.K. fishing Quota. *Land Economics*, 81(1):71-86.

Hatcher, A. Jaffry, S. Thebaud, O. & Bennett, E. 2000. Normative and social influences affecting compliance with fishery regulations. *Land Economics*, 76(3):448-461.

Hauck, M. 2008. Rethinking small-scale fisheries compliance. *Marine Policy*, 32: 635-642.

Heck, S., Béné, C. & Reyes-Gaskin, R. 2007. Investing in African fisheries: Building links to the Millennium Development Goals'. *Fish and Fisheries*,8(3): 211-226.

Honneland, G. 1999. A model of compliance in fisheries: Theoretical foundations and practical application. *Ocean & Coastal Management*, 42: 699-716.

IOM (International Organization for Migration). 2005. *IDP intentions concerning return to their places of origin: Sample survey Khartoum, North, east, central Sudan and Nuba*, volume 1. Report on survey results, Khartoum.

Jenkins, S.P. 2005. *Survival Analysis.* Unpublished book, University of Essex, Colchester, UK. Institute for Social and Economic Research, [Online]. Available from: http://www.iser.essex.ac.uk/teaching/degree/stephenj/ec968/pdfs/ec968lnotesv6.pdf. (Accessed: 2011-10-24).

Jentoft, S. 2000. The community: A missing link of fisheries management. *Marine Policy*, 24:53-59.

JRO (Jebel Aulia Regulation Office). 2004. Unpublished regulation document, 1997. Khartoum: access from Ministry of Agriculture, Animal Wealth and Water Resources Government Printer.

JRO (Jebel Aulia Regulation Office). 2004. Unpublished annual report. Khartoum. Access from Ministry of Agriculture, Animal Wealth and Water Resources.

Kennedy, P. 2003. *A guide to econometrics*. 5th ed. Harvard University Press, Cambridge, MA.

Khalid, A.M. & Salih, H.M. 2006. Water ecology of River Nile, fish fauna and fisheries. Unpublished research paper, Sudan Fisheries Research Centre.

Khalid, A.M., Farah, O. & Ali, M.E. 2008. Aquatic resources of Sudan and possibility of their utilization. Proceedings of the first scientific conference (ARRC), Fisheries Research Centre, Khartoum.

King, D.M. & Sutinen, J.G. 2010. Rational non-compliance and the liquidation of northeast ground fish resources. *Marine Policy*, 34(1):7-21.

Kuperan, K. & Sutinen, J. 1994. Compliance with zoning regulations in Malaysian Fisheries. Paper presented to the 7th Conference of the International institute of Fisheries Economics and Trade, Taipei, Taiwan, 18-21 July 1994.

Kuperan, K. & Sutinen, J. 1998. Blue water crime: Deterrence, legitimacy, and compliance, in fisheries. *Law and Society Review*, 32(2):309-338.

Kuperan, K.V. & Jahan, K.M. 2010. Noncompliance a major threat in fisheries management-experiences from the artisanal coastal fisheries of Bangladesh. Uiversity of Utara Malaysia, World Fish Centre. (Online) at http://mpra.ub.uni-muenchen.de/32330/MPRA Paper No. 32330. Posted 19. July 2011.

Lee, E.T. & Go, O.T. 1997. Survival analysis in public health research. *Annual Review of Public Health*, 18(1): 105-134.

Leung, S.F. 1991. How to make the fine fit the corporate crime?: An analysis of static and dynamic optimal punishment theories. *Journal of Public Economics*, 45(2): 243 -256.

Long, J.S. 1997. *Regression models for categorical and limited dependent variables: advances quantitative techniques in the social science series.* Sage Publications, Los Angeles.

Lorensen, K. 2008. Understanding and managing enhancement fisheries system. *Reviews in Fisheries Science*, 16: 1-3.

Maddan. S.J., Walker, T. & Miller, J.M. 2008. Does Size Really Matter?: A Re-examination of Sheldon's Somatotypes and Criminal Behaviour. *Journal of Social Science*, 330-344.

Marc, B. & Khalid, A.M.1998. Stock assessment in the inland fisheries of Sudan. Unpublished technical cooperation program research paper, Fisheries Research Centre, Khartoum.

MEA (Millennium Ecosystem Assessment). 2005. *Ecosystems and Human Well-Being: Current State and Trends, Volume 1*. Global assessment reports. Island Press, Washington, DC.

Nielsen, J.R. 2003. An analytic framework for studying compliance and legitimacy in fisheries management. *Marine Policy*, 27(5): 425– 432.

Nielsen, J. R & Mathiesen, C. 2003. Important factors influencing rule compliance in fisheries: lessons from Denmark. *Marine Policy*, 27(5): 409–416.

Osman, M.O.M. 2009. *Fishing technology*. Khartoum, currency printing press Environment and Natural Resources Research Institute, the National Centre Research, Khartoum.

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action*. Cambridge University Press, New York.

Pauly, D. 1996. ITQ: The assumptions behind a meme. *Review in Fish Biology and Fisheries*, 6:109-120.

Potter, E.C.E. & Pawson, M.G. 1991. *Gillnetting*. Lowestoft (69); 34pp, Ministry of Agriculture, Fisheries and Ffood Directorate of Fisheries Research, Laboratory leaflet.

Srinivasa, J.T. 2005. State Regulation versus Co-management: Evidence from the Cochin Estuarine Fisheries in India. *Environment and Development Economics*, 10: 97-117.

Sterner, T. 2003. *Policy instrument for environmental and natural resource management.* RRF Press, Washington.

Sumaila, R.U., Alder, J. & Keith, H. 2006. Global scope and economics of illegal fishing. *Marine Policy*, 30(6):696-703.

Sutinen, J.G. & Hennessey, M. 1986. Enforcement: The neglected element in fishing management. In E. Miles, R. Pealy, and R. Stokes, eds., *Natural resource economics and policy application: Essays in Honour of James A. Crutchfield*, University of Washington Press, Seattle.

Sutinen, J.G. & Kuperan, K. 1999. A socio-economic theory of regulatory compliance. *International Journal of Social Economics*, 26 (1, 2, 3):174-193.

Tyler T.R. 2006. *Why people obey law*. Princeton University Press, Princeton, NJ.

Tyran, J.R. & Feld, L.P. 2002. Why people obey the law: Experimental evidence from the provision of public goods. CESifo Working Paper, no. 651 (Online): http://papers.ssrn.com/abstract=290231 and www.CESifo.de (accessed: 2011-10-24).

UNDP (United Nation Development Program). 2005. *United Nations' Development Programme Millennium Development Goals. Eight goals for 2015.* Available at the following website: http://www.beta.undp.org/undp/en/home/mdgoverview.html (access 14.november 2011).

UNEP (United Nation Environmental Program). 2000. *Water Sharing in the White Nile Valley: using GIS/Remote Sensing for the Sustainable use of Natural Resources*. Project GNV011

UNEP (United Nation Environmental Program). 2010. *Blue harvest: Inland fisheries as an ecosystem service.* World Fish Centre, Penang, Malaysia. Authors: Dugan, P., Delaporte, A., Andrew, N., O'Keefe, M., Welcomme, R. Printed by UNON.

U.S. Census Bureau. 2011. International database. (Online) http://indexmuni.com/facts/indicators/SP.POP.GROW. (Access: 2011-9-22)

World Fish Centre. 2009. Approaches and Frameworks for Management and Research in Small-scale Fisheries in the Developing World. Working paper no 1914. Andrew, N & Evans, L. The World Fish Centre, Penang, Malaysia.

World Fish Centre. 2003. Valuing Africa's inland fisheries: Overview of current methodologies with an emphasis on livelihood analysis, Bene, C. & Neiland, A.E. *World Fish Centre Quarterly 26* (3) July-September 2003.

World Fish Centre. 2010. *Implementing resilience management: lessons from fishing communities in the Niger Basin*. The World Fish Centre, Penang, Malaysia.

Welcomme, R.L. 2001. *Inland fisheries: ecology and management*. Oxford: Blackwell Science.

WFP (World Food Program). 2006. *Brief overview of Sudan economy and future prospects for agricultural development.* Experts opinions, Food Aid Forum, 6-8 June. Khartoum. Prepared by Abbadi, K.A. & Ahmed, A.E.

Wooldridge, J.M. 2000. *Introductory econometrics: a modern approach.* Cincinnati, OH: South-Western.

World Bank. 2006. *Final Project Proposal on a Proposed MDTF Grants to the Government of Southern Sudan for* southern Sudan: livestock and fisheries development project October 12. (Online) at: http://siteresources.worldbank.org/INTAFRMDTF/Resources/5_Livestock_and_Fisheries_FPP_Oct_12.pdf (accessed: 2011-10-24).

Annexure A

1. The dynamic deterrence with frequency of violation specification

By taking into consideration the definitions of illegal profits $\pi(m, c, p_{a,}Q_{m,}E_{m,}s, x) = m(p_{a.}Q_m\,(E_{m,}s) - c(E_m)) = m(p_{a.}Q_m\, - c(E_m))$ in the first period and the legal profit $\pi(n, b, p_{n,}Q_{n,}E_n\,, x) = n(p_{n.}Q_n\,(E_{n,}x) - b(E_n)) = n(p_{n.}Q_n\, - b(E_n)$ in the second period, Illegal profits will be denoted by $\pi(m)$ and the legal profit, by $\pi(n)$ and also $v(p_{a.}Q_m\,, E_{m,}, s, c, m, n, b, x, Q_n\,, E_n\,, p_{n,})$ by $v\,(.)$ and $Pr(m)$ by B for simplicity; then the value function for each violator is:

$$v(.) = \int_0^\infty e^{-\delta t}(\pi(m) + \pi(n))\ (1 - G(t)) + \pi(n)G(t) - RFg(t)dt \qquad (1.1)$$

$$v(.) = \int_0^\infty e^{-\delta t}\big(\pi(m) + \pi(n) - \pi(m)G(t)\big) - RFg(t)dt \qquad (1.2)$$

The values of the density and cumulative functions are derived in equation (4.11) in the text (chapter 4) as follow: G(t) = 1-e^{-Bt} and g(t) = B e^{Bt} and B=Pr(m) . Substituting these values in (1.2) above gives:

$$v(.) = \int_0^\infty e^{-\delta t}\pi(m) + \pi(n) - (\pi(m)(1 - e^{-Bt})) - RFBe^{-Bt}\,dt \qquad (1.3)$$

$+\pi(m) and - \pi(m)$ will simplify as follow:

$$v(.) = \int_0^\infty e^{-\delta t}\pi(n) + \pi(m)e^{-Bt} - RFBe^{-Bt}\,dt \qquad (1.4)$$

$$v(.) = \int_0^\infty e^{-\delta t}\pi(n) + (\pi(m) - RFB)e^{-Bt})\,dt \qquad (1.5)$$

$$\pi(m)\frac{e^{-(Pr+\delta)t}}{-(Pr+\delta)}\ \Big|_{t=0}^{t\to\infty} - FRPr\frac{e^{-(Pr+\delta)t}}{-(Pr+\delta)}\ \Big|_{t=0}^{t\to\infty} + \pi(n)\frac{e^{-\delta t}}{-\delta}\ \Big|_{t=0}^{t\to\infty}$$

$$v(.) = \frac{\pi_n}{\delta} + \frac{\pi_m - RFB}{B+\delta} \qquad (1.6)$$

Which is in the expanded form (substituting for B and π) is:

$$v(.) = \frac{(m\, p_{a.} Q_m\,(E_{m,}s) - m\, c(E_m) - RFPr(m)}{\delta + \Pr(m)} + \frac{n\, p_{n.} Q_n\,(E_{n,}x) - n\, b(E_n)}{\delta} \qquad (1.7)$$

This will give the value function for each violator as:

$$v(.) = \frac{(m\, p_{a.} Q_m\,(E_{m,}s) - RFPr(m)}{\delta + \Pr(m)} \qquad (1.8)$$

The second term in equation 1.7 is excluded since doesn't include (m)

2. Derivation of comparative static's properties

Invoking the Implicit Function Theorem for function K (m*(α), α), where α is a vector of the set of arguments in the model and m is at its optimal level m* (hence omitting the * for simplicity), the following holds for each argument α_j at the optimum (Chiang, 1984):

$$\frac{dk}{d\alpha} = \frac{dk}{dm} * \frac{dm}{d\alpha} + \frac{dk}{d\alpha} = 0\ such\ that\ \frac{dm}{d\alpha} = -\frac{dk}{d\alpha} \Big/ \frac{dk}{dm} \qquad (2.1)$$

Employing the first-order conditions' equation (2.1), which determine the optimal frequency of violation (i.e. m^*), we can derive the comparative static' (CS) properties of m* with respect to its parameters $p_{a.}, F, R, C, b, Pr, \delta$. Let K be

$$\mathrm{K} = \frac{dV}{dm} = \frac{[p_{a.} Q_m\,(.) - c(E_m) - RFPr_m\,](\delta + \Pr(m)) - Pr_m[m\, p_{a.} Q_m\,(.) - mc(E_m) - RFPr(m)]}{(\delta + \Pr)^2} = 0 \quad (2.2)$$

The first derivative of equation (1.8) with respect to m is taken, and the result set to zero, to determine the optimal frequency of violation (this implies that the denominator must be different from zero). Thus

$$\frac{dV}{dm} = K = \left[p_{a.}Q_m(.) - c(E_m) - RFPr_m\right](\delta + \Pr(m)) - Pr_m\left[m\,p_{a.}Q_m(.) - mc(E_m) - RFPr(m)\right] = 0$$

(2.3)

Note that for m to be optimal, it is required that the numerator of equation (1.8) to be >0. Equation (2.3) shows that $\delta + \Pr(m) > Pr_{m.}$ using the concavity condition of the profit function. Since m is implicit in equation (2.2), we derive the comparative static of m with respect to F, R, Pr, C, $p_{a.}$ and δ

2.1 Probability of paying the fine R (enforcement)

$$\frac{dK}{dR} = (-FPr_m)(\delta + \Pr(m)) + Pr_m\,FPr(m) = FPr_m(-\delta - Pr + Pr)$$

$$= -FPr_m\,\delta < 0 \qquad (2.4)$$

Equation (2.4) has to yield a negative value since the denominator is +ve and F, Pr_m(m) and δ are all +ve values , e.g. hazard rate is increasing in frequency of violation m). This result $\frac{dK}{dR} < 0$ together with the satisfaction of the second order conditions of value function $v(.)$, $\frac{dK}{dR} < 0$ which implies that, $\frac{dm}{dR} = \frac{dk}{dr} / \frac{dk}{dm} < 0$

Result 2.4 implies that violation rate – frequency (optimal m) decreases with an increase in the probability of paying a fine (R) if detected.

2.2 Level of fine

$$\frac{dK}{dF} = (-RPr_m)(\delta + \Pr(m)) + Pr_m\,RPr(m) = RPr_m(-\delta - Pr + Pr)$$

$$= -RPr_m\,\delta < 0 \qquad (2.5)$$

Following the same argument as above (denominator is +ve and *R*, Pr_m and δ are all +ve values) it is clear that $\frac{dK}{dF} < 0$, which implies that $\frac{dm}{dF} = \frac{dk}{dF} / \frac{dk}{dm} < 0$ frequency of violation (optimal *m*) decreases with an increase in the amount of the fine (F).

2.3 Probability of detection *Pr(m)*

$$\frac{dK}{dPr(m)} = \left[p_{a.} Q_m(.) - c(E_m) - RFPr_m\right] + RFPr_m = \pi(m)_m + RFPr_m < 0 \qquad (2.6)$$

For result (2.6) to yield the expected negative sign (negative impact of probability of detection on violation rate) expected marginal fine should be greater than the discounted marginal gain from violation. This will hold true for larger values of *Pr(m)* implying that the higher the probability of detection, the lower is frequency of violation.

2.4 Discount rate

$$\frac{dK}{d\delta} = p_{a.} Q_m(.) - c(E_m) - RFPr_m > 0 \qquad (2.7)$$

The non-negativity of Result 2.7 is implied by the condition of optimality derived in equation 4.15 for violating fishers (e.g. for $m > 0$). Result 2.7 accordingly suggests that violation rate increases with higher discount rates, i.e. less important is the future.

2.5 Return from violation (price of illegal catch)

$$\frac{dK}{dP_a} = Q_m\left(E_{m,}s\right)(\delta + \mathrm{Pr} - \mathrm{Pr_m}) \geq 0 \qquad (2.8)$$

As we mentioned before, at optimal levels of *m* the adjusted probability of detection is greater than the marginal risk of detection (equation 2.3), which implies non-negativity of Result 2.8, which suggests that frequency of violation increases with higher prices of (returns from) illegal (mixed) catch.

2.6 Fixed cost of illegal net – c

$$\frac{dK}{dc(.)} = -\delta - \mathrm{Pr} + \mathrm{mPr_m} = ? \qquad (2.9)$$

Result 2.9 is indeterminate. For this to yield the expected negative effect of cost of acquiring the illegal net, the following must hold:

$$\mathrm{Pr}_{\mathrm{m}} < \frac{\delta + \mathrm{Pr}(\mathrm{m})}{\mathrm{m}} \qquad (2.10)$$

Condition 2.10 simply requires that the incremental risk of being caught (marginal chance of detection) should be less than the average expected gains from not violating (opportunity cost of waiting for next period plus probability/opportunity of being caught) per violation attempt.

Annexure B

1. Calculation of the modified model

Annexure B1 shows all the steps for the integration to calculate the expected net present value of illegal gain using the modified two times dynamic deterrence model. As noted in the text $u(m) = \pi(m) - z(s) - d(x)$, $u(0) = \pi(0)$, substituting for $u(m)$; $u(0)$ in the value function and integrating gives the followings:

$$J(m) = E\int_0^{\mathcal{T}} e^{-\delta t}\, u(m)dt + E\int_{\mathcal{T}}^{\infty} e^{-\delta t}\, u(0)\; dt - e^{-\delta \mathcal{T}}\, F \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.1$$

$$= E\left[u(m)\left(\frac{-e^{-\delta\tau}}{\delta} + \frac{1}{\delta}\right) + u(0)\,\frac{e^{-\delta\tau}}{\delta} - e^{-\delta\tau}F\right]$$

$$= E\left\{\frac{u(m)}{\delta} - \left(\frac{u(m)-u(0)}{\delta}\right)e^{-\delta\mathcal{T}} - e^{-\delta\mathcal{T}}\,F\right\}$$

$$= E\left\{\frac{u(m)}{\delta} - \left(\frac{u(m)-u(0)}{\delta} + \mathrm{F}\right)\, e^{-\delta\mathcal{T}}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.2$$

$$= \left\{\frac{u(m)}{\delta} - \left(\frac{u(m)-u(0)+F}{\delta}\right)\int_0^{\infty} g(\tau, m, N, v)e^{-\delta\mathcal{T}}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1.3$$

Equation (1.1) is the discounted net present value of a fisher who violates the first period (first term) plus the gain from the second period (second term). After in between calculation and integration, we reached equation (1.2), which give us the exact expected discount profit from violation, the first term is the gain from violation (discounted expected profit from violation) and the second term is the amount of penalty that the fisher gets after being caught (immature catch plus fine) the outcome will be the pure gain from violation.

In equations (1.3), we insert the value of the expectation parameter, which is the net present value of the time of detection.

2. Calculating the Probability density (the relations between the density function and proportional hazard rate)

This is straightforward calculation to get the proportional density function g(.) from the hazard formula and inserts the final results in the maximisation equation.

$$\Pr(\mathcal{T}, m, v, n) = \mathcal{B}(m, v, n)h(\mathcal{T}) \tag{2.1}$$

With the survival function given by:

$$h(\tau) = \frac{g(\tau, m, n, v)}{1 - G(\tau, m, n, v)} \tag{2.2}$$

$$= \frac{\frac{dG(\tau, m, n, v)}{d\tau}}{1 - G(\tau, m, n, v)} \tag{2.3}$$

$$= \frac{-d(1 - G(\tau, m, n, v))/d\tau}{1 - G(\tau, m, n, v)} \tag{2.4}$$

$$= \frac{-dln(1 - G(\tau, m, n, v))/d\tau}{d\tau} \tag{2.5}$$

Integrating both sides we get

$$\int_0^{\mathcal{T}} \mathrm{h}(\tau, m, n, v)\, d\tau = -ln\{1 - G(\tau, m, n, v)\} \tag{2.6}$$

$$-\int_0^{\mathcal{T}} \mathrm{h}(\tau, m, n, v)\, d\tau = ln\{1 - G(\tau, m, n, v)\} \tag{2.7}$$

Hence

$$1 - G(\tau, m, n, v) = \exp\left(-\int_0^t h(\tau, m, n, v)\, d\tau\right) \tag{2.8a}$$

Which can written as

$$1 - G(\tau, m, n, v) = \mathrm{e}^{\left(-\int_0^t \mathrm{h}(\tau, m, n, v) d\tau\right)} \tag{2.8b}$$

If the periodic harvest in this model is assumed to be constant overtime then

$$1 - G(\tau, m, n, v) = \mathrm{e}^{(-\int_0^t \mathrm{h}(\tau, m, n, v) d\tau)} \tag{2.9}$$

$$1 - G(\tau, m, n, v) = \mathrm{e}^{-\mathcal{B}(m,v,n)h(\mathcal{T})} \quad 2.10$$

$$G(\tau, m, n, v) = 1 - \mathrm{e}^{-\mathcal{B}(m,v,n)h(\mathcal{T})} \quad 2.11$$

And,

$$g(\tau, m, n, v) = \mathcal{B}(m, v, n)h(\mathcal{T})\mathrm{e}^{-\mathcal{B}(m,v,n)h(\mathcal{T})} \quad 2.12$$

Substituting fro $g(\tau, m, n, v)$ in the value function we obtain:

$$\left\{\frac{u(m)}{\delta} - \left(\frac{u(m)-u(0)+F}{\delta}\right)\int_0^\infty g(\tau, m, N, v)e^{-\delta\mathcal{T}}\right\} \quad 2.13$$

3. Relation between probability of detection and the discount rate

The relation between, probability of detection and the discount rate calculated as follows:

$$\frac{dD}{d\delta} = -\delta\int_0^\infty \mathrm{g}(\tau, m, n, v)e^{-\delta t}\,d\tau) \quad (3.1)$$

Annexure C

1. Selected socio-economic factors that influence noncompliance with mesh size regulation

Table 1.1: Fishers' typology in Sudan

Violation rate	Frequency	Percent
NV	30	12.45
OV	122	50.62
CV	89	36.93
Total	241	100.00

Table 1.2: Violation rate and age categories

Violation rate	17-37	37-58	58-79	79-100
NV	3	16	11	0
OV	35	54	29	4
CV	36	31	16	6
Total	74	101	56	10

Table 1.3: Fishers' preference about management regimes

Violation rate	Government only	Fishers themselves	Co-management
NV	0	9	21
OV	2	33	87
CV	3	13	73
Total	5	55	181

Table 1.4: Perception of fishers towards peer violators

Violation rate	Fishers used small mesh size	Never use small mesh size
NV	29	1
OV	122	0
CV	89	0
Total	240	1

Table 1.5: Fishers' perception about net type's profits

Violation rate	Small	Normal	No difference	Total
NV	0	30	0	30
OV	103	18	1	122
CV	84	5	0	89
Total	187	53	1	241

Table 1.6: Fishers' typology and education level

VR	Uneducated	Khalwa	Primary	Secondary	Hi-secondary	university
NV	6	3	9	10	2	0
OV	32	14	39	4	15	4
CV	21	4	49	2	4	2
Total	59	21	97	16	21	6

Note: VR is violation rate

Table 1.7: Fishers' typology and household size

Violation rate	1—6	7—12	13—18
NV	7	21	2
OV	30	77	15
CV	20	65	4
Total	57	163	21

NOTE: hh size measured by the numbers of individuals within the family

Table 1.8: Fishers' typology and years of experience

Violation rate	1--20	21—42	43--63	64--84
NV	6	3	9	10
OV	32	14	39	4
CV	21	4	49	2
Total	59	21	97	6

Table 1.9: Fishers' typology and no of crew per boat

Violation rate	1—4	5—8	9—13
NV	28	2	0
OV	101	18	3
CV	84	5	0
Total	213	25	3

Table 1.10: Fishers' typology and source of income

Violation rate	Fishing only	Other sources
NV	14	16
OV	109	13
CV	84	5
Total	207	34

Table 1.11: Fishers' typology and Cash versus credit preference

Violation rate	Pay in cash	Credit
NV	11	19
OV	38	84
CV	14	75
Total	63	178

2. Questionnaire: Fishermen Compliance Behaviour to mesh size regulation measures in Sudan

Greeting, I am a fisheries researcher working at a research institute in Khartoum and I am here to administer a questionnaire on behalf of a PhD student at university of Pretoria South Africa. You have been randomly selected to participate in the fisheries science and research. Please note that all your answers and responses will be taken seriously with great confident. your participations to the questions are one of many answers by other fishers so no one can distinguishes what you are answered among all other answers .we will compensate you for the time that you spend with us by giving you 10,000 SP . Your interview will be taken with you alone to avoid interruption. Through this interview if you don't understand any question please, ask for more explanation. If you agree about that then let us start.

Section 0: Identification

	Name	Code
Q1. State		
Q2. Village		
Q3. Questionnaire number		
Q4. Enumerator		

Section1: Socio-economic Information

	Date	Month	Year
Q5. Date of the interview			2010

	Hour	Minute
Q6. Time of start		
Q7. Time of end		

Q8. Fisher name (optional)	

Q9. Age (year)		
Q10. Sex	Male	1
	Female	2
Q11. Education Level: Only one answer is possible	Uneducated	1
	Khalwa (Religious Education)	2
	Primary	3
	Secondary	4
	high Secondary	5
	University	6
	Post-graduate	7
Q12. How Many members in the household (number)		
Q13. How many years have you been fishing (number)?		

Section 2: Background Information.
Please provide the following information regarding your fishing activities

Q14. Which fishing activities of these do you use? Multiple answer is possible	Net	1
	Vessel	2
Q15. Which fishing equipment do you own? Multiple answers are possible	Net	1
	Vessel	2
Q17. Number of the crew?		
Q18. Number of trips per month		
Q19. Are you always fishing (tick correct answer/s)?	Yes (→ Q21)	1
	No	2
Q20. If no what were you doing?	Farming	1
	employed in Government/private sector	2

Fishing gears maintenance	3
not applicable	0

Q21. What was the percent of income that you got from fishing?

Less than 50 %	1
50 %	2
More than 50 %	3

Section 3: Status of the fisheries

Q22. How do you find the trend of the fish catch now compared to the last five to ten years?

Catch has been declining	1
Catch has been increasing	2
There is no change	3
Seasonal variation	4

Q23. What is the impact of the following factor on the fish stock in this area?

Use these codes:

1= Positive impact

2=No impact

3=Negative impact

4=Do not know

5=both positive and Negative impact

Factors		Code impacts
(1). Excessive number of fishermen		
(2). Excessive number of fishing gears/boats		
(3). The use of small mesh size		

Q24. Were you a member of the fishers' association in the past 12 months?

Yes	1
No	2

Section 4: Knowledge on Laws and Regulations

Q25. Do you think other fishers use small mesh size for fishing?

Yes	1
No (→ Q27)	2

Q26. IF YES indicate why?

Multiple answer is possible

Poor enforcement mechanism	1
Majority of fishermen are poor and not getting enough catch	2
Corruption	3
The level of penalty is low for the first and	4

	second offence	
	Easy marketing because people prefer the small sizes fish	5

Q27. Which type of net/nets were you using (considering mesh size) in the last 12 months?

Nets with small mesh size		1
Nets with prescribe mesh size		2
Both types of nets		3

Q28. If the answer is (3) in previous question how frequency in the previous year do you use both of them?

Q29. In which season(s) fishers like to use nets with small mesh size?

Multiple answer is possible

Winter time	1
Autumn	2
Summer	3
other (to specify)	4

Q30. Which net is more profitable?

The net with small size		1
The net with normal size		2
They are the same		3

Q31. If we offer you two choices to buy net that catch large amount of fish will you be able to pay in credit or cash?

pay in cash	1
pay it in credit	2

Section 5: Now we want to get your views about different regulations that are in place. The principal features of this regulation is mesh size regulation

Q32. For each of the following statements please indicate your level of agreement or disagreement

Use these codes:

1= Strongly agree

2=Partly agree

3=Strongly disagree

4=Partly disagree

Regulation	Code
Gill nets (mesh less than 10 cm)	

The principal reason for the following regulations (ban of gill nets of 10 cm or smaller) is to protect the fishery resources.

Q33. Indicate whether you think the above mentioned are just/fair regulations. Indicate your answer for each of the regulation in the table below

Use these codes:

1= Unfair

2=fair

Regulation	Code
Gill nets (mesh less than 10 cm)	

Please indicate whether you agree or disagree with the following statements

State your answer in the table below.

Use these codes:

1= Strongly agree

2=Partly agree

3=Strongly disagree

4=Partly disagree

Questions	Code
Q34. The mesh size regulations, closed areas licenses and other measures are aimed at improving the long term well being of ALL fishermen	
Q35. Views of fishermen are taken into account in the formulation of fisheries regulations.	
Q36. (Mesh size Regulation) is not enforced consistently	
Q37. Do fishers who violate these regulations getting away with it (i.e. not detected or penalized)	

Section 6: We would like you to tell us about your experience with enforcement authorities during the past 24 months

Q38. How often do you see the fisheries officers in the Reservoir when you were fishing during the last 12 months?

Only one answer is possible

Always	1
Often	2
Seldom	3
I have not seen them for almost a year now	4

Q39. What do you usually do to avoid being caught fishing with small mesh size net?

cell phone	1
tie the net with small mesh to big stone and allow to sink	2
destroy the nets	3
Other (to specify)	4

	Code
Q40. Enforcement in the fishing areas is adequate	

Use these codes:
1= Strongly agree
2=Partly agree
3=Strongly disagree
4=Partly disagree

Q41. Please estimate to the best of your ability the percentage of fishers who usually or always comply with any of the regulation listed in the table

Regulation	Percentages
Gill nets (less than 10 cm)	
Gillnet (monofilament)	
Closed areas	
No license	

Q42. Have you been arrested for violating mesh size regulations over the last 12 months?

Yes	1
No (→ Q44)	2

Q43. If YES, how many times?

Q44. What action did you take to avoid been taken to court

Bribe	1
Discuss with policy friends	2
relative in the government Protect	3
Other (to specify)	4

Q45. What enforcement actions were taken against you for violation of the regulation over the last 3 years?

Verbal warning	1
Written warning	2
Fine	3
Convicted	4

Confiscated/sizing the net		5

Q46. Do you think that enforcement action was right given what you did?

Yes	1
No	2

Q47. What were the total losses to you over the past 12 months as results of the enforcement action (cost of illegal fishing)?

Q48. Compare to the previous years the chance that violator will be caught violating mesh size regulation is:

Increasing	1
Decreasing	2
Constant	3
Fluctuated	4

Q49. The fisher has violated regulations because he is very poor with big family and small children should the fisherman have done that?

Yes	1
No	2

Q50. Why?

Q51. In your judgment what is the view of the other fishers towards those who are violating the mesh regulation.

Is wrong to do	1
Not wrong	2

Q52. What is your judgment on the view that regulations should be complied with even if they are not fair

Agree	1
Disagree	2

Q53. What is your judgment on the view that fishermen should comply with the regulation set by the government even if the regulations are not effective in managing the fisheries

Agree	1
Disagree	2

Q54. In your opinion which one is good for managing

The government	1

the mesh size regulation? Multiple answers are possible	Fishers among themselves	2