Social-ecological tipping points and an initial safe operating space for the Chilika Lagoon, Odisha

Gregory Cooper gsc1g11@soton.ac.uk Supervisors: John Dearing and Stephen Darby

University of Southampton · DECCMA · CARIAA IRCAAA · UKaid · IDRC CRDI · Canada

The 1990s Chilika Lagoon fishery collapse

The Chilika Lagoon of the southern Mahanadi delta provides ecosystem services for ~800,000 people[1], underpinning regional food and livelihood securities. These socio-economic factors and dynamic biophysical processes (e.g. freshwater influx, sediment loading, aquatic vegetation growth) contribute to the interannual variability of Chilika's fish catch levels.

Three breakpoints[2] divide the last 60-yrs of fishery production into distinct regimes (fig.1). A tipping point occurred in 1990, collapsing fishery production until 2001, reaching values less than the 95% confidence limit of the previous 40-yrs. The abrupt decline critically affected various aspects of the fishery system, including export levels[3], fisher income[1] and seasonal migration rates away from the Chilika region[4], producing a legacy of uncertainty regarding the future persistence of the fishery.

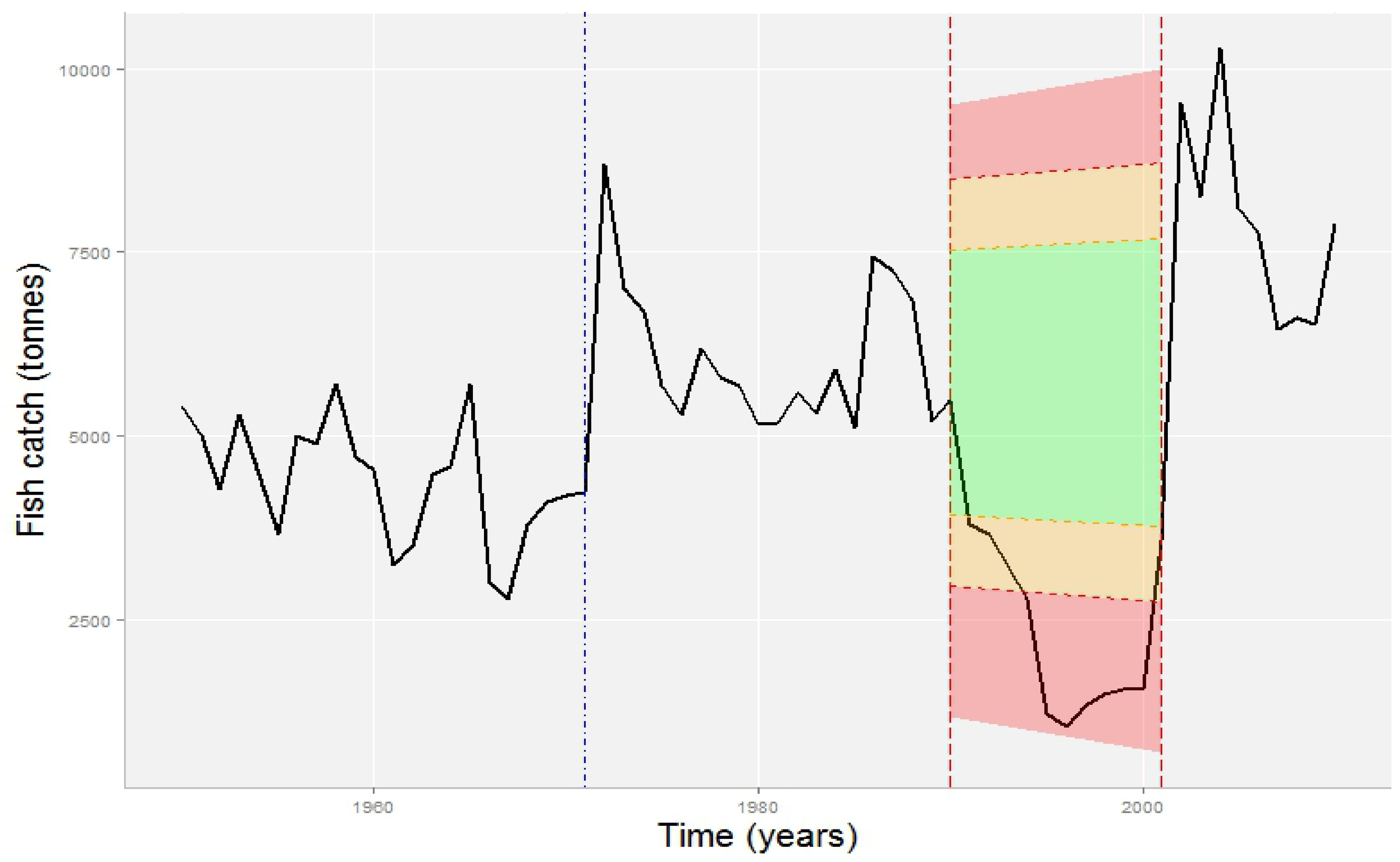

Fig.1: breakpoint analysis of reported Chilika fish catches since 1950 and ARIMA (1,1,1) analysis of the 1990s collapse. Dashed lines represent timeseries breakpoints (p<0.05). Green- within ARIMA forecast range, orange: beyond 80% CI, red: beyond 95% CI.

Key social and biophysical stresses

Various processes are blamed for the 1990s collapse[5]. Strengthening social-economic settings (fig.2) increased both fish demand and catchability, leading to the overexploitation of species during the 1970/80s. Prawn culture (fig.2), choking of the tidal outlet and increasingly variable freshwater influxes all contributed to lagoon freshening (fig.2), degrading the habitat quality of Chilika for commercial brackish species. Consequently, freshwater vegetation infestation (fig.2) blocked fishing grounds and routes. The effect of ecorestoration substantiates these driver-response relationships, as catch rates shifted to an all-time high post 2001 (fig.1).

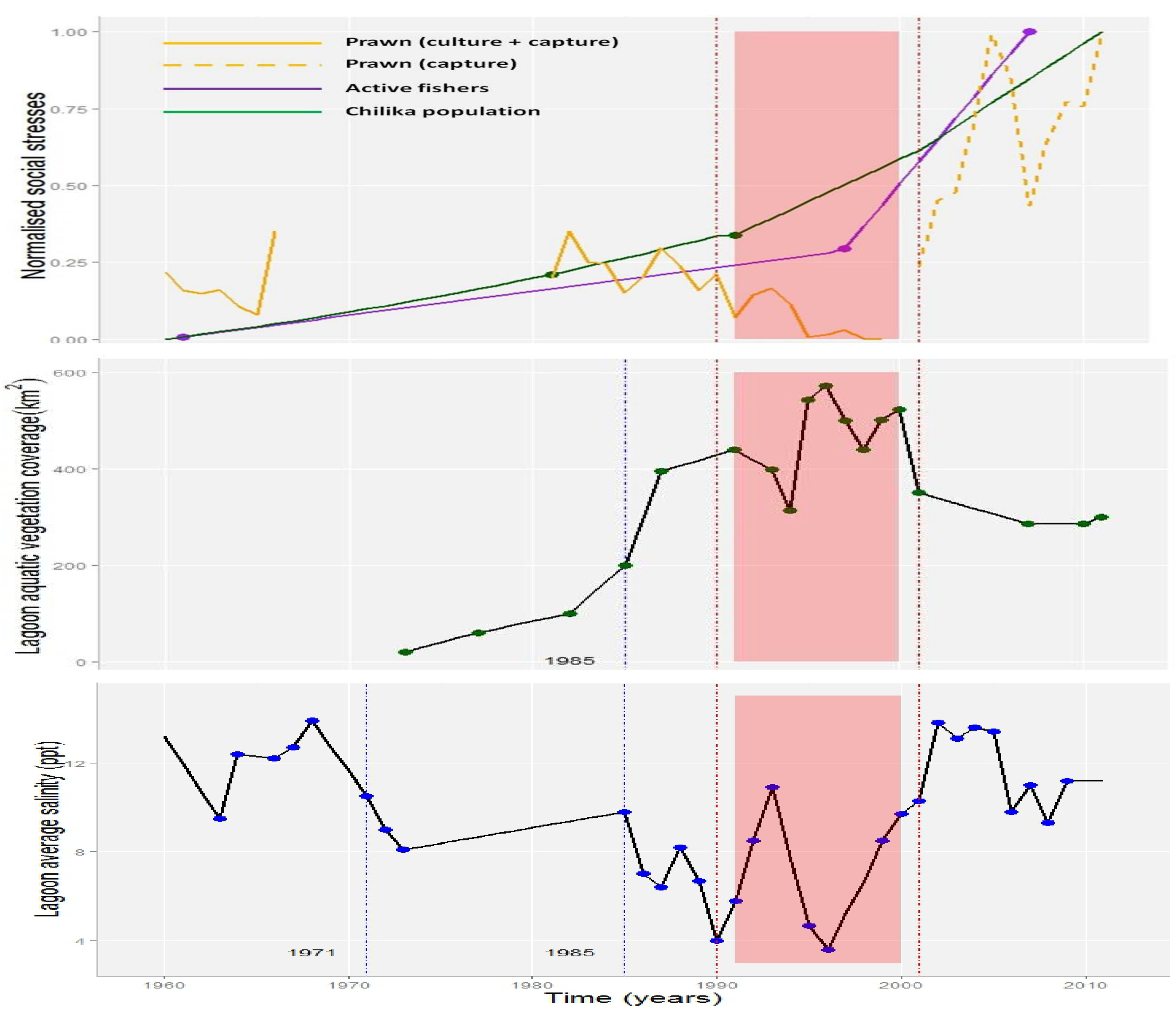

Fig.2: social processes (top), aquatic weeds (mid) and lagoon salinity (bottom) since 1960 in relation to the 1990s fishery collapse (red). Blue lines represent breakpoints (p<0.05) in stresses.

Evidence of social-ecological hysteresis

Hysteresis is observed by comparing the response of Chilika's fish capture rates to changing magnitudes of ecological stress (fig.3). The threshold driving the transition from high to collapsed catch states corresponds to a stress factor (SF) >50; the hysteretic reversal occurs at SF<36.

Saliently for lagoon management, hysteresis means that ecorestoration efforts must reverse system conditions back past the point of collapse, raising questions regarding the potential duration of future collapse lock-ins, and the socio-economic and ecological costs of remediation efforts.

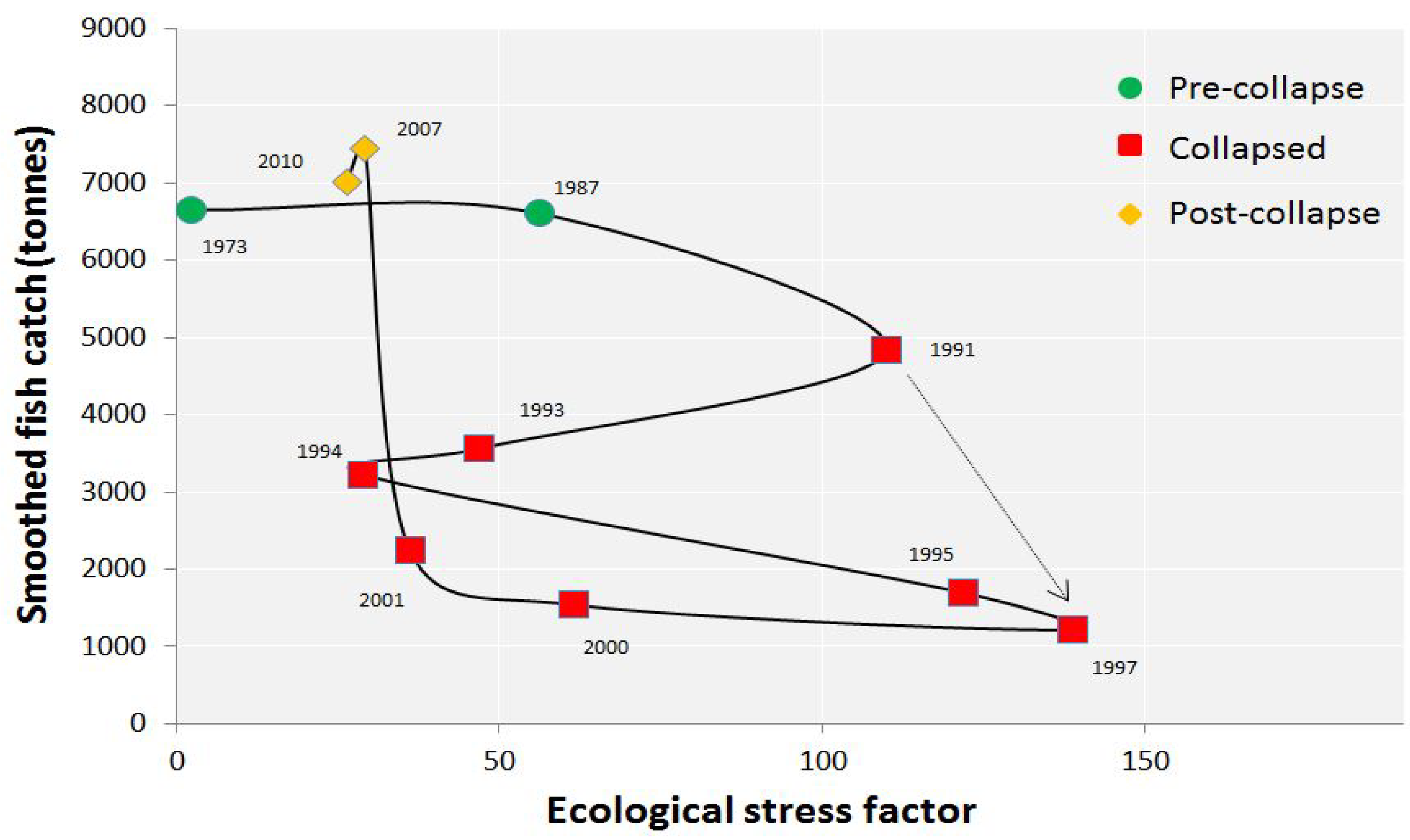

Fig.3: phase space plotting the response of Chilika fish catch levels and states to the ecological SF, defined here as the ratio of aquatic vegetation coverage to lagoon salinity. The dashed line represents the idealised hysteresis path.

An initial ecological 'safe operating space'

Identifying a 'safe space'[6] within which the lagoon has historically persisted provides insights for the avoidance of future collapses (fig.4). Vegetation coverages >410km and salinity <6ppt all equate to collapsed fishery state, forming a known historical 'danger zone'[7]. To date, vegetation coverages <300km and salinity >11ppt form a 'safe space'. However, continued intensification of socio-economic processes may evolve the boundaries of these zones, causing fishery collapse at healthier lagoon conditions.

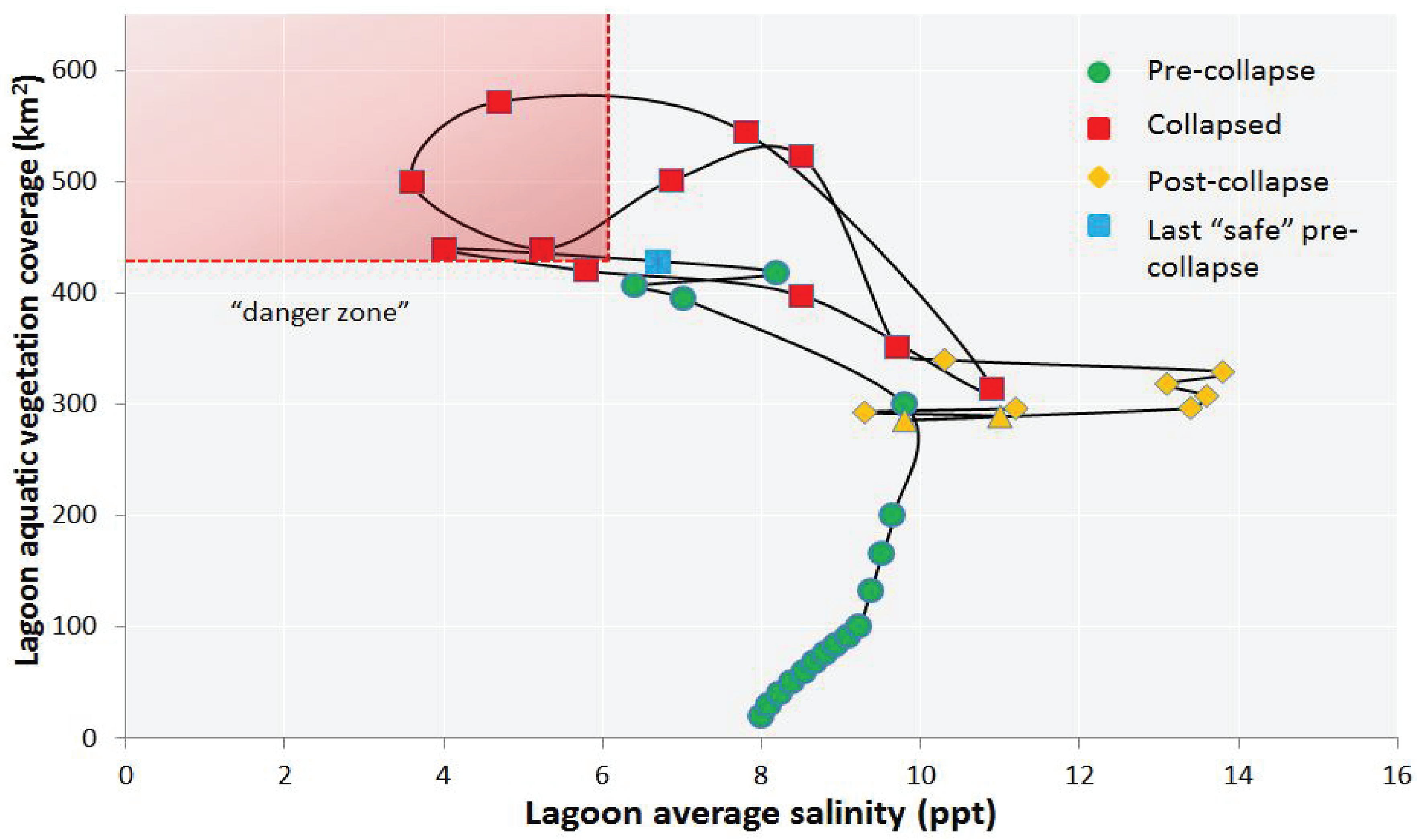

Fig.4: the "danger zone" defined by the relationship between lagoon salinity, vegetation and the fish catch state. Linear interpolation has been used to derive missing values from fig.3.

Current and future modelling

The results discussed here are currently informing a system dynamics model, aiming to project future safe spaces for Chilika bounded by critical levels of key social-ecological stresses. A fair level of historical coherence is currently achieved, but further parameterisation is needed to model the more emergent catchment dynamics (e.g. sediment influx, various socio-economic feedbacks). It is hoped that the field visit to Odisha in February 2016 will greatly aid model construction.

References: [1]Nayak 2014 *Ecol Soc*; [2]Zeileis 2015 *cran r-project online;* [3]Kadekodi & Gulati *CMDR Mono Series 26;* [4]Robson & Nayak 2010 *Pop & Env;* [5]Ghosh et Sal 2006 *Lakes & Reserv: Research & Manag;* [6] Rockström et al 2009 *Ecol Soc* 14:2; [7]Steffen et al 2015 *Science*. **Main data sources:** (i) fish catch levels: (a) Chilika Development Authority (b) Biswas 1995 *book;* (ii) social stats: (a) Kadekodi & Nayampalli 2005 book section (b) Chilika Development Authority (c) Pattanaik 2007 *J. Human Ecol;* (iii) vegetation and salinity: various, please enquire.