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ANNEX I

A BRIEF OUTLINE OF THE TRAFFIC LIGHT METHOD

A precautionary management framework was proposed by Caddy (1999b, c), originally intended for use in data-poor situations and where age-reading methodologies were impossible (in particular, for shrimp, and other invertebrate populations, of the North Atlantic Fisheries Organization, NAFO). This was subsequently developed further and applied in eastern Canada to groundfish management (see especially Halliday, Fanning and Mohn, 2001). For practical applications on shrimp stocks, see recent research documents of DFO Canada (e.g. Koeller *et al.*, 2000).

As originally proposed, this method was seen as a development of the limit reference point approach whereby multiple measures of biomass, fishing mortality, productivity, fleet performance etc, were each considered "Characteristics" of the fishery, and measured by one or more indicators on an annual basis. This approach could simply be to provide an index of stock status, as used by Koeller *et al.* (2000). A further development could be to develop a Traffic Light Precautionary Management Framework (Caddy, 2002) based on reliable indicators, with minimal use of modelling to define RPs; thus, the traffic light (TL) approach could be integrated into a Control Rule for use in routine fishery management, or in a stock recovery plan. Judgements as to which indicator to choose, and what value of the indicator should correspond to a Limit Reference Point, could be arrived at by analysis and/or by "oracle" sessions between experts and stakeholders. These sessions could review past annual values of the indicator from historical performance, especially during the declining phase of the fishery, (which presumably preceded the present need for a management recovery approach). This should help identify the conditions/indicator values in years immediately preceding stock collapse to below an agreed dangerous level. To simplify, each indicator value is then assigned a colour, separated by cut-off values, which may be considered equivalent to reference points, but which were referred to by Halliday, Fanning and Mohn (2001) as "traffic light boundary points".

In Halliday, Fanning and Mohn (2001) several different approaches to defining colour boundaries were explored. The "Strict" cutoff approach proposed in Caddy (1999b, c), proposed a two-colour system with a sharp transition between green and red for each of a multiplicity of indicators. The management response would then be graduated in intensity depending on the proportion of indicators which showed as "red". More elaborate "Ramp" and "Fuzzy" systems were explored by Halliday, Fanning and Mohn (2001), in which three colours were used, and they allowed the value of an indicator to progressively merge between adjacent colours (e.g. 30 percent yellow; 70 percent red), in a way that avoids the need for abrupt judgements and loss of information (for more details see Halliday, Fanning and Mohn, 2001).

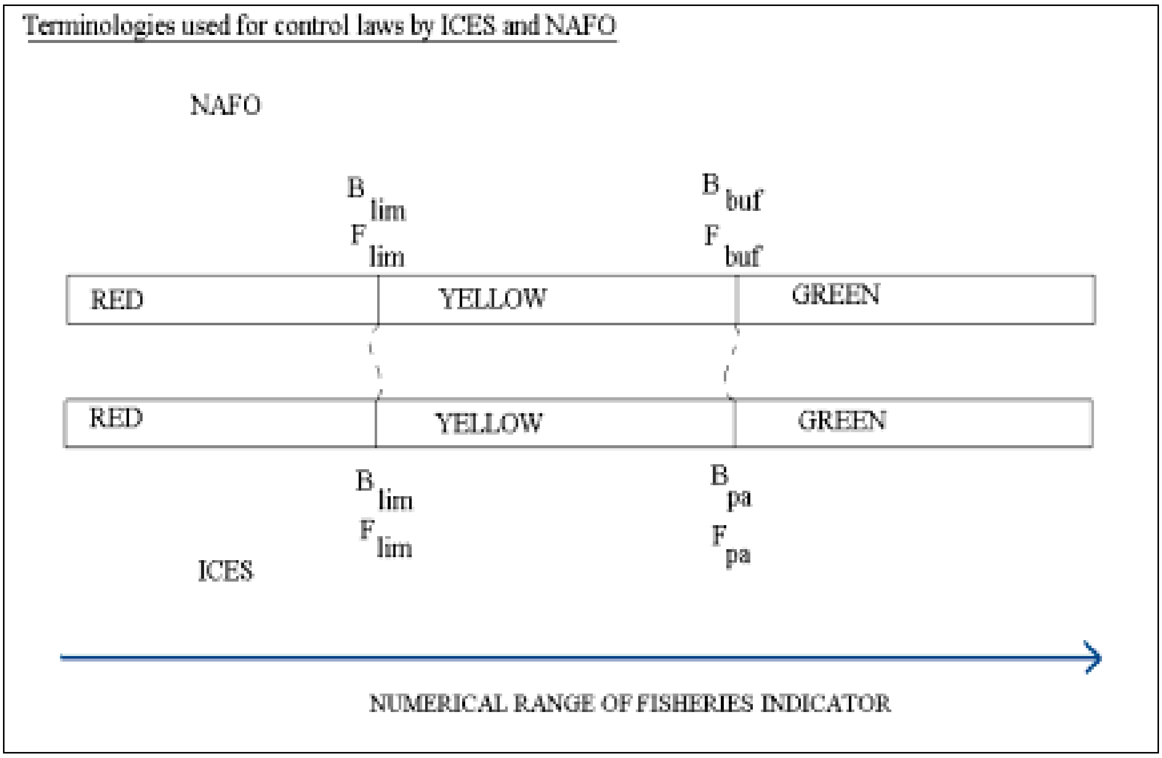

Figure A.1 The range of an indicator and boundary point nomenclature usage in two fisheries organizations, and the colour values assigned to each segment of the indicator range. See text for details on abbreviations.

As suggested by Figure A.1, two boundary points may be envisaged; between green (safe) and yellow (uncertain) conditions, and between yellow (uncertain) and red (unsafe) conditions. This approach is directly analogous to the definitions of "decision points" in a fisheries law, such as were suggested for management purposes by two fisheries bodies, ICES and NAFO, (see Figure A.1). As noted in Caddy (1998), terminologies such as "buf" (buffer), "lim" (limit), "pa" (precautionary), and "*tr*" (target) as in B_{lim}, B_{buf}, B_{pa} ,B_{tr}, F_{tr} , F_{lim}, F_{buf}, F_{pa}, and more generally, the terms TRP (Target reference point) and LRP (Limit reference point), do not of themselves define a specific level of fishing mortality or biomass. What they do represent, are decision points in a Harvest Control Rule or Law, such as is shown in Figure A.2. These RPs will then need to be defined operationally from a precautionary point of view. The point we were making above, was that these "traffic light boundary points" should primarily be values agreed on by the fishing industry and managers, based on their past experience of the fishery, if (as seems likely for most invertebrate stocks), such boundary points cannot be simply derived from a population modelling procedure. Thus, a boundary point in a TL approach, could be based on expert judgement or experience, instead of, (but not exclusive of) analysis, or can represent a previous state of the system which by common opinion marked the onset of unfavourable conditions, such as B_{1966}, where 1966 was the year when conditions in the fishery started to deteriorate for example.

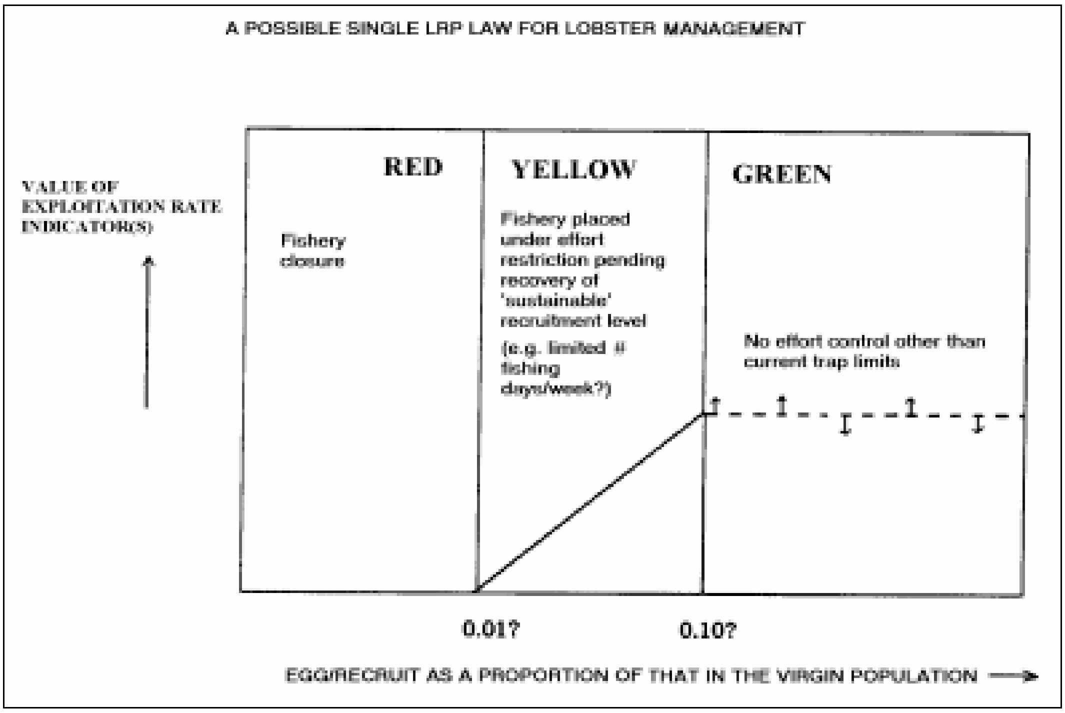

Figure A.2 Illustrating a hypothetical fishery control law for *Homarus americanus* in which a single factor, the egg/recruit for the population decides on the overall exploitation rate to be exerted.

Thus, B_{LIM} could be defined as a proportion of the virgin biomass B_0 (e.g. $0.2*B_0$), the frequently chosen (if arbitrary) minimum level of biomass it is felt it would be unsafe to allow the stock to drop below. F_{pa} could be defined for example as $F_{0.1}$, a level of fishing mortality defined as “one tenth of the initial rate of increase in yield per recruit with fishing mortality” (Gulland and Boerema, 1973).

Another point that could be made here in relation to the TL system as originally conceived, is that it was seen as integral to a fisheries control law, and not just a way of presenting the state of a resource. Perhaps this makes more explicit the need for judgement in applying fisheries science to management, instead of the former illusion that science was occupied with “quantitative analysis” and judgement was an activity reserved solely for managers! The judgement as to appropriate control points in a fisheries law will require input from “stakeholders” with the technical assistance of scientists, and this is in essence what the “co-management approach” is all about. As noted by Halliday, Fanning and Mohn (2001), the assignment of boundary points to indicators in the TL approach can be made precautionary, in that a wide range of indicators can be incorporated, making for some necessary redundancy in information inputs. This approach also allows an “objective-based” management approach to be developed, whether this is aimed at controlling fishing under “normal” stock conditions so that “normal” stock conditions prevail, or stock rebuilding, in that the definition of boundary points, their weightings, and their use in the Control Law, is cleared with stakeholders, and corresponds to some economic or ecological optimum. One immediate advantage of this system for communicating with the fishing industry is ease of understanding, and the sense of urgency and immediacy the colour coding provides.

Some definitions of terms used in the TL system

Elements of a fishery were conceptualized by Halliday, Fanning and Mohn (2001), as having "attributes", such as biomass, growth rate and the mortality due to fishing.

"Attributes" of the population or fishery are monitored by one or more indicators. For example, mean weight per tow of a research vessel survey is a "relative" indicator of population biomass. A normalized summation of two or more indicators for may be referred to as measuring a system "characteristic" of the stock, such as: (a) abundance, (b) production, (c) fishing mortality and (d) ecosystem/ environment. (Note that conventional stock assessments usually only deal with (a) and (c), while the TL system potentially allows much wider ecosystem, or even socio-economic, contexts, to be incorporated into a fishery control law).

A "template" for outlining a TL Indicator

Halliday, Fanning and Mohn (2001) suggest some aspects of indicators which require description:

- data sources, ranges, transformations or smoothings and software used in calculation
- statistical properties (variance, bias, skewness), transformations used, consistency with other estimators
- Interpretability in terms of the characteristic measured
- Sensitivity to changes in stock status

The overall value of an indicator may be scaled relative to other indicators by a weighting factor, so as to reflect the importance of the attribute being measured, or the proven reliability of the indicator. No firm rules have been derived as yet for what in effect is an empirical results-based system, but for example, two indicators derived from the same data source should perhaps each be given a weighting of 0.5, compared with a single indicator based on an independent data source, given a weighting of 1.0.

In general, we start by defining the yellow-red boundary as corresponding to the onset of dangerous conditions, using one of the criteria employed for deciding on LRPs (see e.g. Caddy and Mahon 1995, or examples in the above Table A.1). In judging where to place the green-yellow boundary, one approach is to choose a value taking into account an estimate of the variance of the data series the indicator is based on. That is, choose a boundary point that corresponds to an acceptably low (e.g. five percent), probability that the indicator value, by error, will exceed the LRP established at the yellow-red boundary. An assessment of the performance of an indicator and its boundary points should be carried out periodically, and checked against new findings on resource status, and on those critical factors influencing the risk of stock collapse.

Table A.1 An example of some considerations that might influence the choice of indicators and their LRPs for the fishery for the lobster *Homarus americanus.*

Indicator of:	**Level indicator**	**Change indicator**	**LRP Triggered by:**
Recruitment:	Annual recruitment versus long term average: (R_T/R_{AV})	Annual trends in CPUE of "shorts" in commercial traps	$R_T < R_{AV}$ for three successive years?
Exploitation rate: *(Ratios of numbers in successive moult groups should change with F)*	Overall mortality rate indicator as a log ratio of numbers per moult group: [$Z_m = - \ln (N_{m+1}/N_m)$]	Slice size composition using moult increments to estimate approximate numbers of each moult group (m) in the catch?	Define a limiting value for overall mortality rate per moult group
Exploitation rate: *(Ratio of mature males/ mature females should decline with exploitation, where berried are females returned and survive)*	Estimate sex ratio of mature males/mature females	Examine trends in ratio: (# mature males/ # mature females).	Decide on a value of this ratio below which mature females would have low probability of finding mates within their typical size of individual territory?
Exploitation rate: *(Calculate mean number of eggs/size on berried females in the commercial catch)*	Smaller animals are lower fecundity – Estimate number of eggs produced per female/mean CPUE	Examine trends in mean individual fecundity in commercial catch.	Set a minimum percentage for females in the catch of a size that should have spawned at least twice
Prevalence index: *(Has the species range decreased?)*	Percent non-zero sub-areas in original low exploitation meta-population range, as established from surveys or geographically displayed log book data	Shrinkage/expansion of range can be a useful indicator of population health when abundance data are doubtful.	Set percent of original "pre-decline" stock range or area as LRP
Economic data: *(As catch rate declines, revenue per trip (NR) falls to a level where costs (*ΣC*) are not covered)*	Estimate NR/ΣC (= Net revenue per cost of a trip)	Examine trends in NR through season and annually.	Set LRP at value of NR/ΣC = 1.0-1.05?