Modelling and attitudes towards the Future

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Abstract

The outputs of ecological models often need to be projected several years, or decades, into the future. The psychological literature tells us that stakeholders rarely think of such a distant future and when they do, they employ cognitive styles different from the ones commonly used for planning and decision making, which the ecological models are designed to facilitate. This may affect the reception of modelling efforts in several ways. Stakeholders may question the very purpose of trying to say anything meaningful about such a distant future; may consider model outputs as irrelevant to planning; or may provide emotional, often unconscious, responses motivated by deeply held fears and aspirations. Modellers too may display some of these behaviours. Here, we review the relevant literature and describe a questionnaire a modeller could use to explore these issues within a stakeholder group. We also report an experiment which shows how the very act of answering the questionnaire can significantly change the perception of future time horizon and future concerns and discuss the possible implications for modelling projects.

Keywords: Forecasting; Futures Studies; Ecological Modelling, Natural resource Management; Cognitive Science

Highlights:

- Stakeholders' acceptance of model projections can be affected by attitudes towards the future
- Individual attitudes and attitudes towards the close and far future vary considerably
- Thinking about the future can in turn markedly change these attitudes
- Understanding these processes can help communicating model results

1 Introduction

As a tool to support decision making, is it worthwhile to use computer modelling to explore the future 5, 10 or 20 years ahead of us? What about 50 or 100 years? There are at least two ways to address this question. One is technical and has to do with the process we want to study and the computer model we intend to use. It focuses on issues like the dynamical complexity of the process, its time scale, its sensitivity to initial conditions, the suitability of the model given the task, the type of questions we ask, our scientific knowledge, data availability and the level of inherent uncertainty. The second has to do with whether whoever has to make decisions based on the model's results believes the model can say anything useful about a future 20 or more years away from us. There are cases in which the scientific community believes some model results can reasonably be projected several decades in the future (once some crucial assumptions are understood and accepted) but some stakeholders may not be willing to believe the results, as in the case of the Club of Rome's Limits to Growth results (Meadows, 1972) and climate change and population growth projections, among other examples. There are cases in which the scientific community does not believe model results can be projected even a few years in

the future but some stakeholders are willing to firmly believe the results (macro-economic forecast ahead of GFC).

The technical side of this question is briefly addressed in Section 2, where we discuss four broad scientific principles related to predictability. This core of this paper however is about the cognitive approach the above question. We first review some concepts from the social cognition and the psychology literatures which describe people's ways of thinking and attitudes towards the future. We place particular emphasis on how attitudes towards the future are related to other cognitive and psychological traits which are relevant to decision making and which may affect a stakeholder's willingness to include modelling results in the decision making process. We then describe a questionnaire we have used to survey the attitudes towards the future in a large sample of Australian citizens. The survey identifies five Myths of the Future, which represent beliefs, concerns and expectations about the future which most succinctly and clearly define individual differences in the way the future is conceived. The questionnaire, which we make available online, could be employed by a modeller to explore attitudes towards the future in the stakeholders of a specific modelling project.

One result from our survey is of particular significance for the modelling audience; answers to the purposely fuzzy question '*When you think of the future, what time frame is it*?' change dramatically depending on whether the question is asked at the beginning or in the middle of the questionnaire. Answers to the question '*What are the first five words that come to mind when you think about the future?*' behave similarly. This means that attitudes towards the future are ductile, at least for some individuals, and that the very act of addressing future issues can affect these attitudes. This also suggests that a modeller involved in a project requiring projections into the far future may see the stakeholder audience changing attitudes during the project itself, may need to be aware of this possibility and may need to tune stakeholder communication accordingly.

Before proceeding it is important to define some terminology. Considering modelling results pertinent to the future inevitably leads to the concept of prediction. As we discuss in Section 2, in some disciplines the proposal that i) models generate predictions (Hempel, 1963) and ii) predictions are necessary for decision making (Claveau, 2015; Pielke, 2003), is obvious and does not need justifying. In other disciplines a nuanced distinction is proposed between prediction, forecast, projection (extending model simulations into the future), foresight, prognosis and simulation (Bergman et al., 2010; Borjeson et al., 2006; Miles, 2010; Szpunar et al., 2014) or between potential, possible, plausible and probable futures (Hancock and Bezold, 1994). Given the scope of this work, we simplify the terminology by following (Boschetti et al., 2011). First, we define projection as the output of a model which pertains to the future and prediction as an expectation on ranges of future behaviours, rather than the anticipation of an exact behaviour or event. In other words, a prediction is not a prophecy (Beven, 2002) and does not guarantee the certainty of an event. Second, we interpret a model output as a *conditional* prediction, which depends on the model's (explicit and implicit) assumptions as well as on the purpose of the model in the context of the problem at hand. Third, we assume that decision making implies choosing among potential alternatives and involves *predicting* the likely outcomes of these choices (Boschetti et al., 2013; Bradbury et al., 1985)[1]. With this understanding of the words prediction and projection, below we discuss what psychological and cultural factors affect their reception, how the time horizons of these projections affect their receptions and how these relate to attitudes towards the future in general.

2 Prediction and the future from the modellers' perspective

[1] This sentence may appear as normative, rather than descriptive. But consider the extreme case of a decision maker choosing according to his/her short-term interests, with no regard or knowledge of long term consequences. Even in this case, the decision is made following the prediction that the choice will likely fulfil the short-term interests.

Beliefs about the extent to which a model projection to the far future can provide a useful input to decision making varies not only among stakeholders and decision makers, but also among modellers. It is possible that these different beliefs originate from the same attitudinal and cognitive biases which affect non-modellers and which we describe below. However, it is also likely that a modeller may feel a greater need to rationalise these beliefs, at least for communication purpose. Four broad scientific principles can provide an anchor for such rationalisation. The first invokes a time-symmetry between explanation and prediction: the principle which allows us to employ physical laws or statistical regularities to make a prediction is the same which allows us to explain an event from its past (Suchting, 1967; Symons and Boschetti, 2012). As a result, if we believe in our ability to explain we should also believe in our ability to predict. The second principle invokes a broad analogue of chaos theory, which emphasises predictions' (and model outputs in particular) sensitivity to initial conditions, data gaps and overall uncertainty (Aligica, 2003; Ascher, 1989, 1993; Beven, 2006; Beven, 2002; Brunner, 1999; Oreskes, 2000, 2001). Notice that, technically, accepting both the first and the second principles should lead us to dismiss not only our ability to predict, but also to explain and understand (Symons and Boschetti, 2012), while some modellers defend models' explanatory power, but not their predictive power (Brugnach, 2010; D'Aquino et al., 2003). The third principle highlights a prediction's scale dependence in both time and accuracy (Israeli and Goldenfeld, 2004), of which a well understood example is the difference between weather (fine scale) vs climate (coarse scale) predictions. The fourth principle refers to predictions' self-reference when they involve human behaviour: any prediction which is known to a decision maker can affect his/her decision and as a result the prediction itself.

These principles are well established in both theoretical and applied science as well as in the philosophy of science. In some cases they also come with rigorous mathematical formalisations. Some of these principles justify our reliance on (conditional) predictions, others not. As a result, modellers could invoke them to give firm theoretical justification for a wide range of beliefs regarding what, if anything, a model can say about the far future. This does not necessarily mean that a modeller would do so to deceive. However, scientists, and experts in general, are not immune from 'motivated reasoning' (Kunda, 1990). Motivated reasoning describes how, in order to justify a particular conclusion, people are more likely to employ beliefs and strategies which are compatible with such a conclusion. In the case of modellers, this may affect the adoption of or belief in certain types of models.

As we will see in the next section, the four principles described above (time-symmetry between explanation and prediction, sensitivity to initial conditions and prediction's scale dependence and self-reference) resemble very closely attitudes and beliefs towards the future which are also found among the general public. While motivated reasoning can affect anyone, individuals with higher cognitive skills or expertise will likely have a wider range of rational justifications at their disposal and a better ability to employ them (Kunda, 1990; Nisbet and Markowitz, 2015). It follows that in modellers motivated reasoning may interfere, or even be masked by expertise, something which both modellers and stakeholder need to be aware of.

3 Psychological and individual traits affecting attitudes towards the future

A number of approaches to study attitudes towards the future can be found in the psychological and social science literatures. Nevertheless, a unified framework is not yet available and the field is currently undergoing considerable development. In this section we review five main approaches which go under the labels of (1) Zimbardo's Time Perspective Inventory, (2) the 'mental time travel' literature, (3) Temporal Construal, (4) Consideration of Future Consequences and (5) Time-Discounting. Because our focus is specifically on the use of models to carry out (conditional) predictions, we place particular emphasis on two related concepts: i) perception of time in terms of past, present, close future and far future components and ii) attitudes towards these components.

3.1 Zimbardo's Time Perspective Inventory

Zimbardo's Time Perspective Inventory divides time into three components (Boyd and Zimbardo, 1997; Zimbardo and Boyd, 1999): past, present and future, without particular emphasis on scale, measurement or reference (little emphasis is placed on a distinction between close and far future). It suggests that people cluster around five different attitudes towards time. The first describes a negative attitude toward the past, which is accompanied by pessimistic and aversive feeling towards it. The second describes the opposite: a positive attitude toward the past with a warm and nostalgic connotation. The third describes a hedonistic attitude towards the present, which emphasises a preference for immediate gratification and low priority on procrastinating rewards. Fourth, they describe a fatalistic attitude; this also places priority on the present but, unlike the hedonistic attitude, does so because of perceived lack of control on the future (see also (Sobol-Kwapinska, 2013)). Finally, we have a future orientation, which leads to prioritise planning and achievement of future goals. Zimbardo's Time Perspective Inventory comes with a well-established scale (D'Alessio et al., 2003; Zhang et al., 2013; Zimbardo and Boyd, 1999) which has been widely validated and whose relation with other cognitive constructs has been explored in several studies (Cretu, 2013; Milfont and Gouveia, 2006). Of particular relevance here is the relation with attitude towards the environment. A common finding, shared by several approaches, shows how an environmental concern is closely related to future orientations (Bohm and Pfister, 2005; Hendrickx and Nicolaij, 2004; Milfont and Gouveia, 2006; Milfont et al., 2012), which in turns is related to a conscientious personality type (Borghans et al., 2008) and self-control (Daly et al., 2009).

3.2 Mental time travels and episodic future thoughts

Zimbardo's Time Perspective construct addresses how an individual's *focus* on past, present or future affects his/her behaviour or life's goals. An analysis of *how* and *why* we think of the past and the future is addressed by the 'episodic future thought' or 'mental time travel' literature (Epstude and Peetz, 2012; Szpunar, 2010). Despite their curious labels, they describe some empirical findings which should resonate vividly with modellers, because they explicitly address the concept of simulation. First, people spend a considerable amount of their time consciously thinking about the past or the future (D'Argembeau et al., 2011; Stawarczyk et al., 2013). Much of this time (up to a third of waking time (Szpunar, 2010)) goes into replaying the past, considering alternative versions of the past (counterfactual thoughts) and simulating the future (Epstude and Peetz, 2012; Jason et al., 1989). It is suggested that the purpose of this simulation activity is to learn from the past and plan the future since being able to recombine features of past (or alternative possible past) experiences, provides the material for a large number of hypothetical future scenarios (Addis et al., 2007; Corballis, 2003; D'Argembeau, 2012). Analysing these scenarios is then useful not only for planning and goal setting (D'Argembeau, 2012; D'Argembeau et al., 2012; Suddendorf and Corballis, 2007) but also for preparing ourselves emotionally for possible future events and can have an impact on how we interpret and perceive the present (D'Argembeau and Van der Linden, 2007). In general, this literature views mental time travels in terms of simulation and prediction aimed to support planning. This closely resembles how researchers in computer science, computational mechanics and theoretical biology describe the way agents (either living or artificial) represent their environment in terms of models and how this understanding is subjected to (natural or artificial) evolutionary pressure (Boschetti et al., 2013; Crutchfield, 1994; Crutchfield and Young, 1989; Hohwy; McGregor, 1938; Shalizi, 2001; Shalizi et al., 2004; Suddendorf, 2006; Suddendorf and Corballis, 2007)

A crucial observation arising from this literature is that mental time travels are not spread uniformly in time. Most time travels refer to events occurring in the close past and the close future and they become increasingly rare the farther they are from the present (Spreng and Levine, 2006). Time travels to the future seem to be more frequent than to the past (D'Argembeau et al., 2011; Spreng and Levine, 2006;

Stawarczyk et al., 2013) and seem to have more positive connotations (D'Argembeau, 2012; D'Argembeau et al., 2012; D'Argembeau et al., 2011; Tonn et al., 2006; Trope and Liberman, 2003).

The literature discussed so far also shows that the ways we think about the past and the future have very strong similarities (D'Argembeau, 2012; D'Argembeau et al., 2012; Spreng and Levine, 2006). Our ability to think about the future seems to be fully dependent on the ability to remember the past (Szpunar, 2010). Nevertheless, there is a fundamental difference in the way we think about the far past and future compared to the close past and future, which is addressed next.

3.3 Temporal Construal

According to Temporal Construal Theory (Trope and Liberman, 2003), temporally distant events are represented more abstractly than closer events. In particular, distant future actions are more likely to be represented in terms of high-level goals while near future actions are more about concrete plans for action (Liberman and Trope, 1998; Spreng and Levine, 2006; Stawarczyk et al., 2013; Trope and Liberman, 2003). In other words, the far future is about 'why' questions and the close future about 'what' and 'how' questions (Pahl et al., 2014; Trope and Liberman, 2003). Congruent with this is the observation that far-future thoughts are usually rated as being more personally important than near-future ones (D'Argembeau et al., 2011). Thoughts and time travels to the far past and future are equally broad, poor in details and abstract, but of great significance. They provide a context for retrieving, and interpreting relevant memories (D'Argembeau, 2012) and provide autobiographical narratives and overall sense of unity and purpose which is crucial to the sense of self (D'Argembeau, 2012; D'Argembeau et al., 2012; Epstude and Peetz, 2012). It follows that the far future has a role which is distinct from planning or conceiving practical goals. Rather, it is the realm of abstract representations that do not necessarily refer, or need to refer, to specific events (D'Argembeau, 2012; D'Argembeau et al., 2011).

3.4 Consideration of Future Consequences

Differences between attitudes towards the immediately close and far future are also addressed by the Consideration of Future Consequences scale (Joireman et al., 2012; Strathman et al., 1994), the fourth approach we describe, which measures the extent to which people's actions and decisions are affected by immediate vs future consequences. Extensive empirical evidence shows that individuals high in Consideration of Future Consequences are, as expected, more prone to delay gratification and invest effort for future gains in areas as diverse as health, financial and environmental management (Bohm and Pfister, 2005; Hendrickx and Nicolaij, 2004; Joireman et al., 2012; Joireman et al., 2004). In line with the Time Construal literature, these individuals are also more willing to focus on abstract goals, which naturally pertain to the far future.

3.5 Time-Discounting

Individuals high in Consideration of Future Consequences also show lower time discounting. The study of time discounting, attempts to measure the value of an outcome in the future compared to its present value. Because it is a crucial variable in any economic analysis (Jefferson, 2012), a considerable literature is dedicated to devising mathematical formulations of time discount which are analytically tractable (continuous, differentiable, etc). Among other variables, time discounting is inherently related to perceptions of risk, since the longer a reward or a punishment is delayed the more likely something may prevent its realisation. As a result, it is usually assumed that a 'rational' discount should be positive and monotonic (representing a constant decay over time). Nevertheless, there is evidence that people discount economic, health, environmental and social outcomes differently (Chapman, 1996; Gattig and Hendrickx, 2007). In particular, environmental outcomes may show no discounting at all, even though some consequences of environmental actions and policy may not occur during an individual's life time. A possible rationale for this apparent contradiction suggests that for some people ethical concerns override utility and risk considerations when human decisions and

actions may lead to negative impacts borne by others (Bohm and Pfister, 2005; Hendrickx and Nicolaij, 2004). This is also in line with an observation from the Time Construal literature according to which outcomes low in construal level are discounted more than outcomes high in construal level, for which discounting may even change sign (Trope and Liberman, 2003).

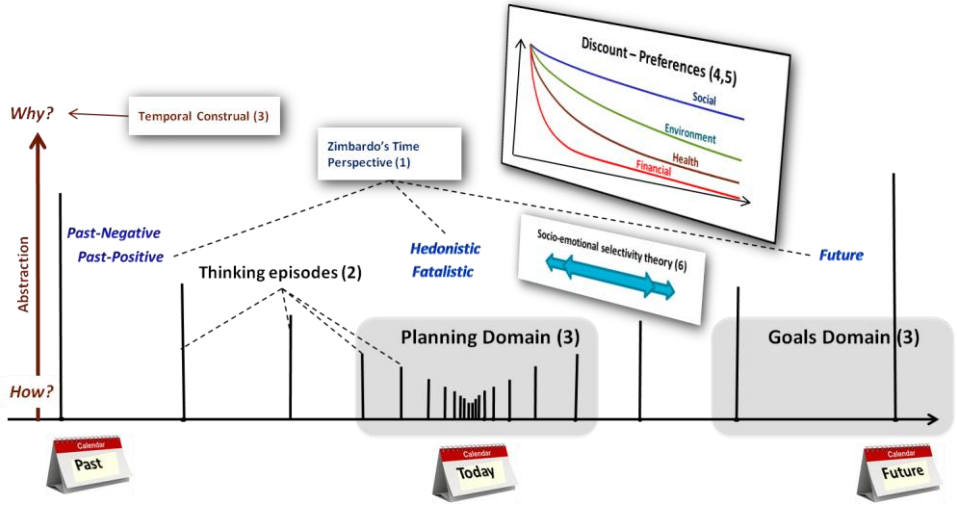

Figure 1. Schematic summary of the literature assessing psychological and individual traits affecting attitudes towards the future. Numbers in parentheses refer to the five approaches described in Section 3. The Socio-emotional Selectivity Theory is discussed in Section 5.

This section has provided a fairly complex picture of how psychological and individual traits affect attitudes towards the future. Regularities can be found and these could help a modeller, if trained in this area, develop some expectations of how stakeholders may receive and react to model results. However, these regularities are context dependent and can be affected by specific topic, risk perception and ethical concerns. We attempt to summarise this complex picture in Figure 1. The horizontal axis maps time into its three broad components: past, present and future. Thinking episodes (or time travels) are represented by the black vertical bars. Their horizontal position refers to their occurrence in time (more frequent close to the present and more rare in the far past and far future, as per the Mental Time Travel literature), while their height represent their level of abstraction and overall significance in an individual's conception of self, as per the Time Construal literature. The past-negative, past-positive, hedonistic, fatalistic and future orientation represent the focus of Zimbardo's Time Perspective approach and the discount-preference panel refers to the different way future consequences can be weighted according to personality traits and different domains.

4 Socially and culturally shared views of the Future

The previous section focussed on the drivers of attitudes towards the future at the individual level. In this section, we review some of the drivers acting at the social and group level, including insights from the Foresight and Futures Studies literature, the Causal Layered Analysis, Narratives Analysis of Environment Discourse and Myths of the Future.

4.1 Foresight and Futures Studies

In the Foresight and Futures Studies literatures an important role is played by the concept of scenario as a '*plausible, challenging, and relevant story about how the future might unfold*' (Bezold, 2010; Hunt et al., 2012; Raskin, 2005). Experience with foresight exercises carried out over several decades, in different places and within different cultural backgrounds has identified that scenarios tend to cluster around a small number of archetypes. These consist of groups of similar scenarios, which represent culturally-shared beliefs about future states and their drivers. We refer to a few

comprehensive review papers (Alford et al., 2014; Bezold, 2009, 2010; Bootz, 2010; Dator, 1978; Hunt et al., 2012; Raskin, 2005) for a good overview of this extensive literature. With some minor variations in terminology, these archetypes tend to describe i) a business as usual future, seen mostly as a continuation of current trends, ii) a future of top-down transformation in the form of institutional and political changes, iii) a future of bottom-up transformation in the form of social or moral changes, iv) a future driven by technological changes, v) a future of decline, due to either ecological or moral ruin, and vi) a fragmented future, with focus on local communities and regionalism (Boschetti et al., 2015).

Very similar views of the future are found experimentally when participants in foresight workshops are asked to identify the two most critical and uncertain drivers of change and analyse their interplay (Hunt et al., 2012). These drivers of change are often represented as axes of a 2D 'Futures' plane, where scenarios can be plotted to facilitate discussions (Amer et al., 2013; Bezold, 2010; Curry and Schultz, 2009; Pinnegar et al., 2006; Ramirez and Wilkinson, 2013; Raven, 2013). Choices for these two axes tend to be very consistent (Boschetti et al., 2015) across workshop purposes, applications and domains, with the first axis mapping amount of social or political regulation (ranging from a global, interdependent, cooperative to a regional, autonomous, uncooperative future) and the second axis mapping social values and priorities (ranging from a self-interested, individualistic, materialistic to a communitarian and sharing future). These two axes define four quadrants, each corresponding to a specific interplay between the drivers, allowing the workshop participants to explore the future implications of these interplays, given the workshop focus, context and purpose. Commonly, this approach leads workshop participants to define scenarios similar to those described in the previous paragraph (Boschetti et al., 2015).

4.2 Causal Layered Analysis

A conceptually different approach is given by the Causal Layered Analysis (Inayatullah, 2004b). The name originates from an attempt to define levels of increasing conceptual or cognitive depth, at which beliefs about the future develop and how they manifest in narratives, attitudes and assumptions. It consists of four levels. The first level (litany) includes statements, (possibly quantitative) trends, stereotypes or vignettes which describe views of the future which are most visible. The second level (social causation) attempts to explain and justify the litanies by analysing their causes, often within a STEEP (social, technological, economic, environmental and political) framework. While this analysis employs mostly conscious, technical or rational arguments, the core assumptions underneath these arguments are rarely questioned at this level. The third level (discourse/worldview) includes the deeper ideological assumptions which support and legitimate the views expressed at the previous two levels. These can be made conscious with time, effort and will to engage. The fourth level (metaphor), includes the emotive dimensions of the issue and may consist of deeply held and culturally shared images rather than explicit statements.

The Causal Layered Analysis is rooted in post-modernism and its original literature is written in a post-modern style which modellers and natural scientists may not find congenial. Nevertheless, in our opinion it can be valuable, especially in workshop settings in which modelling purposes, not just results, need to be discussed. Its main value comes from the clear attempt to break down the often unspoken assumptions underneath specific beliefs and to analyse them in terms of power relations (who is privileged by a certain view of a problem or by a certain future), historical backgrounds (why a problem is formulated in a certain way) and alternatives (which formulations or knowledge would lead us to considering the future differently).

4.3 Narratives Analysis of Environment Discourse

The analysis of the narratives that decision-makers and the general public use to support or justify specific policies is common in several disciplines and has been carried out extensively in relation to environmental issues which are the focus of ecological modelling (Dryzek, 1997; Roe, 1994;

Urhammer and Ropke, 2013). These have clear implications for our analysis because each narrative comes embedded in a set of desired and feared futures. A good review of narratives employed by governmental organisations, NGOs and academic institutes to address the relation between economic development and ecological sustainability with emphasis on eco-centric narratives can be found in (Boschetti et al., 2014; Urhammer and Ropke, 2013). These include Green Growth, which emphasises growth with environmental efficiency as a win-win solution to the challenge of aligning economic growth and environmental sustainability; Green Economy, which also envisages growth, but places emphasis on social inclusiveness and respect for future generations; Green New Deal (defined slightly differently by different sources), which supports government intervention and regulation to address both economic and ecological crises; Steady State Economy, which gives a strong physical and economic rationale to the principle that constant growth is not possible in a finite world; and De-Growth, which takes the concept of the Steady State Economy one step further and proposes a conscious and planned reduction of global economic activities. Similarly, a review of narratives with a market-centric emphasis is found in (Zuidhof, 2014). These include (traditional) Liberalism, which sees markets as a positive, natural, but imperfect force, thus defining a role for government in the economy; Free-Market, which also sees markets as natural to human relations, but de-emphasises their imperfections and holds a sceptical outlook of government intervention, seen as counterproductive; and Neo-Liberalism, which sees markets as instruments for governance and encourages governments to create markets also in areas traditionally not seen as subject to market relations.

4.4 The Myths of the Future

The studies we have so far summarised in this section have a conceptual nature, but are also based on extensive empirical work, carried out either by observing a large number of Foresight exercises or by analysing many publications and academic works. Nevertheless, by their very nature, their contexts did not provide the opportunity to collect and analyse unbiased data, as commonly achieved via the experimental designs adopted in the social sciences. This has been carried out in (Boschetti et al., 2015), which employed an on-line survey to explore images, concerns, expectations and attitudes towards the future among the general public. The main difference between this work and the approaches described above is that foresight exercises and narrative analyses address specific issues or concerns. Also, foresight exercises are usually team-based and occur in a workshop setting. By using an online survey (Boschetti et al., 2015) targeted individuals working in isolation and did not address any specific issue or concern, besides general attitudes towards the future. The survey was conducted in 2014 with 950 Australian participants recruited nationally using an on-line research only internet panel[2]. A copy of the questionnaire used in this survey is available at http://www.per.marine.csiro.au/staff/Fabio.Boschetti/Surveys/Myth_Future_Survey.pdf. It includes a range of different constructs and cognitive measures we had tested in previous works as well as measures specifically designed for this study:

1) twelve statements from the Cultural Environmental Bias measure of environmental worldview (Price et al., 2014). These define two beliefs according to which Nature can be perceived as 'ductile' to human pressure, requiring collective action to conserve the environment, or as 'elastic' to human pressure, justifying its exploitation;
2) thirteen statements from the short-form Cultural Cognition measure of societal worldview adapted to the Australian context (Kahan, 2012), which define participants' worldviews along the egalitarianism-hierarchy and individualism-communitarianism axes;
3) four items from the short-form Social Dominance Orientation (Pratto et al., 2013) and six items from the short-form Right-Wing Authoritarianism measure (Heaven and Bucci, 2001) to define political ideology.

[2] The panel used is administered by ORU, an online fieldwork company with QSOAP 'Gold Standard' and the new Global ISO 26362 standard accreditation. The ORU has a database of over 300,000 individuals from across Australia (http://www.theoru.com/). The online panel consisted of a group of community members who have explicitly agreed to take part in web-based surveys from time to time. In return they are offered a small non-cash incentive for completing such tasks, such as points towards shopping credits. The gender and age profile of the sample accords with the known population characteristics of Australians

4) Consideration of Future Consequences (Strathman et al., 1994) as described above.
5) Expectation about the future evolution of Australian society (Kashima et al., 2011), which asks whether respondents believe that by 2050 Australian society will be more or less safe, skilled, wealthy, honest and friendly. In addition, we also asked in what condition respondents believe science and technology, the environment, society, the economy and the political system will be by 2050.
6) Economic Trade-offs**.** To explicitly gauge the responders' preference for economic growth vs environmental conservation and social welfare.
7) Perceived Need for Change**.** Within a STEEP framework, we asked how much participants believe science and technology, the environment, society, the economy and the political system need to change and where these changes should occur.
8) 95 statements describing a range of potential outcomes in relation to the five STEEP domains, which can be thought of as 'litanies' within the Causal Layered Analysis (Inayatullah, 2004a)). The statements describe potential visible characteristics of alternative futures or growth projections, as well as a range of scenarios of different types of society, technology, environment and polity based on different economies.

The analysis of the 95 statements at point 8 led to the identification of a set of five 'Myths of the Future' (Social Crisis, Eco-Crisis, Techno-optimism, Power and Economic Inequality, and Social Transformation) which describe shared beliefs, concerns and aspirations about the future. The Social Crisis and the Eco-Crisis myths describe beliefs that traditional social order and environmental conditions, respectively, are likely to decline and lead to social unrest. The Techno-optimism myth describes beliefs that science and technology are likely to improve quality of life through innovation. The Power and Economic Inequality myth describes beliefs that big business and governments are likely to become more powerful and cause social inequality and economic crisis. Finally, the Social Transformation myth describes beliefs that society is likely to become more caring and collectively empowered. The relations between these five 'Myths of the Future' and responses to the other constructs at point 1-8 allowed us to define the cognitive signatures which characterise each myth, further helping to clarify their meaning (Boschetti et al., 2015).

There are some differences between the Myths of the Future and the scenario archetypes described above, which are discussed in (Boschetti et al., 2015), but also a considerable overlap. The fact that Myths of the Future and the scenario archetypes originate from a very different analysis makes this overlap particularly significant, highlights the universal meaning of the concepts they represent and suggests that meaningful analysis of attitudes towards the future can be carried out via questionnaire-based surveys.

5 Time horizons: elicitation, determinants and malleability

The literatures summarised so far focus more on the types of futures which may be ahead of us and our attitude towards them than on when such futures may occur. Elicitations of attitudes towards the future and of the subjective perceptions of when the future occurs are often done independently to avoid interference. Given that attitudes toward the close and far future differ markedly, a modeller addressing a project's stakeholders may need to know where these different futures are located in time.

The 'mental time travel' literature suggests that people think often about the future 1 day from now, somewhat less frequently 1 week to 1 year from now (Tonn et al., 2006), much less frequently between 1 and 5 years and rarely beyond 5 years (D'Argembeau et al., 2011; Stawarczyk et al., 2013). People seem to have difficulty in imagining beyond 15–20 years (Boschetti et al., 2014; Tonn et al., 2006). When explicitly asked what time horizons people think when they hear the word 'future', reports differ from 1-2 years (Spreng and Levine, 2006) to 10-15 years (Tonn et al., 2006). This time horizon is important because it can impact motivation, goal setting and cognitive processes. For example, the Socioemotional Selectivity Theory (Carstensen, 2006) shows that the perception of time as more or less finite changes the priority we place on goals related to acquisition of knowledge, planning and experiencing novelty vs cultivating emotionally meaningful relations. While this applies

naturally to differences in age, older and younger people can behave similarly when time horizons are equated (Carstensen, 2006). In other words, the future can 'shrink' or 'dilate' according to context.

Of particular interest to modellers is the extent to which the future horizon can change as a function of the very act of thinking about it. Here we analyse some novel results which describe how not only the time horizon, but also the content of future thoughts can change fairly quickly and dramatically.

In addition to the constructs listed above, the questionnaire at http://www.per.marine.csiro.au/staff/Fabio.Boschetti/Surveys/Myth_Future_Survey.pdf also asked '*When you think of the future, what time frame is it?*'. Responders could choose from 'Later this year', 'Next year', '5', '20', '50', 'More than 50 years from now' and 'Other'. The questionnaire came in two versions. In the first version the question was asked at the beginning of the questionnaire. In the second version it was asked after the 95 statements related to the 'Myths of the Future'. The component of the questionnaire in between the location of these two questions takes 15-20 minutes to complete. Except for the placement of these two questions, the two versions of the questionnaire were identical. Figure 2 shows the difference in responses, which are statistically significant ($p<<0.05$). Very few people chose 'Other' as an answer and to simplify the discussion we removed it from the analysis (its inclusion does not significantly change the outcome). Figure 2 shows how the mode of the responses moves from '5 years from now' (asked at the beginning of the questionnaire, and shown here in black) to '20 years from now' (asked in the middle of the questionnaire, and shown here in white). The mean response almost doubles from ~12 years to ~21 years. In the rest of the document, we refer to these two time horizons as 'unprompted' and 'prompted', respectively.

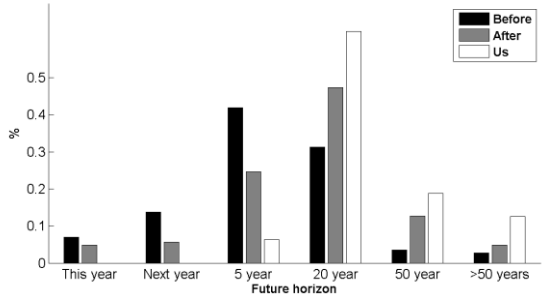

Figure 2. Answers to the question '*When you think of the future, what time frame is it?*'. Black=the questions is asked at the *beginning* of the questionnaire; White=the question is asked in the *middle* of the questionnaire.

Similarly, we asked '*What are the first five words that come to mind when you think about the future?*'. These words were then grouped into 120 categories. Figure 3 shows the occurrence of the 10 most frequent categories in the two versions of the survey. In

Figure 4. Answers to the question '*What are the first five words that come to mind when you think about the future?*'. (a) the question is asked at the *beginning* of the questionnaire; (b) the question is

asked in the *middle* of the questionnaire.
, we compare the relative frequencies of the 15 most frequent categories in the overall questionnaire.

Many of the observations described in the literature we reviewed above are reflected in Figure 3. Hedonistic and monetary concerns see their priority decreasing after the future horizon expands, while the opposite applies to the environment. Positive feelings increase with increasing time horizon. Family and relationships are the concern of the close future more than the far future while the opposite applies to science and technology.

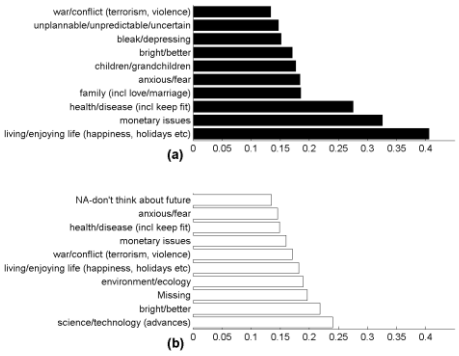

Figure 3. Answers to the question '*What are the first five words that come to mind when you think about the future?*'. (a) The question is asked at the *beginning* of the questionnaire; (b) the question is asked in the *middle* of the questionnaire.

We interpret this result by suggesting that the very act of being exposed to issues pertaining to the future and being asked to actively think about them, changes our perception of the future itself. This notion is also described in the Futures Studies literature (Dator, 1978). It is remarkable that focusing on future issues for only 15-20 minutes (recall that this is the approximate time a responder is exposed to future-relate questions in the second version of the questionnaire) could have such an impact on perceptions of time horizon and concerns about the future. The extent to which this impact is transient or long lasting is an important question which requires further empirical testing which could be achieved, for example, by following a cohort at different time interval after a survey is carried out.

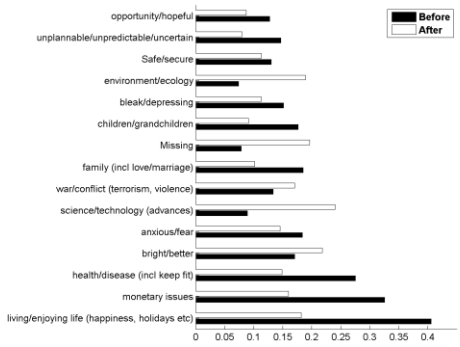

Figure 4. Answers to the question '*What are the first five words that come to mind when you think about the future?*'. (a) the question is asked at the *beginning* of the questionnaire; (b) the question is asked in the *middle* of the questionnaire.

We conclude this section by attempting to anchor the time axis in Figure 1 with some approximate dates. Figure 5 includes some of the time horizons discussed above. In order to relate these to

modelling applications, we also include i) the time horizons of Adaptive Management / Management Strategy Evaluation applications (Bunnefeld et al., 2011; Smith et al., 1999), ii) of projections of main climate change induced impacts (IPCC, 2014), iii) the year 2050, which is used as a horizon for several organisations' foresight exercises (see (Boschetti et al., 2014) and references within) and iv) the Club of Rome's Limits to Growth work (Meadows, 1972) and the First Shell Scenarios (Jefferson, 2012). The actual dates in Figure 5 should be taken merely as indicative. Nevertheless, a few observations appear particularly significant. First, the time horizon for most common future thoughts (<<1 year, usually even shorter) appears to be almost irrelevant to the time horizon of the decision making modelling is supposed to support. For most people, decision making related to time horizons in the range of Adaptive Management-MSE (~0 ÷ ~20 years), for example, occur a handful of times at most in one's lifetime (home-purchase, retirement fund investment, marriage, etc.), making this a fairly unusual exercise. Second, while the time locations of the Planning Domain and the Goals Domain in Figure 1 and Figure 5 are not precisely defined, they are likely to overlap to some extent with the 'unprompted' and 'prompted' horizons, respectively. Recall that the difference between the 'unprompted' and 'prompted' horizons appears to be due to the survey responders' active thinking about the future. This observation suggests that the very act of answering the questionnaire may move some stakeholders from the Planning to the Goals domain. This represents a potentially significant shift because it can affect the stakeholders' reception of model results as well as the perception of the relevance of a modelling exercise. Because of its potential significance, we believe this issue deserves further empirical analysis.

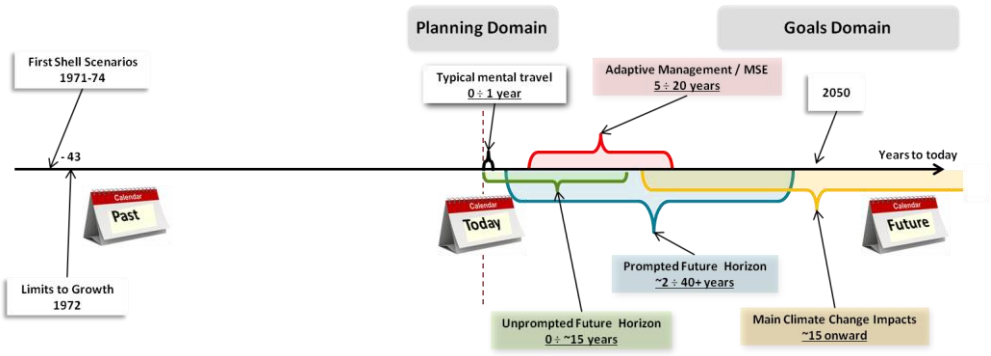

Figure 5. Indicative dates for the time horizons discussed in this work (Planning and Goal Domains, 'unprompted' and 'prompted' horizons, and typical time travels). To highlight their relevance to ecological modelling, we include the time horizons of modelling exercises pertaining to the future (Adaptive Management / Management Strategy Evaluation, climate change projections and the year 2050) as well as some pioneering modelling and scenarios exercises from the past (Club of Rome's Limits to Growth work and the First Shell Scenarios).

Focussing on the past (left hand side of Figure 5), we notice that the Club of Rome's Limits to Growth work and the First Shell Scenarios are farther in the past from today than 2050 is in the future. The observation that the business-as-usual scenario from the Limits to Growth model runs compares favourably with three decades of real data (Turner, 2008), gives some support to the beliefs that, at least under some specific conditions, modelling can say something meaningful about the far future. This provides some sort of evidence that the questions at the opening of the Introduction *('is it worthwhile to use computer modelling to explore the future 5, 10 or 20 years ahead of us? What about 50 or 100 years?'*) may, under appropriate conditions, have a positive answer. As a result, it also offers a different perspective to modelling exercises with time horizons comparable to Adaptive Management-MSE or climate change projections.

We conclude with a final observation. A lot has been written about the positive early receptions of the first Shell Scenarios (Schwartz et al., 2012) and the negative early reception of the Limits to Growth scenarios (Meadows and Meadows, 2007) and their likely political motivations. In the view of the literature we reviewed in this work, we may wonder whether the vastly different time horizons of the two works (a few years to ~15 years for the Shell scenarios vs more than a century for the Limits to

Growth) may also have played a part, by eliciting different attitudes from the Planning vs Goals Domains. This is another question with important implications for ecological modelling which may need further empirical analysis.

6 Summary

When ecological models are used to assess, say, the suitability of natural parks for conservation purposes, an ecosystem's resilience to human pressure, the sustainability of renewable resource extraction regimes or the long-term impact of different energy production systems, their results necessarily need to be projected 5, 10, 20, 100 years into the future. Empirical evidence shows that this time horizon is longer than the one most people consider for any planning purposes. For some people, this time horizon reaches the domain of abstract thoughts, abstract images, abstract goals, abstract aspirations and abstract fears, which relate to a sense of identity more than to the planning and decision making which the models are designed to facilitate. For other people, this time horizon may never be even considered.

Having to deal with time horizons which are rarely, if ever, considered, obviously means having to deal with uncertainty. Stakeholders may respond very differently to these situations depending on their own attitude towards uncertainty (Boschetti et al., 2012; Shuper et al., 2004). In general, people need some structure to rely upon in order to understand a problem and express an opinion about or an attitude towards it (Neuberg and Newsom, 1993; Thompson et al., 1989, 1992) and may behave very differently depending on whether such a structure is at hand or not (Kruglanski, 1989). When one such structure is at hand, people may adopt it more or less critically (Kruglanski et al., 1991; Kruglanski and Webster, 1996; Kruglanski et al., 1993; Kunda, 1990). For example, some stakeholders may call upon instinctive reactions (possibly at a high level in the Causal Layered Analysis framework) which, consciously or unconsciously, may hide deeper motivations. It is quite possible that a modeller's belief regarding the predictability power of her/his own model may have similar roots. In other cases, a problem may be perceived as so novel that stakeholders may struggle to find any structure at all. In these cases, some structure needs to be developed from scratch (Boschetti et al., 2012), which may explain the difficulty some participants find in the initial stages of foresight exercises (Boschetti et al., 2014). This explains why, while deeply held attitudes and worldviews (the content of the lower levels in the Causal Layered Analysis framework) are very stable during one's lifetime, in very uncertain situations the need to find a context to frame the modelling/management questions can make a stakeholder's attitude towards a *specific* problem very malleable.

A modeller may then have to face a complex situation in which the stakeholders' attitudes define the context of the modelling exercises and in turn, the very act of addressing the model's time horizon may change the stakeholders' attitudes and perception of the problem. While in principle this very process could be modelled (Kitto and Boschetti, 2013), this is very much the realm of the literature we have reviewed in this document. Following an approach we proposed in (Boschetti et al., 2012) to assess the cognitive styles of stakeholders in environmental projects, the questionnaire described in Section 4 could be used to explore attitudes towards the future and the predominance of the different Myths of the Future within the stakeholder group. Besides monitoring the attitudes of the stakeholders' of a specific project, using the questionnaire may have two further purposes. First, it may introduce stakeholders to thinking about future issues, thereby possibly anchoring their perceptions of the future itself. While these issues could also be introduced via standard seminar-style presentations, answering the questionnaire is likely to involve a much more active participation, by forcing the stakeholders to express opinions and answer specific questions. Second, the questionnaire could expose the stakeholders to some of the issues pertaining to attitudes towards the future which could then be discussed in a workshop session. The questionnaire is available at http://www.per.marine.csiro.au/staff/Fabio.Boschetti/Surveys/Myth_Future_Survey.pdf.

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