Loosely Annotated Bibliography:
recommended by Applied Environmental Decision Analysis researchers (June-July 2011) and CSIRO researchers (July-August 2011)

The potential use of environmental information to manage squid stocks
(Agnew, Beddington et al. 2002)

The importance of environmental factors in the design of management procedures
(Basson 1999)

Effects of climate-driven primary production change on marine food webs: implications for fisheries and conservation
(Brown, Fulton et al. 2010)

With climate change, increases in primary production are modeled to increase biomass, and consequently, fish catch.
- Used climate forced food web models (EcoPath, EcoSim, and IPCC GCMs) and foraging arena theory
- Conducted sensitivity analyses
- Noted the effects of model complexity

How long can fisheries management delay action in response to climate change?
(Brown, Fulton et al. Submitted)

Simulation models of harvested populations in the presence of climate change suggest that 5-7 year delays in management action could collapse sustainably managed fisheries.
- Simulation modeling includes Schaefer model (harvested population), standard monitoring of a population, and management delay (the > delay, the more change is necessary) → this is a dynamic system that requires management robust to ecological and climate change
- Fisheries management is now based on equilibrium assumptions (which are not likely in climate change conditions)
- Age-structured models are even more likely to collapse.

Risks and decisions for conservation and environmental management
(Burgman and Possingham 2000)

Population Viability Analysis (PVA) is a useful tool for conservation planning and population management on spatial and temporal scales. Decisions under uncertainty depend on the attitude of the decision maker/perception of the risks
- “There is never insufficient data to create a useful model.” → any model can help determine which parameters are important and guide future data collection
  - The only “correct” model is a representative of the whole system (in which case, it’s no longer a model!)
- “Biological models are no different from any other scientific tool.”
- Decision making is a “spatially complex landscape that itself changes randomly through time.”
- Models should be decision SUPPORT rather than decision MAKERS → “disquiet, if not distrust, develops when the models take over the decision-making process”
- With decision theory, social costs are important

Population viability analysis for conservation: the good, the bad and the undescribed
Using non-probabilistic decision theory, Information Gap Theory optimizes robustness to failure with deviations in error. It employs an uncertainty model, a robustness/opportuneness model, and a decision-making model.

North Sea cod and climate change - modelling the effects of temperature on population dynamics
(Clark, Fox et al. 2003)
By coupling the output of large-scale climate models with fisheries population simulations, projections suggest an increased rate of decline in North Sea cod populations compared with simulations that do not consider environmental change.

- Adaptation of a standard stock recruitment function with temperature as an added parameter
- A bootstrapped residual approach was used to produce confidence intervals for recruitment and spawning stock biomass over the projected years
- As simulations that are currently used for providing management advice do not take account of environmental change, they do not provide an accurate projection of populations and conditions.

Impacts of spatial uncertainty on performance of age structure-based harvest strategies for blue eye trevalla (Hyperoglyphe antarctica)
(Fay, Punt et al. 2011)
“Spatial variability, either in the population dynamics, fishery operations, or in data collection, has the potential to impact harvest control rule (HCR) performance as this can drive variability in indicators used for stock assessment. A management strategy evaluation (MSE) approach was used to evaluate the performance of HCRs for blue eye trevalla.”

- “A successful HCR should provide an appropriate response to deviations from management targets, be robust to key uncertainties, and emphasize precautionary action given uncertainty”
- Performance of HCRs can be evaluated with a simulation modeling framework which incorporates feedbacks between the rules and the population dynamics
- Operating model used = age-structured population dynamics model parameterized to include spatial regions and multiple fleets
- Provides operating model specifications

Effect of complexity on marine ecosystem models
(Fulton, Smith et al. 2003)
There is a “humped” relationship between model detail and performance of models. “Comparative and confirmatory use of ‘minimum-realistic’ models is strongly recommended.”

- Multispecies and ecosystem models improve our understanding of system dynamics
- Complexity can lead to inherent uncertainty in predictions
- Model complexity in ecology = appropriate degrees of trophic aggregation
- Ecosystem model components: trophic complexity, nutrients, spatial resolution
- Empirical (describe observed patterns without capturing real-dynamics) vs. dynamic
- Model assumptions have their greatest impact with ‘forced’ conditions
  - “Performance under changing conditions is an important measure of how robust model behavior is to the level of complexity employed in a particular aspect of model structure or scope”
- Computational demands to parameterize and validate ecosystem models is a major drawback. The challenge is to define the optimal scope that minimizes complexity but facilitates valid and robust predictions.
- Highly aggregated models can perform better than more complex realistic ones because parametric sensitivity of more detailed models can propagate errors.

**Effective conservation planning requires learning and adaptation**
(Grantham, Bode et al. 2010)

*By definition, adaptive management involves learning which is a process, not a single event.* “Passive” adaptive management involves incorporating the performance of previous management actions into decisions about future conservation planning. “Active” adaptive management involves directed, experimental application of different conservation approaches.

- Adaptive conservation planning acknowledges uncertainties and addresses them through learning.
- Recognizing opportunities can help achieve learning objectives in a dynamic context.

**Effects of fishing and acidification-related benthic mortality on the southeast Australian marine ecosystem**
(Griffith, Fulton et al. 2011)

*Using increased benthic-invertebrate mortality as a proxy for the effects of ocean acidification, the impacts of climate change and overexploitation act synergistically – increasing the sensitivity of ecosystems to change from long-term fisheries exploitation.*

- Of considerable concern is the impact of ocean acidification on ecosystems subject to fisheries exploitation. Fisheries alter an ecosystem’s ability to respond to climate change.
- Complexity of interactions between an exploited ecosystem and the effects of climate change are challenging to separate. Need to investigate the possibility of additive, synergistic, or antagonistic interactions of fishing and acidification.
- Atlantis: simulates oceanography, ecology, fishing fleet dynamics, economics, and management decisions: coarse 3-D scale; the response across an ecosystem was summarized as changes in biodiversity.
- Fishing had a positive impact on biodiversity evenness and richness.

**The promises and pitfalls of including decadal-scale climate forcing of recruitment in groundfish stock assessment**
(Haltuch and Punt 2011)

**Habitat overlap of southern bluefin tuna and yellowfin tuna in the east coast longline fishery - implications for present and future spatial management**
(Hartog, Hobday et al. 2011)

_A habitat prediction model was constructed by combining data from an ocean model and pop-up satellite archival tags used to define habitat zones based on the probability of southern bluefin tuna occurrence._ The results suggest an optimal way to manager for yellowfin tuna fishing by minimizing habitat overlap with bluefin by restricting fisher access based on the seasonal distribution of bluefin.

**Derived environmental products for fisheries oceanography: improvement in predictive models**
(Hobday 2011)
Seasonal forecasting of tuna habitat for dynamic spatial management  
(Hobday, Hartog et al. 2011)  
*Southern bluefin tuna (SBT) distribution was seasonally forecasted using a coupled ocean-atmosphere model and a habitat model.* For this fishery, seasonal forecasts provide dynamic spatial management that allows for the protection of SBT and optimized utilization of yellowfin tuna. This is one of the only examples of dynamic spatial fisheries management in action.

Dynamic spatial zoning to manage southern bluefin tuna capture in a multi-species longline fishery  
(Hobday, Hartog et al. 2010)  
*Managers and fishers have embraced the use of dynamic spatial zoning using seasonal forecasts of southern bluefin tuna distributions.* Over the 6 years of the program, managers request more habitat predictions and change management based on the reports more often. This is a successful implementation of a decision support tool using dynamic spatial zoning.

Ensemble analysis of the future distribution of large pelagic fishes in Australia  
(Hobday 2010)  
*To investigate uncertainty surrounding fish projections from global climate models, an ensemble analysis was conducted to examine potential changes in large pelagics with multiple climate models.*

- “Testing the ability of the climate models to predict present species distribution is an important validation step prior to making future predictions.”
- “Despite the number of simulations performed and the spread of the results, the outcome was overwhelmingly similar...at a coarse scale.”
- Robust projections are important for stakeholders
- **When climate impacts involve changes in distribution, impacts can be both positive and negative for future exploitation – an increase in suitable habitat is potential for an increase in population**

Near real-time spatial management based on habitat predictions for a longline bycatch species  
(Hobday and Hartmann 2006)  
*To minimize bycatch of souther bluefin tuna (SBT), near real-time predictions of location are generated with a habitat suitability model.* The habitat model included: (i) predictions based on the current vertical structure of the ocean; (ii) seasonally adjusted temperature preference data for the 60 calendar days centred on the prediction date; and (iii) development of a temperature-based SBT habitat climatology that allowed visualisation of the expected change in the distribution of the SBT habitat zones throughout the season.

A framework for modelling fish and shellfish responses to future climate change  
(Hollowed, Bond et al. 2009)  
*To forecast the implications of climate change on the production of marine fish: 1) identify mechanisms of reproductive success, growth and distribution of the population; 2) downscale climate models; 3) extract environmental variables from the climate scenarios and incorporate them into projection models for the population; 4) evaluate the mean, variance, and trend in fish production under a changing ecosystem.*

- Modeling approaches: statistical downscaling*, dynamic downscaling on regional scales, dynamic downscaling on regional scales, dynamic global models
  - Simplified interactions may miss non-linear responses or feedbacks within the system
• Use simulations to evaluate the performance of different management strategies under different conditions
  o To separate out a meaningful signal from a simulation, apply quasi-Bayesian methods to constructing weighted ensemble mean projections of regional environmental conditions (designed to limit the use of unrealistic and improbably climate trajectories)
• Methods for incorporating environmental forcings into population dynamics equations:
  o Project recruitment by modifying average recruitment by an environmental variable
  o Modify the spawner-recruitment relationship with incorporated environmental variables and random variability
  o Utilize spawner-recruitment functions that incorporate processes at multiple life stages

Forecasting Climate Impacts on Future Production of Commercially Exploited Fish and Shellfish
(Hollowed, Beamish et al. 2008)
With the goal to develop a coordinated international effort to provide quantitative estimates of the impacts of climate change on major fish populations, the outcomes of the workshop collaboration will be quantitative estimates of the impacts of climate change and produce a coordinated interdisciplinary and multinational effort to forecast and respond to climate change.

Modeling approaches:
• Coupled bio-physical models
• Stock assessment projection models
• Comparative approaches

Biocomplexity and fisheries sustainability
(Hilborn, Quinn et al. 2003)
Biocomplexity, the diversity of stock life-history characteristics and adaptation to local variations in spawning and nursery habitat, for example, allow populations to sustain productivity in spite large fluctuations in environmental conditions. Maintaining biocomplexity may help fisheries adjust to environmental change, such as climate change, and maintain sustainable harvests.
• “The stability and sustainability of Bristol Bay sockeye salmon have been greatly influenced by different populations performing well at different times during the last century”

The dangers of ignoring stock complexity in fishery management: the case of the North Sea cod
(Hutchinson 2008)
Applying the same management strategy to multiple stocks with different population parameters can result in overfishing if the management measures are not set for the least resilient stock.

• “The recent move from single-species management to ecosystem-based fisheries management reflects the recognition that a more holistic multi-species approach is required to ensure that fisheries are exploited sustainably, while conserving biodiversity and maintaining the status of the ecosystem”

Between-country collaboration and consideration of costs increase conservation planning efficiency in the Mediterranean Basin
(Kark, Levin et al. 2009)
Between-country collaboration will maximize conservation returns on minimal budgets. There is spatial variability in biodiversity threats and cost of conservation action. It costs significantly more money if each country acts independently than if there is a Mediterranean Basin coordinated plan (US$67 billion/45% of total cost). Regional collaboration is particularly important where a single biome is split into multiple geopolitical units.

• Efficient conservation planning requires integrating: biodiversity, its threats, cost of conservation action
• It should be noted that there are additional expenses related to large-scale planning and communications across multiple cultures, languages, etc.

Environmental variability and fisheries: what can models do?
(Keyl and Wolff 2008)
Review of 58 climate-fisheries models that describes the impacts of fishery pressure and environmental variability on populations and ecosystems and includes basic principles of population dynamics. The review demonstrates that “the performance of fished stocks can better be described if environmental or climatic variability is incorporated into the fisheries models.

• Poor yield predictions and unexplainable natural stock fluctuations is often attributed to “environmental noise” – fishery pressure isn’t the sole extrinsic factor important for population dynamics
• Example models that integrate environmental variability
  o Stock-Recruit Analysis (include non-linear function describing extrinsic influences of the environment and fishery impacts; nonparametric smoothing and bootstrapping to estimate parameter uncertainty)
  o Surplus production models (compare several models with and without fishing pressure and climate effects via the model’s parameters of the population’s intrinsic growth rate)
  o Structured models (compare observed data with predicted catch in a deterministic model → model residuals assumed to be due to environmental variability)
  o Trophic multispecies models (when single species models are not suitable for the detection and interpretation of the lag response of different system compartments to environmental variability)
  o Individual based models (spatially explicit with integrated life history)
General additive models (do not explicitly describe intrinsic functional factors regulating the fluctuation of populations – empirical relationships between data series; no need to specify the relationship beforehand – exploratory tools)

- Issues to deal with include: non-linearity; multi-dimensionality; direct and indirect impacts; temporal lags; spatial considerations

Preliminary forecasts of Pacific bigeye tuna population trends under the A2 IPCC scenario
(Lehodey, Senina et al. 2010)

Spatial ecosystem and population dynamics model SEAPODYM was used to forecast future populations of Pacific bigeye tuna. The simulations were driven by a global marine biogeochemistry-climate simulation and suggest an improvement to bigeye spawning habitat and adult feeding in the eastern tropical Pacific (but not in the western central Pacific).
- Parameter estimation was conducted using historical fishing data; uncertainties were provided by the diagonal elements of the error-covariance matrix calculated as the inverse of the Hessian

Development and evaluation of a cpue-based harvest control rule for the southern and eastern scalefish and shark fishery of Australia
(Little, Wayte et al. 2011)

A general framework for integrating environmental time series into stock assessment models: model description, simulation testing, and example
(Maunder and Watters 2003)

When do environment-recruitment correlations work?
(Myers 1998)

Fisheries - Climate variability and North Sea cod
(O’Brien, Fox et al. 2000)

Stressed by overfishing, declines in you cod production have also paralleled North Sea warming. There is evidence of environmentally driven variability in recruitment.
- Increasing temperatures are favorable for stocks at the highest latitudes but detrimental to though at the southern limit of the species
- Because of the potentially lethal combination of exploitation and climate change, managers should take precautionary to allow the mature cod stock to rebuilt

Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia
Part 1: Fisheries and Aquaculture Risk Assessment
(Peel, Ward et al. 2011)

Selecting global climate models for regional climate change studies
(Pierce, Barnett et al. 2009)

In choosing global climate models for regional climate change assessments, ensembles are important to have runs with enough realizations to reduce the effects of natural internal climate variability. A multimodel ensemble average is useful for offsetting errors in individual global models

Spatial population dynamics of a marine organism with a complex life-cycle
(Possingham and Roughgarden 1990)
Spatial population dynamics models develop a realistic framework to study the interactions of oceanic and biological factors on the distribution and abundance of space-limited species. The model population dynamics in both space and time.

Zoning design for cross-border marine protected areas: The Red Sea Marine Peace Park case study

(Portman 2007)
Spatial multi-criteria analysis (MCA) combines environmental data (land and ocean) with stakeholder preferences to identify areas suitable for various types of protective zoning. MCAs can address some inherent challenges in zoning cross-border, multi-jurisdictional MPAs where there are varying levels of information shared between countries and limited amounts of cooperation between involved managers, scientists, and stakeholders. Physical criteria and stakeholders are the most significant drivers in the case study.

Waterfront land use change and marine resource conditions: The case of New Bedford and Fairhaven, Massachusetts

(Portman, Jin et al. 2009)
There is a significant relationship between coastal land use and fisheries stock conditions. “Do observed land use changes reflect changes in the fisheries industry?” Using the case study of New England marine fishing communities, with drastic changes in stock conditions came major changes in waterfront land use.

The impact of climate change on the performance of rebuilding strategies for overfished groundfish species of the U.S. west coast

(Punt 2011)

Robust decision-making under severe uncertainty for conservation management

(Regan, Ben-Haim et al. 2005)
Conservation management decisions made; conservation management decisions made without regard for uncertainty can result in poor decisions.

• Information-gap theory assists with decision making with severe knowledge gaps and when probabilistic models of uncertainty are unreliable; Info-gap methodology requires:
  o Mathematical model
  o Performance requirement
  o Model for uncertainty
• The “best strategy” is one that produces a “good enough” outcome with no possibility of an unacceptable outcome
• Decision making involves trade-offs; the goal is to maximize the reliability of an acceptable outcome

Pushing the limits in marine species distribution modelling: lessons from the land present challenges and opportunities

(Robinson, Hobday et al. In Press)
Species distribution models (SDMs) have had limited application in marine ecosystems; to use them dispersal, species interactions (e.g., competition and feeding), aggregation, and ontogenetic shifts should be considered. They can be applied in place of correlative, coupled correlative, or process-based models depending on the context. SDMs may prove to be quite useful for climate change adaptation because they can have spatial and temporal resolution.
Population diversity and the portfolio effect in an exploited species
(Schindler, Hilborn et al. 2010)

The portfolio effect suggests that species-rich ecosystems are temporally more stable because of variance dampening through diversification. Likewise, population diversity temporally stabilizes fisheries catches.

- “growing recognition that population diversity within exploited species can contribute to their long-term sustainability and should be incorporated more explicitly into management and conservation schemes”
- “The degree of temporal covariation among portfolio assets controls the strength of portfolio effects”

Scientific tools to support the practical implementation of ecosystem-based fisheries management
(Smith, Fulton et al. 2007)

Detection and attribution of climate change: a regional perspective
(Stott, Gillett et al. 2010)

“Detection is the process of demonstrating that climate has changed in some defined statistical sense (e.g., 5% chance that trend is due to internal variability alone); Attribution is the process of establishing the most likely causes for a detected change with some level of confidence (e.g., compare observed changes in model simulations with and without the potential forcing).”

- Attribution studies can be complicated by non-climate quantities that could be the result of additional influences

Literature Cited:
Brown, C. J., E. A. Fulton, et al. (Submitted). "How long can fisheries management delay action in response to climate change?".


