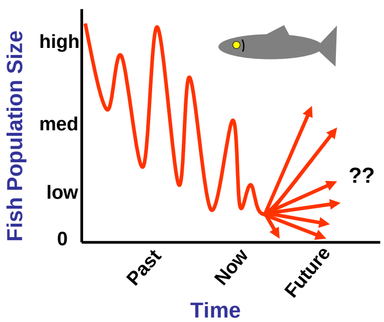
Understanding Risks and Uncertainties in Fisheries

Dave Mac Neill, Fisheries Specialist, New York Sea Grant

New York Sea Grant
62B Mackin Hall
SUNY Oswego
Oswego, NY 13126-3599
Phone: 315.312.3042
Fax: 315.312.2954
E-mail: SGOswego@cornell.edu
Web: www.nyseagrant.org



Understanding fisheries and their management

Fish populations or groups of individuals of the same species living in the same area, are closely linked to complex physical, biological, economic and social factors which are not directly observable. Hence, these populations are difficult to study and measure. Many fish populations worldwide are subject to harvest for economic benefit. Those fish in the populations that are targeted for fishing are called **fisheries**. **Fisheries management** is concerned with how the resource grows and survives, so that fisheries managers can decide how much of the fishery to harvest.

Because not all fish in a single population are equal, fisheries biologists continuously strive to collect important information in a scientifically-based way (**data**) that is unfamiliar to many stakeholders. These data are obtained from samples of fish populations collected over a large geographic area and over time so that data are a representation of what is going on in the fish population and fishery of interest.

Fisheries data are analyzed using sophisticated techniques to provide estimates of important characteristics of the fish population such as abundance (including numbers of fish at each age) growth, diet, habitat ("where they are and when they're there"), reproductive output, survival, impacts from fishing and interactions with other species (fish and non-fish). The *great difficulty* is trying to separate the effects of Mother Nature and fishing and understand how nature and harvesting interact.

These data are sometimes used to develop the **management decisions** that are designed to simultaneously protect fisheries, (accomplished mainly through limits on numbers or sizes caught and kept) and to meet diverse stakeholders' interests. These complex decisions have important biological, economic, and social consequences, often over a very short timeframe. In reality, successful fisheries management depends upon the ability to anticipate/ prepare for future changes in fisheries, identify **risks** and **uncertainties**, identify new management opportunities, as well as to properly monitor progress in reaching fisheries goals.

New York Sea Grant Extension Program provides Equal Program and Equal Employment Opportunities in association with Cornell Cooperative Extension, U.S. Department of Commerce, and cooperating Extension Associations.

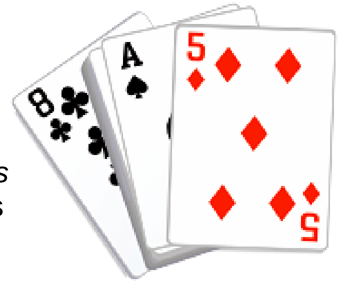
Risks, Uncertainties, Models and a Deck of Cards

Making decisions about how best to manage fisheries, like all human activities involves an element of risk in that there can be negative and unintended consequences from decisions. **Risks** are the odds based on our past experiences that some event could happen, even though we can't predict exactly what event will happen next. Risks come from limited human control of certain situations (weather, climate, and economics) and a lack of information needed to understand the situation in which decisions are made.

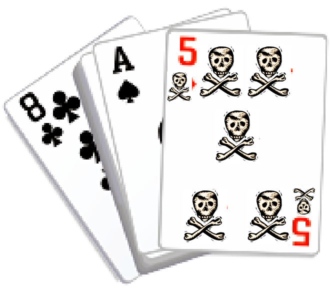
There are risks in establishing fishing/harvest regulations and fish stocking rates to provide economically viable fisheries and to prevent fish population collapses. These particular risks are especially troublesome because, should they occur, their fisheries effects are often either irreversible or extremely difficult to remedy. Within the last 20 years, there has been a shift in decision-making to consider ways to minimize risk, to account for risks and benefits (biological and economic) in developing decisions and to communicate risks to all concerned. All in all, it is a huge balancing act.

Uncertainty is a term used to describe those situations in which the risks are unknown. These are the sudden, unexpected events that can appear and really catch us off-guard with occasionally catastrophic results (i.e. 9/11, a storm-of-the-century, tsunamis, economic recessions, a new flu pandemic, the appearance of zebra mussels, and so on). In these cases, we not only don't know what will happen next, but we have absolutely no information on the risks or odds of it occurring in the first place.

Experienced card players know that there are certain probabilities or chances of drawing particular cards or combinations of cards from a deck based on many past repeated trials or "experiments." For example, the chance occurrence (**probability**) of obtaining an ace of spades from a single drawing of cards is 2% or we would predict that it would occur 2 times out of every hundred repeated drawings, if the card was replaced and the deck reshuffled before each draw. Similarly, we can also predict that the probability of drawing a "*dead mans hand*", 2 black aces, 2 black eights and a 5 of diamonds (an unlucky hand for Wild Bill Hickok, who was holding this hand as he was killed by an assassin's bullet) is about .0609%. If all people holding this hand were this unlucky, we could say that the *risk* of this happening is the same as its probability. So again, we can use our knowledge or data collected from the past to predict future events.



If we apply this simple concept to the natural world, the card deck would represent our concept or **model** of what we know about the natural world. Now, consider what happens if we draw a card with a skull and crossbones? It tells us that the probability (or risk) of drawing any particular card or hand is now unknown. These new cards grossly increase the **uncertainty.** This suggests that our model of the natural world (here, the card deck)



Famous Quotes on Risks & Uncertainties

"The future just ain't what it used to be."

– **Yogi Berra,** Major League Baseball great

"Prediction is very difficult – especially if it is about the future."

– **Niels Bohr,** Nobel Prize recipient in theoretical Physics, 1913

"They couldn't hit an elephant at this distance…"

– **Union General John B. Sedgwick**, his last words uttered just before being hit by a Confederate sniper's bullet, Battle of Spotsylvania, 1864 is flawed, or incomplete, or is somehow changing. It also tells us that some unpredictable results can occur beyond our control or outside our range of predictability.

Where do fisheries uncertainties come from?

Uncertainties originate from biological, economic and political factors that influence fisheries and interfere with the ability to develop effective management plans. Managing fisheries under uncertainty has become a top priority for fisheries biologists around the world. Such uncertainties in fisheries, as in all natural resources, stem primarily from these inescapable facts:

1. Nature is seldom very stable and things can change quickly from one time to the next. Nature always casts the deciding vote.

2. Humans will make mistakes when observing, measuring, or interpreting nature --no matter how careful.

3. The human concepts (or models) used to describe fisheries are like jig-saw puzzles. Although models can be accurate, they can often be too complex, or, too simple, incomplete or simply wrong, because there is limited understanding of how many pieces there are, and where/how they fit together.

5. Some parts of the natural world are better understood than others. Effective management decisions can be made, but sometimes putting the full plan into action falls short because of circumstances beyond control of fisheries managers.

6. Science is *not* a magic box in which data are added on one end and the *right* answer or decision comes out on the other end. Science *is* an objective process by which information is collected and evaluated so that judgments can be made. How to balance between providing fish to harvest while also conserving the resource, however, is not entirely a science based question.

These uncertainties are normal, everyday things common to *all* natural resources. They cannot be avoided. They are extremely difficult, if not impossible to deal with. Because there are so many uncertainties nowadays, there can be a range of possible management strategies developed to address a single issue. The difficulty lies in trying to predict which management strategy will best solve the problem *before* it is put into place.

What are some common fisheries uncertainties?

Uncertainties are challenges to managers trying to balance **sustainable** fisheries (maintaining fishing opportunities for diverse stakeholders for as long as possible) with conserving fish populations. Uncertainties affect the ability to understand complex mechanisms that drive fish population sizes up and down. Among global fisheries, there are many uncertainties that prompt all of us to ask some common questions (listed in the side panel).

Fisheries Uncertainties: Some Common Questions

- How many fish are there in the lakes and oceans to catch?
- For how long will these fisheries be sustainable?
- How does fishing effect these fish populations?
- How many fish should be stocked?
- How many survive after stocking? How many fish are produced naturally?
- How many bait fish are out there to feed the predatory fish?
- What are the best ways to collect fish to get good information to manage fisheries properly?
- How do ecosystem changes in the ocean, lakes and rivers affect their respective fisheries?
- What are the impacts of invasive species on our fisheries?
- How will budget issues or changes in political leadership affect fisheries management?
- How much control do fisheries managers really have in managing fisheries?

Uncertainties pose major communication problems for stakeholders and managers

The inability to fully answer these common questions leads to communication gaps that are the most direct cause of polarity between stakeholders and fisheries managers. There are also communication gaps among fisheries stakeholders from perceptions of competing demands: recreational versus commercial fisheries, tributary versus lake anglers, native fish community supporters versus put-grow and take fisheries, environmental activism versus recreational and commercial fishing etc. These communication gaps often carry over for a long time. Fisheries stakeholders, unaware that fisheries are beyond total management capabilities of fisheries managers, often grow frustrated, perceiving that fisheries managers are not doing enough to provide sustainable fishing opportunities for businesses.

Fisheries managers also grow frustrated with their inabilities: 1) to better understand the underlying forces driving fish populations from the complexity of nature, 2) to get enough information, 3) to reduce time delays between collecting information and making a decision and 4) to overcome budget/manpower limitations in getting the data needed to do a better job. Realistically fisheries managers can only regulate such things as angling or harvest regulations (sizes, catch/harvest limits, season duration etc.), stocking levels, nutrient loading, and management of natural fisheries predators (e.g. seals, sea lamprey and fish-eating birds such as cormorants)---not to mention that any proposed change in fisheries management policies often involves state, federal or international dialogue. Managers also wrestle with conflicting stakeholder demands for economically and ecologically sustainable fisheries. As a result, management objectives are often developed with little consideration of risk -- again, not the result of inattention to detail but from operational limitations and unfamiliarity with newer “uncertainty tools” that are extremely difficult to use.

Famous Quotes on Risks & Uncertainties

“If you don't know for sure what will happen, but you know the odds, that is risk. If you don't even know the odds, that is uncertainty”

– **Frank Knight,** Economist, University of Chicago, 1921

“A severe depression like that of 1920-1921 is outside the range of probability.”

– **The Harvard Economic Society,** 16 November 1929

“*No matter what happens, the U.S.Navy is not going to be caught napping.”*

– **Frank Knox**, Secretary of the Navy, 4 December 1941

Should uncertainties be ignored or addressed?

Biologists have two choices; they can either ignore uncertainty or develop better tools for understanding it and including it in the decision-making process. Problems of ignoring uncertainty have led to fisheries collapses and have been widely reported:

- In some cases, the effects of overfishing, overstocking, or prey fish declines are not easily observed, are sometimes underestimated, and may only be detected after it is too late to take protective action. This suggests that some fisheries problems are inevitable.
- These overfishing effects can increase the vulnerability of a fish population to other environmental effects i.e. winter kills.
- Even if harvest and stocking rates can be changed to try and head off disaster, they are hard to enact due to resistance by the fishing industry.
- Recovery of damaged fisheries can be slowed or prevented as less desirable fish either compete with or prey on economically important species.

- There is often little opportunity to improve information gathering, understanding and decision-making because of budget/manpower limitations.

- Because estimates of biological and economic risk are difficult to obtain, there is often little consideration of risk in communicating with stakeholders and in making decisions.

- There are often no fish recovery plans in place when a fishery collapses.

Because uncertainties exist in all natural resources, it appears that the best approach is to try to better understand them so that more effective management decisions can be made. *One must also recognize, however, that it will be impossible to have the complete picture of what is really going on in fisheries no matter how much effort is put into understanding risk and uncertaintiy.*

How can fisheries uncertainties be addressed?

There are three general strategies for sustainable fisheries management that address uncertainty – robust, adaptive or precautionary.

1. Robust management. In robust management, biologists develop a management strategy or plan that relatively insensitive to uncertainty. In this case, there will be some level of success in achieving a desired objective. Even if there is not enough information on the fisheries, the outcome will not be disastrous if the plan fails.

Two decisions from Lake Ontario are good examples of robust management: the 1968 decision to stock salmon and trout (**salmonines**) and the 1972 decision to begin sea lamprey control. The first decision was made to control alewife and provide a recreational fishery under the assumption that salmonines would eat excess alewife, which were then considered a nuisance because of their die-offs and negative interactions with native species.

The uncertainties of this decision centered on whether salmonines could be raised successfully, their unknown survival in the lake, and whether they would grow and eat enough alewife. The risks to the lake if the stocking program failed were few, other than that alewife would still dominate in the lake.

In the second example of robust management in Lake Ontario, the sea lamprey control program was developed to protect lake trout and other native species. The uncertainty of this decision was whether the treatments would be effective enough to control lamprey. There was little overall risk to the lake if this failed, other than that lamprey predation would continue.

Famous Quotes on Risks & Uncertainties

"There is no reason for any individual to have a computer in their home."

– **Ken Olsen**, President, Digital Equipment Corporation, 1977

"As we know, there are known knowns. There are things we know we know. We also know there are known unknowns. That is to say we know there are some things we do not know. But there are also unknown unknowns, the ones we don't know we don't know."

– **Donald Rumsfeldt**, 12 February, 2002, Department of Defense news briefing

The Precautionary Approach:

Precautionary management tools rely upon complex mathematical methods that are familiar to only a few experts operating outside resource management. Although this approach attempts to be more realistic, it involves tremendous effort on the part of fish managers to collect additional biological data on fish populations of interest. The models are extremely mathematically complex and are difficult to understand and use. Moreover, making management decisions based on precautionary management *will never completely address* all risks and uncertainties in our fisheries.

2. Adaptive management. Ideally, fisheries management strategies need to be periodically evaluated and tweaked to take advantage of what has been gleaned from information collected, after the management action began. Adaptive management stresses more flexibility in that new fisheries data are collected regularly, and there is continual learning about the fisheries by monitoring and evaluating effects of management decisions. Managers are more adaptive, and can make adjustments to certain biological changes in the fisheries to better the fisheries.

Lake Ontario also provides us with an example of adaptive management. Salmonines are studied to examine their diets, stream returns, harvests, growth, and lamprey scarring rates. If lamprey abundance increases (as evidenced by increases in scarring rates, numbers of lampreys on fish, and numbers of juvenile lampreys in streams), fisheries managers could respond by increasing the level of sea lamprey control (treating more streams with lampricide or by treating streams more frequently). The uncertainties are whether the increased lamprey control program will be effective enough to reduce predation and the unknown economic cost benefits of the increased level of treatment.

If this effort fails and lamprey predation remains high, managers can further adjust the level of treatment until it becomes more effective and reaches an acceptable level. In a sense, adaptive management actions are living experiments from which more information is learned about the fishery. There is some level of risk with adaptive management, but the decisions are less likely to result in fisheries catastrophes should the wrong management action be implemented.

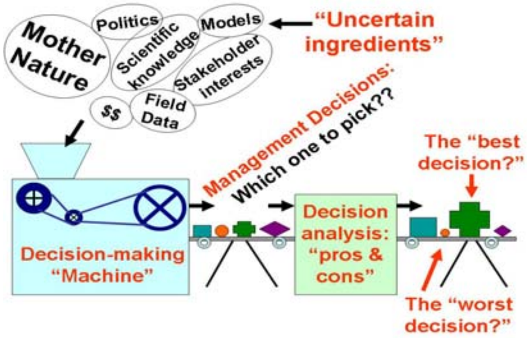
3. Precautionary management. New and very sophisticated techniques have been developed to address uncertainties by simulating, predicting or **modeling** the effects of proposed management decisions in a computer-simulated-world, so that the "best" (hopefully, anyway) decision can be chosen from among several alternatives before applying it to the "real world." Most experts agree such that precautionary management strategies are the most difficult to develop, but are the most powerful means of incorporating risk and uncertainty into making fisheries management decisions, particularly when uncertainties and risks are considerable.

As the term implies, precautionary management involves more caution on the part of fisheries managers because risks are considered in the decision-making process. Although some important advancements have been made in Australia and New Zealand marine fisheries, precautionary fisheries management is still largely under development in North America.

One example of a precautionary management tool is the Lake Michigan Chinook model being developed by Dr. Jim Bence, a researcher at Michigan State University. This model simulates the effects of different Chinook salmon stocking levels on alewife population size. A similar effort is in progress to simulate the effects of stocking levels on the Lake Ontario alewife population that will provide probabilities of alewife population "crashes" at different stocking levels.

Making the Tough Decisions

Fisheries biologists, using a precautionary management approach, apply a ***risk assessment*** process to estimate the probabilities of success and failure of several different (often competing) management plans and select the plan or plans that provide the greatest benefit while minimizing risks to the fishery. Through another process called ***decision analysis,*** the least risky management decision can be chosen among several different alternative decisions (based again on computer world fisheries before applying to the real-world). The "**best" decisions** are considered to be those that consider the needs of all stakeholders, fisheries managers, maximize economic benefits, minimize risks and allow for protection of the fishery.



Fish and their Environment

Other tools have been developed that help biologists develop a more realistic understanding of fish populations. Relationships between fish populations and environmental factors such as food web structure, water chemistry, water temperature, water currents, habitat etc. can be simulated using "**biophysical models**." In addition because models of physical systems (weather, climate) are steadily improving, once relationships between the physical features of a fish's environment and its biology are better known, these relationships can be better forecasted. This will be very useful in predicting future changes in fish recruitment, growth rates and survival to establish more powerful and effective management strategies.

Traditionally, biologists use **single species models** to simulate population trends of a particular species and to describe the effects of fishing on the fish population. Since each fish species occupies a certain place in the food web, all species are really interconnected, meaning that management decisions made for a key species can indirectly affect populations of other species. Over the last two decades, biologists have developed complex, ***multi-species models*** to better understand the links among different fish populations and the relationships among different species regarding such management issues as prey consumption, stocking, regulation effects etc.

Such models are possible because of major advancements made in monitoring fish populations such hydroacoustics (fish sonar) methods and underwater cameras. Greater accuracy in estimating fish abundance is achieved when data from these sophisticated techniques are combined with trawling data because each technique samples a different part of the population.

New, more complex ***spatial modeling*** techniques when combined with hydroacoustic information could help biologists obtain a 3–D map of fish distribution in a lake. Ultimately, if spatial models are combined with real-time satellite and remote sensing data on water temperatures, waves and currents, one could obtain real-time images of a lake, showing where target species are most likely to be found via a 3-D fish distribution mapping system on the web.

Uncertainties in Fisheries

Money matters: Economic Models

A complete ecosystem approach to managing fisheries would involve integrating economic and social aspects of fisheries. Biologists are just beginning to develop models that assess the economic value of the fisheries resources and incorporate this information into developing managing strategies that better optimize economic growth of the fisheries. Fisheries-related business owners can also benefit from these tools in that changes in their client market, and fuel/operational costs can be anticipated so that adjustments in the management of their businesses can be made. In recent years, there have been major advancements in the development of powerful modeling tools in the area of ecological economics. These tools enable a better understanding of the relationship between the ecology of the resource and its economic value. This information would be particularly valuable for coastal communities in better understanding how changes in local fisheries resources impact their economic growth.

The bottom line…..

Risks and uncertainties common in all fisheries pose great challenges for fisheries managers and stakeholders alike. Some useful tools have been developed that will help managers and stakeholders understand risk and uncertainties and incorporate this knowledge in the decision-making process. Broader adoption of these tools remains slow because they are difficult to use and require expertise outside of fisheries management. And even then, they are imperfect. Therefore, fisheries scientists, managers and stakeholders should work more closely in an effort to better address common risks and uncertainties through a more precautionary management process. Most fisheries experts agree that sustainable fisheries are more achievable when a decision-making process is adopted that includes:

- Consideration of diverse economic, social and biological factors.
- Improved assessment of risk and uncertainties.
- Communication of risk and uncertainties to diverse audiences,
- Incorporation of risk and uncertainties in decision –making to evaluate social, economic and biological impacts of alternative decisions.
- Selection of the "best" decision out of several alternatives based on tradeoffs by "weighing" costs versus benefits resulting from a better understanding of risks and uncertainty.

New York Sea Grant
62B Mackin Hall
SUNY Oswego
Oswego, NY 13126-3599
Phone: 315.312.3042
Fax: 315.312.2954
E-mail: SGOswego@cornell.edu
Web: www.nyseagrant.org

New York Sea Grant is part of a nationwide network of 30 university-based programs working with coastal communities through the National Oceanic Atmospheric Administration (NOAA). Sea Grant research and outreach programs promote better understanding, conservation, and use of America's coastal resources. Sea Grant is funded in New York through SUNY and Cornell University and federally through NOAA.