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A Fisheries Management Primer for the Bait Harvester

INTRODUCTION

Fisheries rely on fish production for sustained harvest through time. The growth and survival of individual fish, when aggregated across a population or stock, is what we observe to be the production and ultimately harvest or yield of fish in a fishery. Decisions regarding the timing, location, and targeting of certain fish sizes in fish stocks are based on a number of factors including where and when catch rate is maximized and what level of harvesting can be sustained without diminishing the stock over time. The theory of fisheries management has a long history of addressing these kinds of issues but declines in commercial and recreational fisheries point to failure in the practice of fisheries management. Fisheries that struggle to sustain harvest levels provide a rather pessimistic view of our ability to match theory and practice.

The reasons for failure in fisheries are complex but almost always involve some combination of:

1. poor or simplistic assumptions of fish ecology and harvest theory;
2. failure to grasp the scale of movements of both the fish and fishery;
3. insufficient or biased data from the fishery itself;
4. a lack of reporting of all catch by participants in a fishery;

5. failure to grasp the ecosystem impacts of harvesting;
6. social and political trade-offs; and
7. over-capitalization of fishing fleets and equipment.

The list of factors is rather long and has led some people to despair regarding our ability to make good and sustainable decisions on fishery resources. One feature that all failed fisheries seem to possess regardless of what combination of factors contributed to their demise is the common property feature of the fish stock. That is, there is no effective ownership of a fish stock. Instead, commercial harvesters try to maximize profits by competing for licenses (access) and fish production (yield) on a common fish stock. The purpose of this outline of fisheries



management is to point to basic principles that have been learned about fisheries theory and practice, either through failures or successes, and to indicate the relevance of these lessons for bait harvesters. Bait fisheries offer an intriguing difference from most other fisheries in terms of the frequency of harvest, and quite possibly, a glimpse of the future in fisheries management.

FISHERIES MANAGEMENT

Fisheries management is a set of decisions based on ecological, economic and social information whose purpose is to sustain fish production and harvest from fish stocks. This definition is derived from the review of fish stock assessment by *Hilborn and Walters (1992)*. The set of decisions may focus on the control of harvest, protection of habitat necessary for stocks to persist such as spawning habitat or on the need to limit harmful substances in the environment for consumption and health reasons. Controlling species distributions either by restricting introductions or promoting introductions (stocking) is another category of management decisions. Socioeconomic decisions related to access to the fishery, investment in fishing equipment and regulations of equipment and harvesting efficiency represent the fifth major area of fisheries management decisions.

These categories focus directly on the participants and management agency charged with decision making on fisheries. Consumption and health guidelines bring a wider perspective of the public to bear on fisheries management decisions but for the most part fisheries management decisions have been concerned largely with the harvesters themselves. This is no longer the case. High profile and costly failures of fisheries have resulted in much closer public scrutiny of fisheries

management decisions and the operating practices of the harvesters. The social and economic disruption stemming from fishery failures like the northern cod stocks or recreational fisheries lost to factors such as habitat destruction, contamination and overexploitation are in full public view. The consequences of these failures are born by the public at large and their scale and frequency now make news headlines. Concerns over biodiversity and species distributions are also in the news. The scope and audience of fisheries management decisions are much wider now than in the past. As a consequence of this scrutiny, restoration of ecosystems and fisheries is now regarded by many as a necessary addition to the categories of fisheries management decisions listed above.

Despite the problems and pessimism in some quarters, the past has provided some clear guideposts for future fisheries management. I focus on key points and hard lessons from the past that can serve as general principles for fisheries management decisions. Then the major components of any fisheries management decision are discussed. These include:

1. the fishery itself and the particular aspects of a bait fishery that are in clear contrast to most fisheries;
2. stock assessment and the important distinction between fishery dependent data and fishery independent data;
3. models as ways of representing fish stocks and seeing possible outcomes; and
4. the ecosystem context of fisheries.

I end with a general outline of information needed in the bait fishery and why bait fisheries may be a guide to future fisheries management.

KEY POINTS AND HARD LESSONS

There needs to be a common understanding of basic principles before any exploration of what constitutes fisheries management decisions. These principles are relevant to bait fisheries. The topics are not new but failures and successes of fisheries have brought them into focus and, in a number of cases, generated interest in finally settling debates about their operation. These are effectively key points and hard lessons won often at the expense of catastrophic failures of fisheries followed by the benefit of hindsight, long-term stock assessment and monitoring, and the combination of basic and applied fisheries research. They are the first guideposts in the fisheries management process.

STOCK RECRUITMENT RELATIONSHIP

The idea that the abundance of new recruits to a fish stock is related to the abundance of spawners (expressed as numbers, total biomass or total eggs deposited) is referred to as the spawner/recruit or stock recruitment relationship. At some carrying capacity in the environment, the number of recruits no longer increases with increasing levels of spawner abundance. There is now good evidence for the general presence of stock recruitment relationships and the fact that recruitment does not always rise unchecked with increasing spawner abundance. In cases where recruitment goes up with increases in spawner abundance then the fish stock shows clear signs of being below the carrying capacity of the environment. The stock may be sufficiently below carrying capacity that recruitment overfishing is a strong possibility. That is, the fishery is taking enough of the adult stock to control the recruitment process itself, so much so that recruitment increases with corresponding increases in adult abundance once fishery exploitation is relaxed or removed altogether.

Fisheries management decisions can change depending on the strength of belief in the stock and recruitment relationship. If one believes a connection exists between adult spawners and recruitment of young fish to the stock then decisions that protect spawning stocks or decisions that manage stock sizes to within a range that provides for sufficient spawners seem prudent. If one does not believe that spawner abundance and subsequent recruitment are connected then allowing harvest in spawning areas or disregarding size of the spawning stock are fair game in fisheries management. Some recreational fisheries operate on the belief of no stock recruitment connection. This is short-sighted. The consensus is that stock and recruitment relationships become apparent once fisheries begin to heavily exploit stocks even in cases where the stock recruitment relationship was initially hard to detect. Bait harvesters should operate on the assumption that a stock recruitment relationship exists for the species of baitfish in their fishery. This means that some level of adult baitfish need to be left in the stock after harvesting.



COMPENSATORY CAPACITY

Growth, survival and reproduction in fish stocks often depend on how many other fish are in the stock. These processes are said to be density-dependent if they change as a result of the number of fish in the stock. Density-dependent processes show compensation if processes such as growth rate, survival rate or

reproductive rate change with changes in density of the stock in the following manner—they slow down at high stock levels because of crowding and increase at low stock levels when there is less crowding. The word “compensation” refers to the speeding up or slowing down of processes such as growth, survival and reproduction. For example, if density of a stock is reduced due to harvesting then some combination of growth, survival and reproduction ‘speed-up’ as if to compensate for the reduction in competitors that were once present but now removed by harvesting. In this scenario, the ‘speed-up’ part can vary in intensity depending on how tight the connection is between stock density and the processes of growth, survival and reproduction.

Compensatory capacity refers to the ability of a stock to return from (by growth, survival, and/or reproduction) losses due to mortality, either natural mortality or from harvesting. Compensation and compensatory capacity are essential for sustained harvest of fish stocks to exist. Without compensatory capacity fish stocks would be reduced through harvesting. Interestingly, if one believes that no stock recruitment relationship exists in a fish stock then one also believes in unlimited compensation since any spawning stock size, no matter how small, would suffice for full recruitment. If one believes a stock recruitment relationship is present then one also believes in limited compensation. For bait fisheries, high growth rates and reproductive rates in baitfish point to a high compensatory capacity for most stocks.

SMALL STOCK SIZES

How can compensatory capacity be revealed in a fish stock? Growth, survival and reproduction of fish at small stock sizes are typically at their maximum rate because crowding effects on these processes are minimal or absent. It is these rates at low stock sizes, particularly the reproductive rate, that provides estimates of compensatory capacity. If one believes that recruitment of fish to the stock is not connected to adult stock size (i.e., no stock recruitment relationship) then fisheries management decisions can not incorporate compensatory capacity. This is because recruitment is the same whatever the adult stock size so the response of a fish stock at low stock sizes is basically the same as at high stock sizes. In the presence of a stock recruitment relationship, compensatory capacity is revealed at the lowest spawning stock sizes where production of new recruits is the highest.

Baitfish have high growth rates, produce large quantities of eggs, and have short generation times. Even without detailed knowledge of a stock recruitment relationship for baitfish, these factors indicate that baitfish have a large compensatory capacity. For bait harvesters, this is reflected in the rapid recovery of fish stocks after harvesting under a system of rotational fishing.

CATCH-PER-UNIT-EFFORT AND STOCK SIZE

Catch-per-unit-effort is not proportional to stock size. This is one of the hardest lessons learned in fisheries management and one that has been a frequent contributor to fisheries collapses. Catch-per-unit-effort from the fishery, sometimes expressed in ways such as catch per trawl, catch per net per night, etc., is a reflection of the harvesters skill at finding and catching fish. The economic incentive to maximize the difference between landed catch and costs of harvesting do not readily permit an individual harvester to track the ups and downs of a fish stock across its entire range. Instead it forces harvesters to simply track where the fish are now. This is an important concept and one that will be discussed further in the section on Stock Assessment. The key point for bait harvesters is to maintain a healthy skepticism regarding their trap catches as a reflection of stock abundance.

EXPLOITATION PLEASE

Fisheries management decisions will depend on the fishery itself, stock assessment, models or representations of the important processes and their combined effects on sustainable harvest, and hopefully, consideration of the ecosystem context of harvesting. After all these considerations, exploitation of fish stocks is necessary for understanding their population response to periodic harvesting. Even at a conceptual level, fisheries management decisions will have many unknowns and require good guesses as to what is happening to a fish stock being exploited. Until there is harvesting of the fish stock then uncertainties regarding different choices within fisheries management decisions can never be adequately sorted and understood. Certain decisions on levels of harvesting are made more easily than others. For example, reducing stock size to levels that reveal compensatory capacity may also jeopardize profits for the harvester for some period of time. However, shifting some stocks to low abundance is a way to understand their growth response in the absence of competition, in other words, full compensatory capacity. Bait harvesters have probably detected these kinds of changes in their fish stocks by noting shifts in the size distribution of their catches once harvesting begins or after harvesting is stopped for a period of time.

LARGE BODY SIZES

All fish grow through life and different species grow to different sizes. Patterns of growth and maturity are different from one species to the next, as well as from stock to the next, revealing a great deal about fish production, mortality, and ultimately yield to the fishery. The saying, "Live fast – die young", really does



apply to fish. Species with fast growth rates typically have early maturity and short life spans. Individuals within a fish population tend to follow this rule as well. At a broad level, this pattern allows for predictions of fish production based on standing biomass. If estimates of biomass of a fish stock are available then production can be estimated. At a finer level, large individual fish in a stock probably provide a large number of offspring for recruitment. These individuals typically have more eggs, spawn earlier, and allocate more energy to reproduction than smaller individuals in the stock. Harvesting rapidly depletes large fish in a stock and in this way acts as a means of selection against fish that grow to large sizes in a stock. Bait harvesters need to ensure that harvesting does not fully eliminate large fish in their stocks.

SPATIAL SCALE

One of the most important guideposts has been acquired from the benefit of hindsight. An impending fishery collapse or one in serious trouble will first be revealed by the spatial distribution of harvesters before it is revealed in the catch statistics or even on the deck of a boat. In both commercial and recreational fisheries, harvesters change position as part of sustaining a high catch-per-unit-effort and will continue to do so even as harvesting reduces the fish stock. Fisheries management has rarely incorporated this guidepost in the past but this process, along with the disappearance of large fish, represents some of the best early warning signs of trouble. Bait harvesters need to be aware of changes in their harvest locations. Do harvesters shift locations within a lake or stream to sustain



catch rates? If there was a shift in location, did it occur relatively early in their fishery and now they are relying on fewer locations for harvesting? Are they moving around the landscape in a continual search for harvest locations, particularly after heavily exploiting certain stocks?

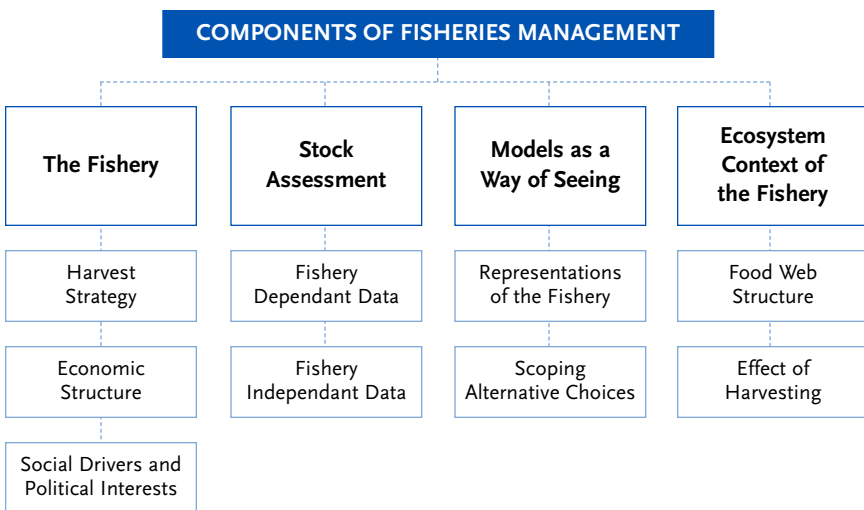
FISHERIES SCIENCE IS HARDER THAN ROCKET SCIENCE; SOCIOLOGY IS HARDER THAN FISHERIES SCIENCE

A rocket scientist requires an understanding of physics and engineering to propel a rocket from ground, sometimes through the gravitational pull of Earth, to intercept another object at great distance from the point of launch. This is an intimidating process, requires lots of knowledge and has taken enormous resources of

governments to accomplish. However, it is achievable and we witness this success again and again. Predictions in rocket science (the target), despite complex physics and engineering, are narrowly defined and accurate almost all of the time. Even when rockets are inaccurate they retain the capacity to make lasting impressions on observers. Obviously, it helps to have the laws of physics to guide the whole endeavour. No such luck in ecology or one of its sub-disciplines, fisheries science. There are not many laws that ecologists can agree upon and the ones that appear fairly consistent are related to body size and how physiology changes with increasing size. This is helpful but not sufficient to fully confront the complexity observed in the real world where fish stocks are distributed over a wide area, move around on a daily and seasonal basis, live underwater and are therefore difficult to count. After harvesting begins all of these aspects of fish stocks and more change.

Sociology is lawless and self-interest is predictable. Social, economic and political considerations are key factors in determining important elements of fisheries management decisions. The social considerations involved in fisheries management decisions are significant and frequently undocumented. Because socioeconomic considerations are important, difficult to predict and manage, and ultimately loom large in any fishery failure, sociology turns out to be harder than fisheries science.

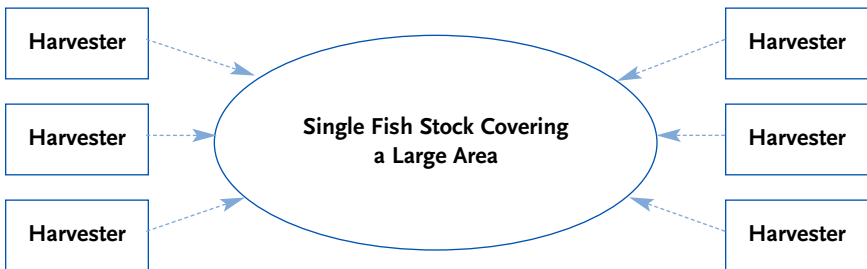
THE COMPONENTS OF FISHERIES MANAGEMENT



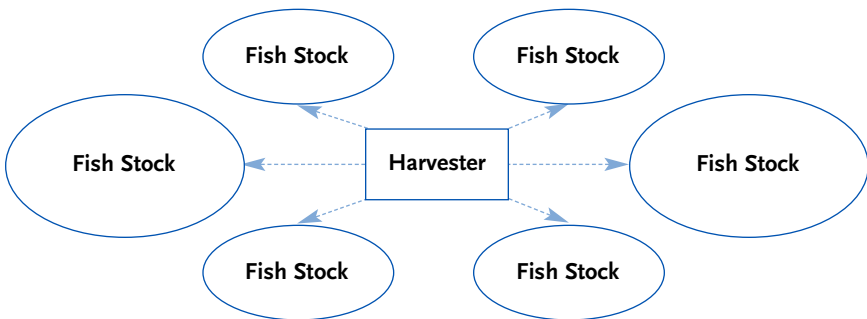
THE FISHERY ITSELF

There are a number of reasons why a bait fishery offers an interesting contrast with most other commercial fisheries. The key difference is bait fisheries move towards or wholly adopt rotational fishing rather than always fishing a stock each year or season on a regular basis. In rotational fishing, harvesting in any given year at a particular site is separated by periods of no harvesting. The periods of time of no harvest can stretch over a few years or be on an annual basis if the productivity of a stock can sustain annual harvest. The main point is that fishing mortality is effectively zero by design for a period of time.

Commercial Fishery – Multiple Harvesters with Single Fish Stock



Baitfish Fishery – Single Harvester with Distributed Fish Stocks



In fisheries science, rotational fishing can follow two basic patterns. First, all available fish vulnerable to the fishing gear are removed during those times when harvesting takes place. This is referred to as pulse fishing. Second, only a proportion of available resource is removed, which is typically defined as being above a size criterion, and this is referred to as periodic fishing. Whether rotational fishing is of the pulse-type or periodic-type, the key feature is that fishing mortality is occasionally high during harvesting and effectively non-existent during periods without harvesting. The overall losses due to fishing are therefore lower when spread out over time rather than when harvesting is based on high fishing mortality sustained at all times.

Differences between pulse-type and periodic-type rotational fisheries depend on two factors. First, pulse-type rotational fishing requires what is referred to as 'knife-edge' vulnerability to fishing gear. In other words, all fish over a certain minimum size are vulnerable to removal by fishing. Periodic-type rotational fishing can occur either because 'knife-edge' vulnerability is really only 'partial vulnerability' over a minimum size (some fish over a minimum size are caught while others are not), or following 'knife-edge' vulnerability, the catch is graded and fish in smaller sizes or, say, in spawning sizes are returned to the water. It appears that most bait harvesters are operating periodic rotational fisheries because of a lack of knife-edge vulnerability, sorting catch for the purpose of returning some fish to the water, or harvester preference for maintaining a spawning stock size to list only a few of the reasons why all vulnerable fish are not taken. This discussion of the finer points of rotational fishing does have practical relevance for the management of bait fisheries. Much depends on the motivation of the bait harvesters. Are they attempting to capture all fish in an area but fail to do so because of inefficient gear? In this case the fish stock may persist because fishing gear just can't catch all fish over a minimum size. Or are harvesters consciously avoiding taking all fish at a site because some size classes provide a low economic return, some sizes are needed for spawning stock, or growth of survivors is sufficient to compensate for losses to fishing? In the first case, inefficient gear produces periodic rotational fishing by default. In the second case, periodic rotational fishing is occurring by design because stock health is an important concern for the harvester.

A rotational harvest strategy can come about through the allocation of limited access areas (or bait harvest areas) where individual control of harvesting occurs.



In this case, like fisheries that allocate seabed for mollusc harvesting, individuals can divide an area into sites that can be harvested on a rotational basis. Limited access areas effectively remove the common property feature of most fisheries leaving the harvester with future yields.

An economic rationale also helps push bait fisheries towards rotational fisheries (Hilborn and Walters 1992). Good bait harvest sites are not evenly distributed through an area so costs of travel and field operation among dispersed locations are important and potentially limiting total harvest. Given the costs in time and effort it can be more efficient to harvest a large catch every few years from different sites on a rotational basis. This kind of consideration is also important in fisheries that rely on divers to harvest seabed organisms as well as artisanal harvesters who move across landscapes. This may be an important factor in the harvest strategy within limited access areas.

Another economic argument for periodic pulse fishing occurs when the value of larger fish is much greater than that of small fish. From a biological yield perspective, another way for the large fish/small fish dichotomy to drive harvesting towards rotational fishing occurs when small individuals are unavoidably lost during harvesting while targeting larger fish.

Not all bait harvesting follows a rotational strategy. On large lake or river systems the combination of a large overall standing biomass of baitfish along with access to seasonal concentrations of these fish can provide efficient annual harvesting. This may not represent a fundamental difference from rotational fishing. In large lake and river systems limited access to the total biomass of baitfish may effectively be rotational fishing since bait harvesters rarely have access to the entire stock of fish. Fishing mortality is reduced because it occurs only in limited areas when compared to the total distribution of the fish stock rather than by means of years with little or no harvest.

STOCK ASSESSMENT

There are two general kinds of data that can be collected for stock assessment in a fishery. First, the fishery itself provides data through catch records that typically include catch in terms of numbers or biomass per unit of effort. Effort can be represented as number of net sets, traps, hours fishing or other measures as a means of standardizing catch in relation to fishing. Second, stock assessment can occur through surveys that do not rely on the fishery but instead are conducted to determine the distribution and abundance of fish stocks without regard to sustaining high catch rates. The difference between these two approaches has proven to have profound implications for sustainability of fisheries and rests on fundamental principles of fishing theory.

Fishery Dependent Data

As outlined above, fishery dependent data on catch-per-unit-of-effort is not proportional to stock abundance. Skill, technology, and economic incentives (such as borrowing costs or profit margins) combine to ensure that harvesters in fisheries find and catch fish even if that means moving to new locations. The net effect is to maintain consistent levels of catch even though the spatial distribution of the fishery is changing. This change can appear as an increasing concentration of harvesters in a region. Basically, stocks that are heavily fished often shrink in the overall area they occupy and but remain at relatively high densities in prime habitat. Heavy exploitation removes fish throughout the stock's range but eventually the fishery locates the last place with a high density of fish. This pathway to overexploitation is found in many of the noted collapses of commercial fisheries. The spatial change in a fishery is also observed in recreational fisheries because anglers will eventually change locations to continue catching desired species. It appears to be a general syndrome of heavily exploited, and certainly over-exploited, fish stocks.

The basic theory behind this observation is important enough to warrant some consideration by harvesters. A catch of fish from a fishing gear can be understood as an outcome of two important factors. First, the catch depends on the true density or biomass of fish in the pond or stream. Second, the catch depends on the vulnerability of these fish to the fishing gear. This factor is referred to as gear selectivity. This description of catch incorporates an element that all harvesters and recreational anglers know about a fish stock. While they may not know the true abundance of a fish stock they do know that vulnerability of fish to fishing gear changes depending on a number of factors. Vulnerability can change depending on the type of trap or mesh size used to catch fish, the habitat where fishing occurs, and the time of year to name a few obvious factors.

Vulnerability of fish to fishing gear can also change depending on the true density of the fish. The general observation is for vulnerability to increase with decreases in the abundance of a fish stock. To assume that catch-per-unit-effort is proportional to stock size is to assume that vulnerability of fish to fishing gear does not change. Is this a realistic assumption? No. As already discussed, fishery dependent data on catch-per-unit-effort can be stable and independent of stock abundance for some straightforward reasons. Sometimes gear changes occur in an ongoing fishery that changes the vulnerability of fish but, in the absence of substantial gear changes, harvesters compensate for any decline in fish stocks by moving to locations where good catch rates are sustained. However, fishery dependent data can be very valuable and reflect stock abundance once a good understanding of fish abundance, vulnerability to different gears and the location and movement of the fishery is achieved. In many cases, fishery dependent data is all that's available so understanding the factors that control catch rates is needed. However, in the absence of this kind of information, caution should be exercised in accepting fishery dependent data at face value.

Fishery Independent Data

An alternative way of collecting stock assessment data is to conduct a survey without regard to the economic imperative of sustaining catch rates. In other words, a survey that is designed to sample over an area for the purpose of determining the distribution of high and low catches. In contrast to fishery dependent data, fishery independent surveys look for zero catches as much as high catches. This can determine both the spatial distribution of a fish stock and stock size if some understanding is achieved on the vulnerability of fish to the fishing method employed in this kind of survey.

Another method for determining stock size that is employed in many recreational fisheries is by means of mark and recapture. A catch of fish is identified by some tagging or marking method and abundance is inferred based the ratio of marked and unmarked fish in subsequent catches. This method gives an estimate of stock size but rarely achieves any insight on the spatial distribution of a fish stock.

New stock assessment methods employ advanced technology to acquire estimates of stock abundance and distribution. The most promising of these technologies is hydroacoustics where fish abundance and distribution is estimated based on sound reflection from sonar signals contacting the swim bladder of fish. This method is widely used for fish that occupy open lake or ocean habitats but reaches its limits in shallow areas or shallow depths. Like traditional netting or trapping methods, hydroacoustics comes with its own sets of assumptions about vulnerability of fish and the need to respect sampling designs that will adequately capture the spatial distribution of the fish stock.

MODELS AS WAYS OF REPRESENTING FISH STOCKS

Natural resource management, whether in fisheries, forestry or wildlife, requires representations of the population or stock as a means of understanding the basic processes of growth, survival and recruitment that lead to yield but also for addressing alternative management choices. These models of the real world typically take on a mathematical form and generally fall into two categories with a third being a mix of the first two. First, models can reflect changes in the overall biomass of a stock for the purpose of determining patterns of production. Second, models can reflect the age structure of the stock and incorporate a more demographic approach to decision making. Finally, models can combine both biomass and age structure to determine production patterns resulting from growth and survival of cohorts or year-classes. The choice of what model or modelling approach to use is based on the ecology of the fish themselves, the nature of the fishery, goals or objectives of fishery management, and one important principle.

The important principle in modeling can be stated in the following way. There is a trade-off between trying to achieve a general view of fish stocks in a model versus the desire to capture specific elements of a fishery for a specific fish stock. This trade-off can be viewed as sacrificing the idiosyncrasy and details of any given lake or stock of fish as the price for achieving a general perspective on how stocks respond or should respond to exploitation in general. It is the trade-off between getting elements of the big picture correct and rather than focusing on site-by-site details. Based on this principle, simple models often do better than very specific models as representations of harvesting of fish stocks. This is because simple general models of fish stocks more clearly present the kinds of information that needs to be collected on the stock.

The need for models in fisheries management can be illustrated by analogy in the following way. Forestry can combine the biomass and age-structure approach to generate sophisticated harvest models. Trees stand still, can be counted from aerial surveys and can be sampled on the ground for growth rates and age structure. Because trees stand still, whether as a big adult or a small juvenile, they are the ideal organism from a stock assessment perspective. If forestry models were to be based on fisheries methods, then some version of the following procedure would have to be used. Foresters would have to be in a hot air balloon high above the forest with a thick bank of cloud cover between themselves and the ground. They would have to use grappling hooks to grab trees from below the clouds for the purpose of collecting biological data for input into decisions on the production of the entire area to be cut or preserved. Furthermore, these decisions



would have to be based on adults because the hook rarely samples juveniles which in turn means good guesses will need to be made about future stock structure after some proportion of the adults are removed. In such a world, simple models ought to be appealing as a sufficient representation of a stock over complex models.

For a bait fishery, the category of models that appears most promising, as a representation of stocks, is the family of biomass and production models. These have a long history in fisheries science and have the appeal of addressing the concept of surplus production upon which fishery yields rest. These models appear to work well when the yield is combined for species with similar ecology rather than on a species-by-species basis. Baitfish are similar in their foraging and habitat locations and represent a common 'guild' of fish within a lake or stream. The combined yield approach should work well for the baitfish.

Surplus production is the growth in biomass of a stock each year that is necessary to offset losses to natural mortality. In a fish stock that is not exploited, or in other words at carrying capacity, the surplus production is zero because the stock fully occupies available habitat without any ability to grow in numbers or biomass. Of course, at fully depleted or non-existent levels, a fish stock also has zero surplus production! Somewhere between a stock at low to non-existent levels and one at the carrying capacity of the environment is a stock level at which surplus production is well above zero. Reducing a fish stock below its level at carrying capacity results in an increase in some combination of survival, growth and recruitment to the stock. When these factors are aggregated into a biomass estimate, they in turn reveal the surplus production. The difficulty in applying biomass models to fish stocks is knowing what the stock biomass is at carrying capacity (in an unexploited state) and at what level of stock reduction is surplus production relatively high. One can imagine the difficulty these problems present when addressing stock assessment of large and spatially diverse fisheries such as oceanic tuna fisheries. Is this the case for bait fisheries?

The possibility of directly measuring standing biomass of a stock (whether exploited or unexploited) makes the application of biomass and surplus production models quite interesting and straight forward. Having direct estimates of stock biomass is a rare event in fisheries management but because bait harvesting frequently occurs in small lakes, ponds and rivers the opportunity exists to estimate stock biomass by, say, underwater survey methods or mark-recapture methods. In addition, there exist many sites where no harvest of baitfish occurs and these locations provide an opportunity to acquire estimates of unexploited stock biomass. Estimates of unexploited stock biomass are essentially estimates of biomass at the carrying capacity of the environment. This information can be used to estimate surplus production as some fraction of unexploited biomass. Surplus production can also be easily determined from exploited bait stocks if direct measures of biomass are in hand. Bait fisheries may be some of the best applications of biomass and production models.

Bait harvesting on stocks that occupy large lake or river systems present some of the traditional problems in applying biomass and surplus production models. Namely, determining stock biomass and in particular unexploited stock biomass on fish that live in large ecosystems. The seasonal behaviour of baitfish may present a solution to this problem because different baitfish tend to congregate in limited locations during winter and spring. Biomass estimates during these time periods may not reflect stock biomass as a whole but it would represent an estimate for the exploitable portion of the stock.

ECOSYSTEM CONTEXT

Traditional approaches to fisheries management have focused on single species models and management of fish stocks. Single species approaches have proven successful to some degree but as most harvesters, managers and biologists know, fish stocks live in ecosystems and not alone without any interactions with other species or the environment. Any time spent using fishing gear quickly reveals that the target species are not the only species found in the gear. Furthermore, using fishing gear at different times of the year and in different places reveals the universal fact that fish are not evenly distributed in the environment either in terms of location or time of year. Finally, the catch of fish in fishing gear can rise and fall from time-to-time. All of these common observations stemming from simply operating any type of fishing gear point to the ecosystem as playing a role in fisheries management. The ecosystem context of fisheries management includes considerations of the overall fish community, climate as a driving factor, and the importance of habitat as an essential element of any sustainable fishery.

There are profound changes in fish stocks that follow from changing the fish community. For bait harvesters, introductions of top predators such as bass or walleye can fundamentally change a fish community from one dominated by small bodied species to one with few small species at very low levels of abundance. Besides the reduction and removal of small fish, top predators also change the way food webs work in lakes and rivers by changing the role of prey fish in channeling energy through the ecosystem. A good example of food web changes involving baitfish is now well understood in small lake trout lakes. Introductions of predators like bass in lakes where prey fish are abundant and an important part of lake trout diet shifts the food web from a lake trout dominated system to one where bass living inshore control the food web. In this example, prey fish are abundant because lake trout only have access to them during cool periods of the year when lake trout can operate effectively inshore. Bass are effective predators in the shallow zones of lakes most of the year and dramatically reduce prey fish. Lake trout maximum size actually decreases in this scenario because they switch from what was a relatively large prey item, small baitfish, to zooplankton which requires a great deal of costly foraging activity by the lake trout. This example serves both as a demonstration of the reduction/removal phenomenon as well as wider community impacts of fish introductions.

Introduction of unwanted baitfish have similar effects on fish communities and the food webs they occupy. Baitfish that forage extensively on zooplankton can change the food web and food source of resident baitfish. Loss of species or, more likely, sharp declines in abundance can occur for resident species because they can not compete with the new species.

Many baitfish harvest sites are in locations and at times of the year when fish are relatively concentrated and harvesting can be done efficiently. Pool areas in streams and rivers as well as backwater sites in lakes and ponds can serve as places where wintering and spring concentrations of fish can be found. However, these locations do not define the full distribution of any baitfish stock. During the reproductive season and summer months, the baitfish disperse more widely in lakes and watersheds. Since key processes, such as reproduction and young-of-year rearing, occur in these dispersed locations the integrity of the habitat in the wider aquatic ecosystem is an important part of sustaining harvest levels for baitfish. In streams and rivers, this means that upper reaches of aquatic habitat be maintained in a state that ensures no loss of essential habitat. This may mean that land use practices and nearshore habitat like riparian zones be the concern and focus of management actions for bait fisheries. In lakes and ponds, this means that areas such as the mouths of small streams and the zone of transition between lake and stream habitat be identified and maintained in a natural state. These are a few examples of the bigger picture that habitat provides when considering its role in fisheries management of bait harvesting.

One additional feature of habitat needs to be considered in addition to the physical attributes themselves that are important for sustaining fish stocks. This feature is the process of how habitat decisions are made. Because of the increasing use of geographic information by resource management agencies to sort through issues related to the multi-use of natural resources across the landscape, it is important for individuals or organizations harvesting fish stocks, or any other resource, to realize that agencies "see" ecosystems largely through mapped information. This information has a very fine resolution (one square metre resolution is now available) and covers most areas. Computer-based geographic information systems can integrate a number of resource features such as forest type, road networks, and land use categories (agriculture, urban, etc.), in addition to terrain and elevation as a means of coming to grips with the complexity of what constitutes major parts of ecosystems. Most agencies have base maps of these features, and many more, and are now largely moving towards this system of integration. For harvest sites that rely on the integrity of landscapes and watersheds, typically those found in stream watersheds, lakes and ponds, this approach to habitat management requires that they be present in this integrated system. The risk of being invisible to agency databases, such as geographic information systems, is the risk of not being part of management decisions that affect harvest locations or the habitat needed to sustain fish stocks. Integrated databases are used for forest allocation decisions, urban development and land classification leading to protection to name only a few that may affect harvest sites for good or bad. Being part of this kind of integrated system is being part of the social and economic factors that go into making fisheries management decisions.

CONCLUDING COMMENTS

Harvesting baitfish is a natural resource activity that seems small on a site-by-site basis but is a significant fishery when harvesters are considered together and the fishery yield is aggregated across regions. Bait harvesting is really a landscape fishery. Harvest sites are restricted to certain locations for reasons of access and efficient harvesting and harvesters themselves rely on a watershed perspective to select sites and move across the landscape to target sites (which in turn can lead to rotational fishing). Management systems that rely on limited access areas for bait harvesting promote a landscape fishery simply by means of partitioning the landscape into management units. Furthermore, the number of independent fish stocks targeted by bait harvesters at a regional or sub-regional level is quite high.

Because bait harvesting is a landscape fishery, harvesters are critically important as the only people with actual field data and knowledge needed to understand how their specific fish stocks work and the response of these stocks to exploitation. Unlike most fisheries, where harvesting occurs on relatively few stocks, bait harvesting covers so many independent stocks that traditional models of management actions on large single stock fisheries would seem ineffective. Harvesters themselves need to maintain thorough catch records to provide trend through time information to help them make management actions that provide for sustainable yields. It is simply beyond most agency capacities to monitor all local stocks of baitfish yet public demands for sustainable fisheries requires defensible choices leading to sustainability. Harvesters are an essential part of the fisheries management process for bait harvesting.

A landscape fishery has landscape issues to address for effective fisheries management. Below are listed some of these information needs for the bait fishery and recognize that others will add to the list to better reflect additional priorities.

Get the Basics Right: Identification of different species of baitfish can take on a regional or local flavour because there is no format for common names of fish often referred to by harvesters and their retail customers. Getting species identification straightened out is important for lots of fisheries management reasons but also for the bait harvester's credibility.

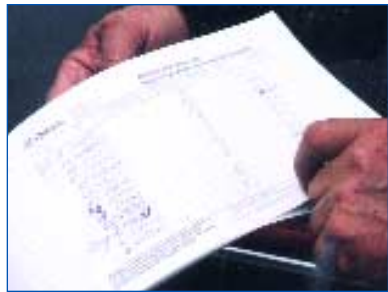
Understand the Fishing Gear: Fishery dependent data can be useful but it requires an understanding of gear selectivity for different gear types. How many kinds of fishing gear are used in a bait fishery? How does the vulnerability of fish change from one gear type to another?

Understand Rotational Fishing: I have made a point of highlighting rotational fishing as a part of bait harvesting. The period of time between harvests can range from months to years depending on the productivity of the fish stock. To what extent is rotational fishing occurring in a bait fishery? Where it occurs, what is the rotational schedule employed by harvesters?

Collect Relevant Biological Information: Surplus production models require information on biomass at carrying capacity of the environment. Sites where bait harvesting is not occurring offer a chance to collect biomass at carrying capacity to help build production models.

Locate Harvest Sites in an Ecosystem: Harvesters need to be mindful of changes in how resource management will develop now and in the future. Computer-based geographic information systems, or detailed mapped information, is how landscapes will be seen by agencies charged with resource management. Harvest sites need to be located in mapped ecosystems like all other resource activities so that landscape decisions will not adversely affect harvest locations.

Maintain Good Catch and Yield Data: For bait harvesters, catch and yield data help them spot changes that are occurring at harvest sites on various stocks of fish. It will prove extremely useful when incorporated into surplus production models that describe yield as some fraction of biomass at carrying capacity. More importantly, it provides a public assurance that harvesters are



assuming an important role in the management of their local fish stocks. For a resource management agency, catch and yield data provide a similar public assurance but at regional scales. Ultimately, as time goes by, catch and yield data provide the only broad based monitoring of fishery data for the large number of fish stocks that comprise a bait fishery.

Maintain Yield Information at a Site Level: There is a tendency to combine fishery yields from different local sites into management units for reporting purposes. This approach will suffice in broad-scale reporting of catch and yield but will not provide site-based recommendations for harvest levels. It may be inefficient to report yield data from all harvest sites given the amount of sites visited by single harvester or the time required to process a catch at any given site. However, experimental harvesting at sites with known fish biomass, along with data on fishery yields at similar sites, would go a long way towards general recommendations for sustainable harvest levels.

Bait fisheries offer an intriguing glimpse into the future of fisheries management. Pessimism about sustainable fisheries outlined in the beginning of this chapter stems from common property fisheries that target fish stocks over wide areas with unrelenting and increasing levels of fishing mortality. Solutions to this dilemma are, in almost all cases, focusing on limiting harvest to certain regions within the distribution of a fish stock and reducing fishing effort. Bait fisheries that operate based on limited access areas along with rotational harvesting appear to have the basic elements of these new approaches to fisheries management. The landscape aspect of bait fisheries also points to the need to adopt an ecosystem perspective in managing harvest sites and yields. The fisheries management challenge for bait harvesters is the need to use their extensive local knowledge of their own fishery to assure the public that the fishery is sustainable as well meeting management demands at more regional levels where ecosystem planning occurs.