Deering Estate At Cutler

R.J. DUNLAP MARINE CONSERVATION PROGRAM

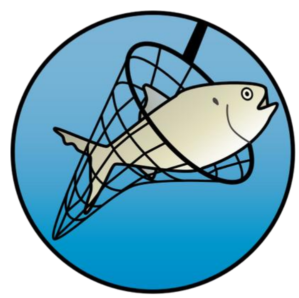
MIAMI

Marine Conservation Science and Policy Service Learning Program

Generally, a **fishery** is an entity engaged in raising and/or harvesting fish, which is determined by some authority to be a fishery. Fishery is typically defined in terms of the "people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, purpose of the activities or a combination of the foregoing features". The definition often includes a combination of fish and fishers in a region, the latter fishing for similar species with similar gear types. A fishery may involve the capture of wild fish or raising fish through fish farming or aquaculture. Directly or indirectly, the livelihood of over 500 million people in developing countries depends on fisheries and aquaculture. Overfishing, including the taking of fish beyond sustainable levels, is reducing fish stocks and employment in many world regions.

Module 5: Management, Conservation, Research and Actions

Section 2: Fisheries and Management Strategies



Sunshine State Standards

SC.912.L.17.12, SC.912.L.16.10, SC.912.L.17.17, SC.912.L.18.12

Objectives

- Learn about fisheries and management strategies
- Understand the importance of sustainable resources
- Learn about overfishing and the consequences to the environment
- Understand different alternatives for managing fisheries

VOCABULARY

Anadromous- Fish that migrate from saltwater to fresh water to spawn.

Annual Mortality- The percentage of fish dying in one year due to both fishing and natural causes.

Aquaculture- The raising of fish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used.
Feed is often used. A hatchery is also aquaculture, but the fish are released before harvest size is reached.

Availability- Describes whether a certain kind of fish of a certain size can be caught by a type of gear in an area.

Biomass- The total weight or volume of a species in a given area.

Bycatch- The harvest of fish or shellfish other than the species for which the fishing gear was set. Examples are blue crabs caught in shrimp trawls or sharks caught on a tuna longline. Bycatch is also often called incidental catch. Some bycatch is kept for sale.

Catadromous- Fish that migrate from fresh water to saltwater to spawn.

Catch- The total number or poundage of fish captured from an area over some period of time. This includes fish that are caught but released or discarded instead of being landed. The catch may take place in an area different from where the fish are landed. Note: Catch, harvest, and landings are different terms with different definitions.

Commercial Fishery- A term related to the whole process of catching and marketing fish and shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses.

Fishery- All the activities involved in catching a species of fish or group of species.

Harvest- The total number or poundage of fish caught and kept from an area over a period of time. Note that landings, catch, and harvest are different.

Juvenile- A young fish or animal that has not reached sexual maturity.

Mariculture- The raising of marine finfish or shellfish under some controls. Ponds, pens, tanks, or other containers may be used, and feed is often used. A hatchery is also mariculture but the fish are released before harvest size is reached.

Overfishing- Harvesting at a rate equal to or greater than that which will meet the management goal

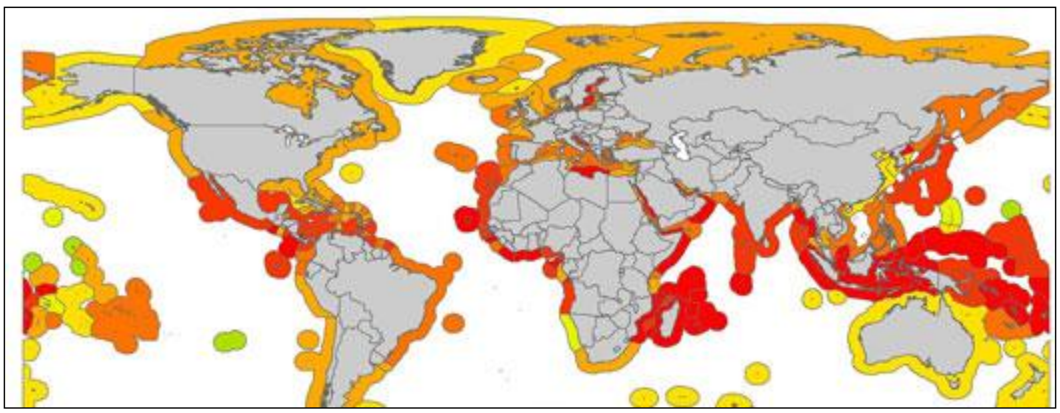
Population- Fish of the same species inhabiting a specified area.

Population Dynamics- The study of fish populations and how fishing mortality, growth, recruitment, and natural mortality affect them.

Stock- A grouping of fish usually based on genetic relationship, geographic distribution, and movement patterns. Also a managed unit of fish.

BACKGROUND

Fisheries are harvested for their value (commercial, recreational or subsistence). They can be saltwater or freshwater, wild or farmed. Examples are the salmon fishery of Alaska, the cod fishery off the Lofoten islands, the tuna fishery of the Eastern Pacific, or the shrimp farm fisheries in China. Capture fisheries can be broadly classified as industrial scale, small-scale or artisanal, and recreational.



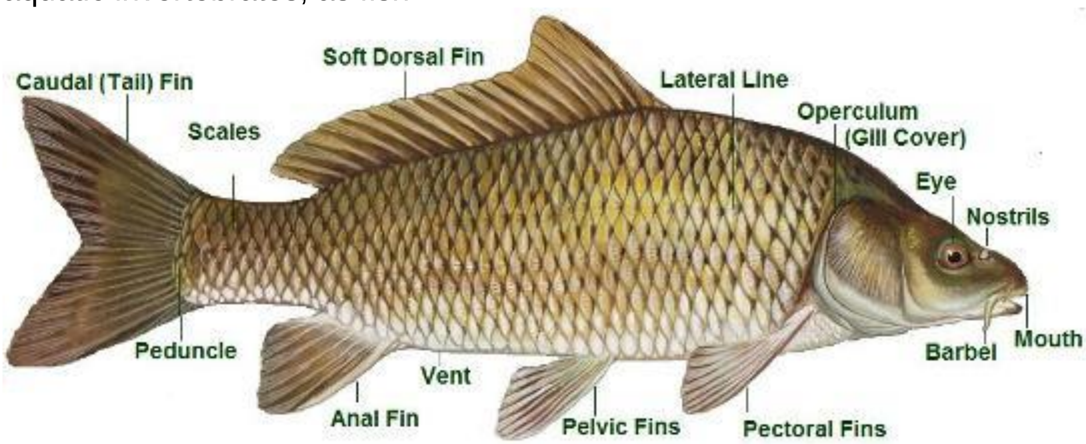
Close to 90% of the world's fishery catches come from oceans and seas, as opposed to inland waters. These marine catches have remained relatively stable since the mid-nineties (between 80 and 86 million tonnes). Most marine fisheries are based near the coast. This is not only because harvesting from relatively shallow waters is easier than in the open ocean, but also because fish are much more abundant near the coastal shelf, due to coastal upwelling and the abundance of nutrients available there. However, productive wild fisheries also exist in open oceans, particularly by seamounts, and inland in lakes and rivers.

Most fisheries are wild fisheries, but increasingly fisheries are farmed. Farming can occur in coastal areas, such as with oyster farms, but more typically occur inland, in lakes, ponds, tanks and other enclosures.

There are species fisheries worldwide for finfish, mollusks, crustaceans and echinoderms, and by extension, aquatic plants such as kelp. However, a very small number of species support the majority of the world's fisheries. Some of these species are herring, cod, anchovy, tuna, flounder, mullet, squid, shrimp, salmon, crab, lobster, oyster and scallops. All except these last four provided a worldwide catch of well over a million tonnes in 1999, with herring and sardines together providing a harvest of over 22 million metric tons in 1999. Many other species are harvested in smaller numbers.

The Term "Fish"

In biology – the term fish is most strictly used to describe any animal with a backbone that has gills throughout life and has limbs, if any, in the shape of fins. Many types of aquatic animals commonly referred to as fish are not fish in this strict sense; examples include shellfish, cuttlefish, starfish, crayfish and jellyfish. In earlier times, even biologists did not make a distinction - sixteenth century natural historians classified also seals, whales, amphibians, crocodiles, even hippopotamuses, as well as a host of aquatic invertebrates, as fish.



In fisheries – the term fish is used as a collective term, and includes mollusks, crustaceans and any aquatic animal which is harvested. The strict biological definition of a fish, above, is sometimes called a true fish. True fish are also referred to as finfish or fin fish to distinguish them from other aquatic life harvested in fisheries or aquaculture.

Population dynamics of fisheries

A fishery is an area with an associated fish or aquatic population which is harvested for its commercial or recreational value. Fisheries can be wild or farmed. Population dynamics describes the ways in which a given population grows and shrinks over time, as controlled by birth, death, and emigration or immigration. It is the basis for understanding changing fishery patterns and issues such as habitat destruction, predation and optimal harvesting rates. The population dynamics of fisheries is used by fisheries scientists to determine sustainable yield.

A fishery population is affected by three dynamic rate functions:

- Birth rate or recruitment. Recruitment means reaching a certain size or reproductive stage. With fisheries, recruitment usually refers to the age a fish can be caught and counted in nets.

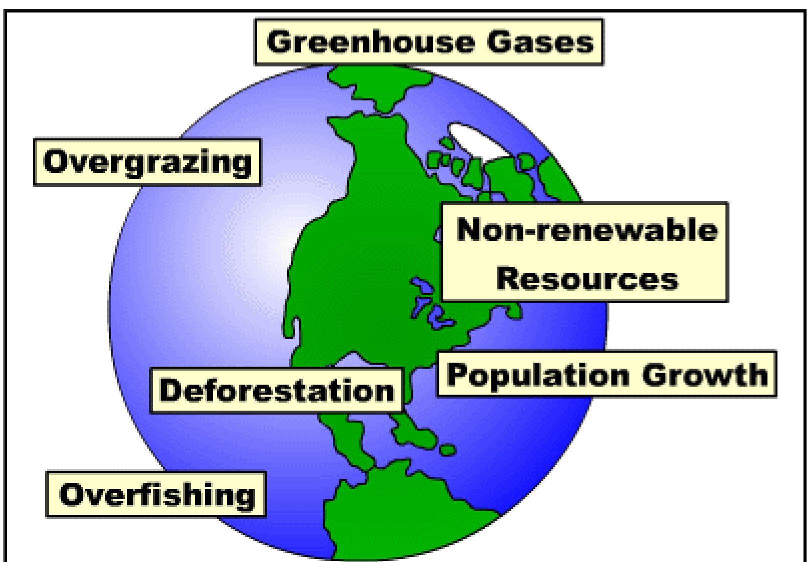
- Growth rate. This measures the growth of individuals in size and length. This is important in fisheries where the population is often measured in terms of biomass.
- Mortality. This includes harvest mortality and natural mortality. Natural mortality includes non-human predation, disease and old age.

If these rates are measured over different time intervals, the harvestable surplus of a fishery can be determined. The harvestable surplus is the number of individuals that can be harvested from the population without affecting long term stability (average population size). The harvest within the harvestable surplus is called compensatory mortality, where the harvest deaths are substituting for the deaths that would otherwise occur naturally. Harvest beyond that is additive mortality, harvest in addition to all the animals that would have died naturally.

Care is needed when applying population dynamics to real world fisheries. Over-simplistic modelling of fisheries has resulted in the collapse of key stocks.

Tragedy of Commons

The tragedy of the commons can be considered in relation to environmental issues such as sustainability. The commons dilemma stands as a model for a great variety of resource problems in society today, such as water, land, fish, and non-renewable energy sources such as oil and coal.



TRAGEDY OF THE GLOBAL COMMONS

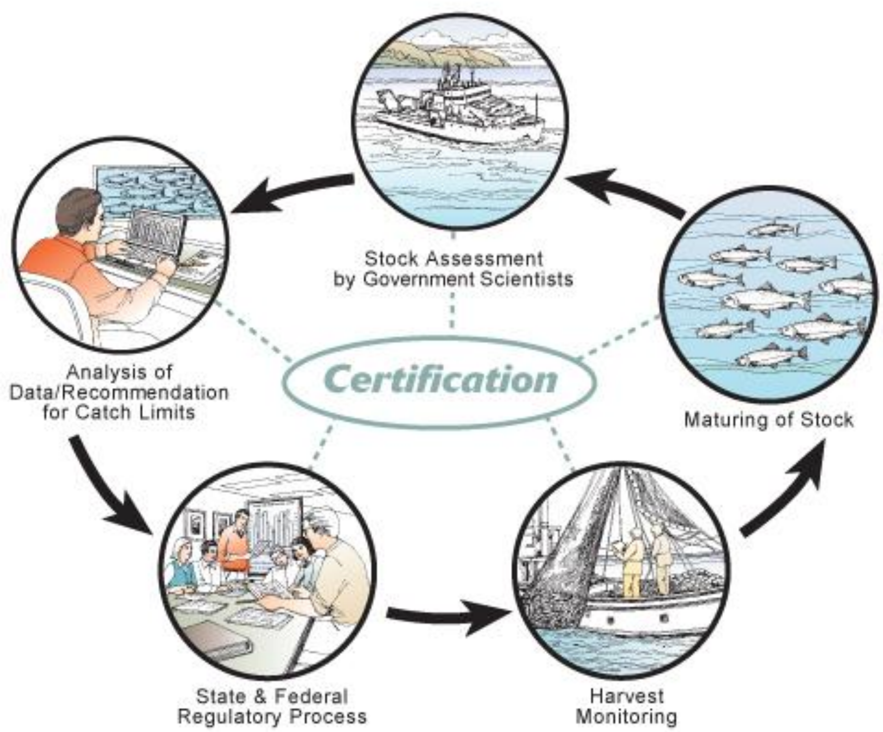
Situations exemplifying the "tragedy of the commons" include the overfishing and destruction of the Grand Banks, the destruction of salmon runs on rivers which have been dammed – most prominently in modern times on the Columbia River in the Northwest United States, and historically in North Atlantic rivers – the devastation of the sturgeon fishery – in modern Russia, but historically in the United States as well – and, in terms of water supply, the limited water available in arid regions (e.g., the area of the Aral Sea) and the Los Angeles water system supply, especially at Mono Lake and Owens Lake.

Other situations exemplifying the "tragedy of the commons" include pollution caused by driving cars. There are many negative externalities of driving; these include congestion, carbon emissions, and traffic accidents. For example, every time 'Person A' gets in a car, it becomes more likely that 'Person Z' – and millions of others – will suffer in each of those areas.

More general examples of potential and actual tragedies include:

- Clearing rainforest for agriculture.
- Uncontrolled human population growth leading to overpopulation.
- Air, whether ambient air polluted by industrial emissions and cars among other sources of air pollution, or indoor air.
- Water - Water pollution, Water crisis of over-extraction of groundwater and wasting water due to overirrigation.
- Forests - Frontier logging of old growth forest and slash and burn.
- Energy resources and climate - Burning of fossil fuels and consequential global warming
- Animals - Habitat destruction and poaching leading to the Holocene mass extinction.
- Oceans – Overfishing.

Sustainable fisheries



Sustainability in fisheries combines theoretical disciplines, such as the population dynamics of fisheries, with practical strategies, such as avoiding overfishing through techniques such as individual fishing quotas, curtailing destructive and illegal fishing practices by lobbying for appropriate law and policy, setting up protected areas, restoring collapsed fisheries, incorporating all externalities involved in harvesting marine ecosystems into fishery economics, educating stakeholders and the wider public, and developing independent certification programs.

The primary concern around sustainability is that heavy fishing pressures, such as overexploitation and growth or recruitment overfishing, will result in the loss of significant potential yield; that stock structure will erode to the point where it loses diversity and resilience to environmental fluctuations; that ecosystems and their economic infrastructures will cycle between collapse and recovery; with each cycle less productive than its predecessor; and that changes will occur in the trophic balance (fishing down marine food webs).

Global wild fisheries are believed to have peaked and begun a decline, with valuable habitats, such as estuaries and coral reefs, in critical condition. Current aquaculture or farming of piscivorous fish, such as salmon, does not solve the problem because farmed piscivores are fed products from wild fish, such as forage fish. Salmon farming also has major negative impacts on wild salmon. Fish that occupy the higher trophic levels are less efficient sources of food energy. Fishery ecosystems are an important subset of the wider marine environment.

Defining sustainability fishery

Three ways of defining a sustainable fishery:

- *Long term constant yield* is the idea that undisturbed nature establishes a steady state that changes little over time. Properly done, fishing at up to maximum sustainable yield allows nature to adjust to a new steady state, without compromising future harvests. However, this view is naive, because constancy is not an attribute of marine ecosystems, which dooms this approach. Stock abundance fluctuates naturally, changing the potential yield over short and long term periods.

- *Preserving intergenerational equity* acknowledges natural fluctuations and regards as unsustainable only practices which damage the genetic structure destroy habitat, or deplete stock levels to the point where rebuilding requires more than a single generation. Providing rebuilding takes only one generation, overfishing may be economically foolish, but it is not unsustainable. This definition is widely accepted.

- *Maintaining a biological, social and economic system* considers the health of the human ecosystem as well as the marine ecosystem. A fishery which rotates among multiple species can deplete individual stocks and still be sustainable so long as the ecosystem retains its intrinsic integrity. Such a definition might consider as sustainable fishing practices that lead to the reduction and possible extinction of some species.

Overfishing

Overfishing occurs when fishing activities reduce fish stocks below an acceptable level. This can occur in any body of water from a pond to the oceans.

Ultimately overfishing can lead to resource depletion in cases of subsidized fishing, low biological growth rates and critical low biomass levels For example, overfishing of sharks has led to the upset of entire marine ecosystems.

The ability of a fishery to recover after overfishing depends on whether the ecosystem conditions are suitable for the recovery. Dramatic changes in species composition can result in an ecosystem shift, where other equilibrium energy flows involve species compositions other than those that had been present before. For example, once trout have been overfished, carp might take over in a way that makes it impossible for the trout to re-establish a breeding population.

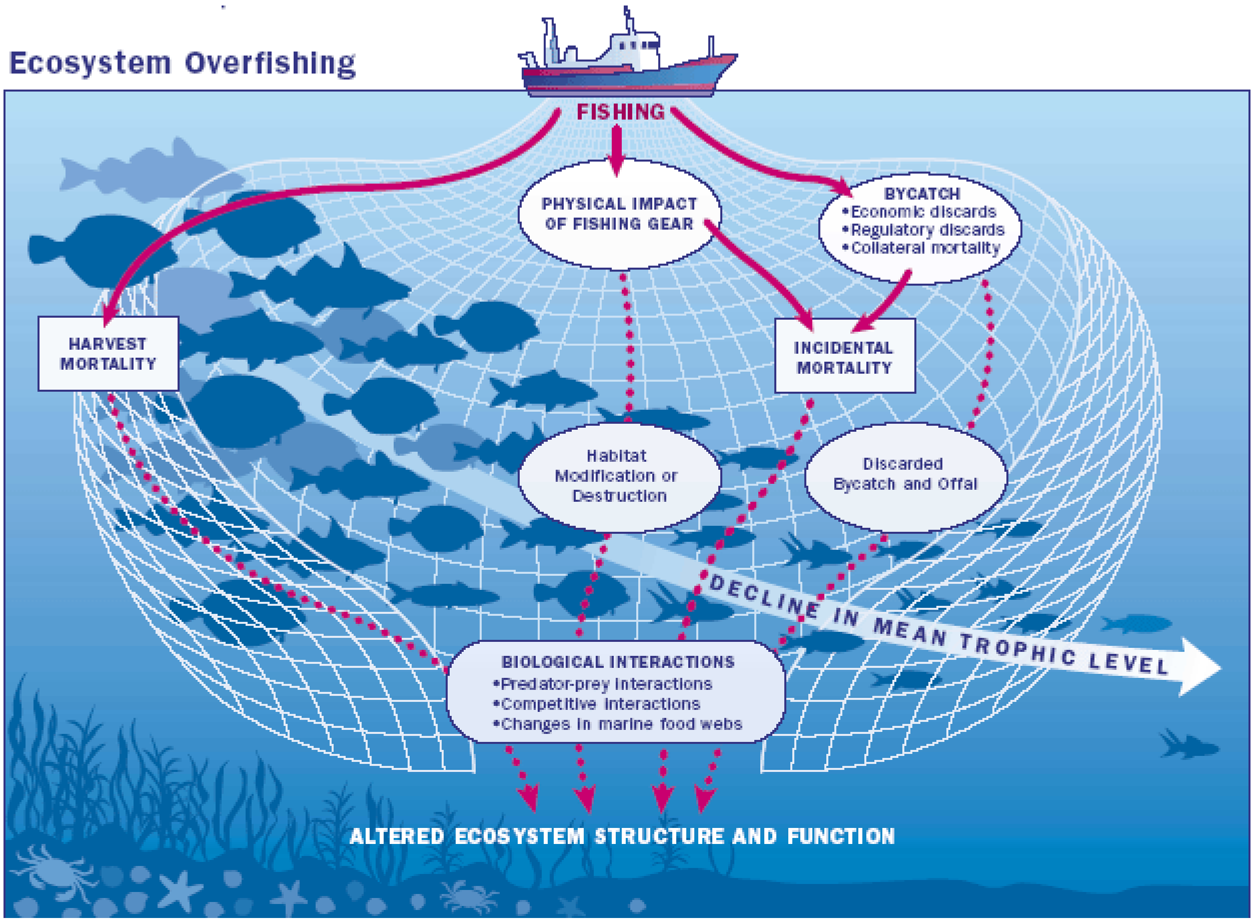
Types of Overfishing

There are three recognized types of overfishing: growth overfishing, recruit overfishing and ecosystem overfishing.

- **Growth overfishing** – is when fish are harvested at an average size that is smaller than the size that would produce the maximum yield per recruit. This makes the total yield less than it would be if the fish were allowed to grow to a reasonable size. It can be countered by reducing fishing mortality to lower levels and increasing the average size of the fish harvested to a length that will allow maximum yield per recruit.

- **Recruit overfishing** – is when the mature adult (spawning biomass) population is depleted to a level where it no longer has the reproductive capacity to replenish itself. There are not enough adults to produce offspring. Increasing the spawning stock biomass to a target level is the approach taken by managers to restore an overfished population to sustainable levels. This is generally accomplished by placing moratoriums, quotas and minimum size limits on a fish population.

- **Ecosystem overfishing** – is when the balance of the ecosystem is altered due to overfishing. Declines in the abundances of large predatory species declines and in turn small forage type species increase in abundance, causing a shift in the balance of the ecosystem towards smaller species of fish.



Source: Adapted from Pauly et al., 1998; Goñi, 2000. Art: John Michael Yanson

Overfishing outcomes

Examples of the outcomes from overfishing exist in areas such as the North Sea of Europe, the Grand Banks of North America and the East China Sea of Asia.[3] In these locations, overfishing has not only proved disastrous to fish stocks but also to the fishing communities relying on the harvest. Like other extractive industries such as forestry and hunting, fishery is susceptible to economic interaction between ownership or stewardship and sustainability, otherwise known as the tragedy of the commons.

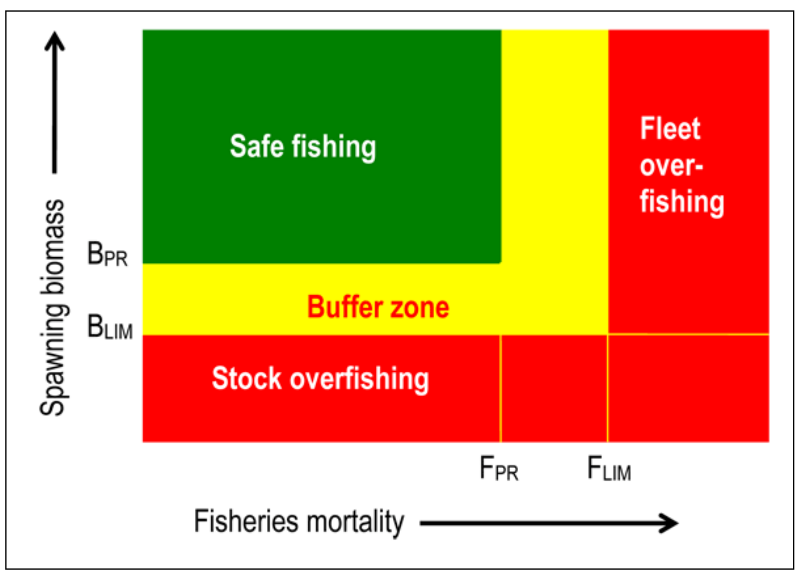
The Peruvian coastal anchovy fisheries crashed in the 1970s after overfishing, following an El Niño season which largely depleted anchovies from its waters.[5][6] Anchovies had previously been a major natural resource in Peru; indeed, 1971 alone yielded 10.2 million metric tons of anchovies. However, in the following year, and the four after that, the Peruvian fleet's catch amounted to only about 4 million tons. This was a major loss to Peru's economy.

The collapse of the cod fishery off Newfoundland, and the 1992 decision by Canada to impose an indefinite moratorium on the Grand Banks, is a dramatic example of the consequences of overfishing.

The sole fisheries in the Irish Sea, the west English Channel, and other locations have become overfished to the point of virtual collapse, according to the UK government's official Biodiversity Action Plan. The United Kingdom has created elements within this plan to attempt to restore this fishery, but the expanding global human population and the expanding demand for fish has reached a point where demand for food threatens the stability of these fisheries, if not the species' survival.

Many deep sea fish are at risk, such as orange roughy, Patagonian toothfish and sablefish. The deep sea is almost completely dark, near freezing and has little food. Deep sea fish grow slowly because of limited food, have slow metabolisms, low reproductive rates, and many don't reach breeding maturity for 30 to 40 years. A fillet of orange roughy at the store is probably at least 50 years old. Most deep sea fish are in international waters, where there are no legal protections. Most of these fish are caught by deep trawlers near seamounts, where they congregate because of food. Flash freezing allows the trawlers to work for days at a time, and modern fishfinders target the fish with ease.

Acceptable levels of fishing



The notion of overfishing hinges on what is meant by an acceptable level of fishing. More precise biological and bioeconomic terms define acceptable level as follows:

- Biological overfishing occurs when fishing mortality has reached a level where the stock biomass has negative marginal growth (slowing down biomass growth), as indicated by the red area in the figure. (Fish are being taken out of the water so quickly that the replenishment of stock by breeding slows down. If the replenishment continues to slow down for long enough, replenishment will go into reverse and the population will decrease.)

- Economic or bioeconomic overfishing additionally considers the cost of fishing when determining acceptable catches. Under this framework a fishery is considered to be overfished when catches exceed maximum economic yield where resource rent is at its maximum. Fish are being removed from the fishery so quickly that the profitability of the fishery is sub-optimal. A more dynamic definition of economic overfishing also considers the present value of the fishery using a relevant discount rate to maximize the flow of resource rent over all future catches.

Environmental effects of fishing

The environmental effects of fishing can be divided into issues that involve the availability of fish to be caught, such as overfishing, sustainable fisheries, and fisheries management; and issues that involve the impact of fishing on the environment, such as by-catch.

These conservation issues are part of marine conservation, and are addressed in fisheries science programs. There is a growing gap between how many fish are available to be caught and humanity's desire to catch them, a problem that gets worse as the world population grows.

Similar to other environmental issues, there can be conflict between the fishermen who depend on fishing for their livelihoods and fishery scientists who realise that if future fish populations are to be sustainable then some fisheries must reduce or even close.[citation needed]

The journal Science published a four-year study in November 2006, which predicted that, at prevailing trends, the world would run out of wild-caught seafood in 2048. The scientists stated that the decline was a result of overfishing, pollution and other environmental factors that were reducing the population of fisheries at the same time as their ecosystems were being degraded. Yet again the analysis has met criticism as being fundamentally flawed, and many fishery management officials, industry representatives and scientists challenge the findings, although the debate continues. Many countries, such as Tonga, the United States, Australia and New Zealand, and international management bodies have taken steps to appropriately manage marine resources.

Effects on habitat

Some fishing techniques also may cause habitat destruction. Dynamite fishing and cyanide fishing, which are illegal in many places, harm surrounding habitat. Bottom trawling, the practice of pulling a fishing net along the sea bottom behind trawlers, removes around 5 to 25% of an area's seabed life on a single run.[3] A 2005 report of the UN Millennium Project, commissioned by UN Secretary-General Kofi Annan, recommended the elimination of bottom trawling on the high seas by 2006 to protect seamounts and other ecologically sensitive habitats.

In mid October 2006, U.S. President Bush joined other world leaders calling for a moratorium on deep-sea trawling, a practice shown to often have harmful effects on sea habitat and, hence, on fish populations.

Ecological disruption

Fishing may disrupt food webs by targeting specific, in-demand species. There might be too much fishing of prey species such as sardines and anchovies, thus reducing the food supply for the predators. It may also cause the increase of prey species when the target fishes are predator species such as salmon and tuna. Fisheries can reduce fish stocks that cetaceans rely on for food.

By-catch

The term “bycatch” is usually used for fish caught unintentionally in a fishery while intending to catch other fish. It may however also indicate untargeted catch in other forms of animal harvesting or collecting. Bycatch is of a different species, undersized individuals of the target species, or juveniles of the target species.

In 1997, the Organisation for Economic Co-operation and Development (OECD) defined bycatch as “total fishing mortality, excluding that accounted directly by the retained catch of target species”. Bycatch contributes to fishery decline and is a mechanism of overfishing for unintentional catch.

There are at least four different ways the word “bycatch” is used in fisheries:

- Catch which is retained and sold but which is not the target species for the fishery
- Species/sizes/sexes of fish which fishermen discard
- Non-target fish, whether retained and sold or discarded
- Unwanted invertebrate species, such as echinoderms and non-commercial crustaceans

Possible Solutions

Many governments and intergovernmental bodies have implemented fisheries management policies designed to curb the environmental impact of fishing. Fishing conservation aims to control the human activities that may completely decrease a fish stock or washout an entire aquatic environment. These laws include the quotas on the total catch of particular species in a fishery, effort quotas (e.g., number of days at sea), the limits on the number of vessels allowed in specific areas, and the imposition of seasonal restrictions on fishing.

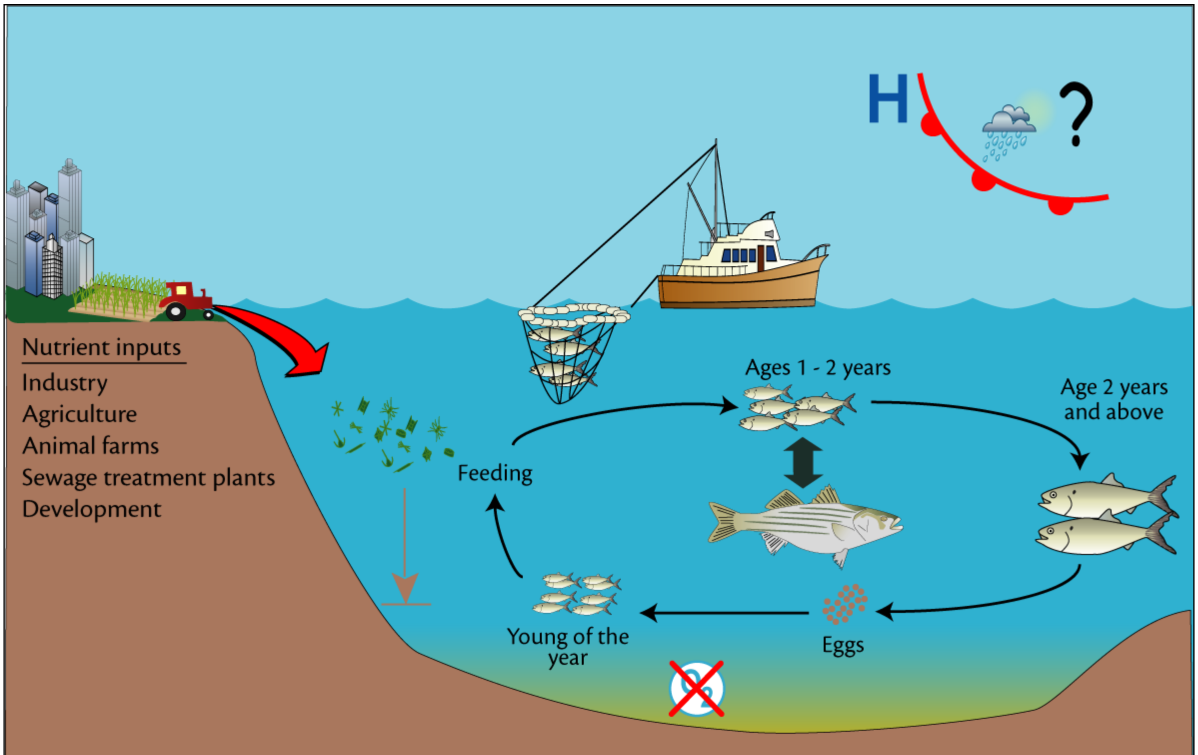
In 2008 a large scale study of fisheries that used individual transferable quotas and ones that didn't provided strong evidence that individual transferable quotas can help to prevent collapses and restore fisheries that appear to be in decline.

Fish farming has been proposed as a more sustainable alternative to traditional capture of wild fish. However, fish farming has been found to have negative impacts on nearby wild fish. Further, farming of predatory fish like salmon can rely on fish feed that is based on fish meal and oil from wild fish.

The environmental impact of recreational fishing may be alleviated to some extent by catch and release fishing.

Fisheries Management

Traditionally, fisheries management and the science underpinning it was distorted by its "narrow focus on target populations and the corresponding failure to account for ecosystem effects leading to declines of species abundance and diversity" and by perceiving the fishing industry as "the sole legitimate user, in effect the owner, of marine living resources." Historically, stock assessment scientists usually worked in government laboratories and considered their work to be providing services to the fishing industry. These scientists dismissed conservation issues and distanced themselves from the scientists and the science that raised the issues. This happened even as commercial fish stocks deteriorated, and even though many governments were signatories to binding conservation agreements.



Ecosystem based fisheries management aims to manage fisheries in a manner that considers a variety of interactions with the fishery of interest. Ecosystem based fisheries management is now strongly advocated and in some cases even mandated. Some of the main ecological interactions affecting menhaden biomass and recruitment are availability of food (plankton), level of predation from fish such as striped bass , and habitat quality such as dissolved oxygen , nutrient input , and weather pattern variability .

Fisheries management draws on fisheries science in order to find ways to protect fishery resources so sustainable exploitation is possible. Modern fisheries management is often referred to as a governmental system of appropriate management rules based on defined objectives and a mix of management means to implement the rules, which are put in place by a system of monitoring control and surveillance.

Fisheries management should be based explicitly on political objectives, ideally with transparent priorities. Typical political objectives when exploiting a fish resource are to:

- maximize sustainable biomass yield
- maximize sustainable economic yield
- secure and increase employment
- secure protein production and food supplies
- increase export income

Such political goals can also be a weak part of fisheries management, since the objectives can conflict with each other.

Fisheries objectives need to be expressed in concrete management rules. In most countries fisheries management rules should be based on the internationally agreed, though non-binding, Code of Conduct for Responsible Fisheries, agreed at a meeting of the U.N.'s Fish and Agriculture Organization FAO (Food and Agriculture Organization of the United Nations) session in 1995. The precautionary approach it prescribes is typically implemented in concrete management rules as minimum spawning biomass, maximum fishing mortality rates, etc. In 2005 the Fisheries Centre at the University of British Columbia comprehensively reviewed the performance of the world's major fishing nations against the Code.

International agreements are required in order to regulate fisheries in international waters. The desire for agreement on this and other maritime issues led to three conferences on the Law of the Sea, and ultimately to the treaty known as the United Nations Convention on the Law of the Sea (UNCLOS). Concepts such as exclusive economic zones (EEZ, extending 200 nautical miles (370 km) from a nation's coasts) allocate certain sovereign rights and responsibilities for resource management to individual countries.

Other situations need additional intergovernmental coordination. For example, in the Mediterranean Sea and other relatively narrow bodies of water, EEZ of 200 nautical miles (370 km) are irrelevant. International waters beyond 12-nautical-mile (22 km) from shore require explicit agreements.

Straddling fish stocks, which migrate through more than one EEZ also present challenges. Here sovereign responsibility must be agreed with neighboring coastal states and fishing entities. Usually this is done through the medium of an regional organization set up for the purpose of coordinating the management of that stock.

UNCLOS does not prescribe precisely how fisheries confined only to international waters should be managed. Several new fisheries (such as high seas bottom trawling fisheries) are not (yet) subject to international agreement across their entire range. In November 2004 the UN General Assembly issued a resolution on Fisheries that prepared for further development of international fisheries management law.

Management mechanisms

Many countries have set up Ministries/Government Departments, named "Ministry of Fisheries" or similar, controlling aspects of fisheries within their exclusive economic zones. Four categories of management means have been devised, regulating either input/investment, or output, and operating either directly or indirectly:

	Inputs	Outputs
Indirect	Vessel licensing	Catching techniques
Direct	Limited entry	Catch quota and technical regulation

Technical means may include:

- prohibiting devices such as bows and arrows, and spears, or firearms
- prohibiting nets
- limiting the average potential catch of a vessel in the fleet (vessel and crew size, gear, electronic gear and other physical "inputs".
- prohibiting bait
- snagging
- limits on fish traps
- limiting the number of poles or lines per fisherman
- restricting the number of simultaneous fishing vessels
- limiting a vessel's average operational intensity per unit time at sea
- limiting average time at sea

Catch quotas

Individual fishing quotas (IFQs) also known as "individual transferable quotas" are one kind of catch share, a means by which many governments regulate fishing. The regulator sets a species-specific total allowable catch (TAC), typically by weight and for a given time period. A dedicated portion of the TAC, called quota shares, is allocated to individuals. Quotas can typically be bought, sold and leased, a feature called transferability. As of 2008, 148 major fisheries (generally, a single species in a single fishing ground) around the world had adopted some variant of this approach, along with approximately 100 smaller fisheries in individual countries. Approximately 10% of the marine harvest was managed by ITQs as of 2008. 218 The first countries to adopt individual fishing quotas were the Netherlands, Iceland and Canada in the late 1970s, and the most recent is the United States Scallop General Category IFQ Program in 2010. The first country to adopt individual transferable quotas as a national policy was New Zealand in 1986.

Ecosystem based fisheries

According to marine ecologist Chris Frid, the fishing industry points to pollution and global warming as the causes of unprecedentedly low fish stocks in recent years, writing, "Everybody would like to see the rebuilding of fish stocks and this can only be achieved if we understand all of the influences, human and natural, on fish dynamics." Overfishing has also had an effect. Frid adds, “Fish communities can be altered in a number of ways, for example they can decrease if particular sized individuals of a species are targeted, as this affects predator and prey dynamics. Fishing, however, is not the sole perpetrator of changes to marine life - pollution is another example. No one factor operates in isolation and components of the ecosystem respond differently to each individual factor."

In contrast to the traditional approach of focusing on a single species, the ecosystem-based approach is organized in terms of ecosystem services. Ecosystem-based fishery concepts have been implemented in some regions. In 2007 a group of scientists offered the following commandments:

- Keep a perspective that is holistic, risk-adverse and adaptive.
- Maintain an “old growth” structure in fish populations, since big, old and fat female fish have been shown to be the best spawners, but are also susceptible to overfishing.
- Characterize and maintain the natural spatial structure of fish stocks, so that management boundaries match natural boundaries in the sea.
- Monitor and maintain seafloor habitats to make sure fish have food and shelter.
- Maintain resilient ecosystems that are able to withstand occasional shocks.
- Identify and maintain critical food-web connections, including predators and forage species.
- Adapt to ecosystem changes through time, both short-term and on longer cycles of decades or centuries, including global climate change.
- Account for evolutionary changes caused by fishing, which tends to remove large, older fish.
- Include the actions of humans and their social and economic systems in all ecological equations.

Elderly maternal fish

Traditional management practices aim to reduce the number of old, slow-growing fish, leaving more room and resources for younger, faster-growing fish. Most marine fish produce huge numbers of eggs. The assumption was that younger spawners would produce plenty of viable larvae.

However, 2005 research on rockfish shows that large, elderly females are far more important than younger fish in maintaining productive fisheries. The larvae produced by these older maternal fish grow faster, survive starvation better, and are much more likely to survive than the offspring of younger fish. Failure to account for the role of older fish may help explain recent collapses of some major US West Coast fisheries. Recovery of some stocks is expected to take decades. One way to prevent such collapses is to establish marine reserves, where fishing is not allowed and fish populations age naturally.

Data quality

According to fisheries scientist Milo Adkison, the primary limitation in fisheries management decisions is the absence of quality data. Fisheries management decisions are often based on population models, but the models need quality data to be effective. He asserts that scientists and fishery managers would be better served with simpler models and improved data.

The most reliable source for summary statistics is the FAO Fisheries Department.

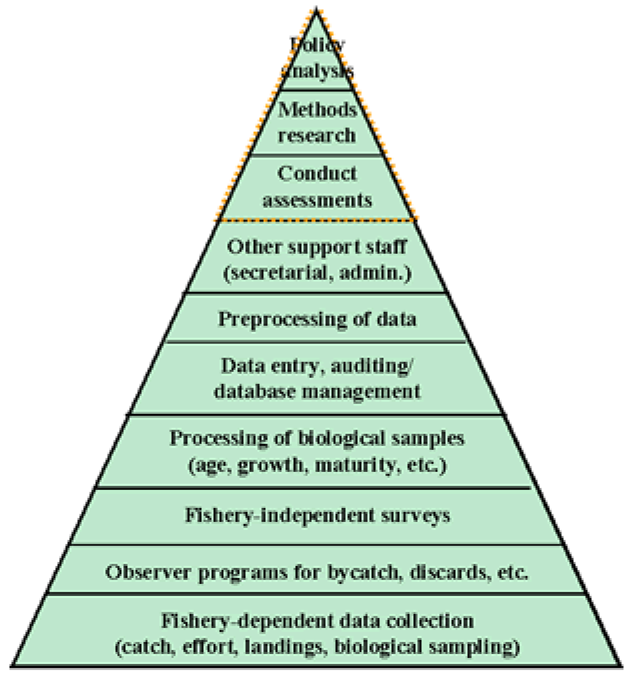


Figure 5. Schematic showing relative staffing requirements in support of providing scientific advice for fisheries management. Staff requirements for stock assessment modeling represent just the tip of the iceberg.

Human factors

Managing fisheries is about managing people and businesses, and not about managing fish. Fish populations are managed by regulating the actions of people. If fisheries management is to be successful, then associated human factors, such as the reactions of fishermen, are of key importance, and need to be understood.

Management regulations must also consider the implications for stakeholders. Commercial fishermen rely on catches to provide for their families just as farmers rely on crops. Commercial fishing can be a traditional trade passed down from generation to generation. Most commercial fishing is based in towns built around the fishing industry; regulation changes can impact an entire town’s economy. Cuts in harvest quotas can have adverse affects on the ability of fishermen to compete with the tourism industry.

Fish Farming

Aquaculture, also known as aquafarming, is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants. Aquaculture involves cultivating freshwater and saltwater populations under controlled conditions, and can be contrasted with commercial fishing, which is the harvesting of wild fish. Mariculture refers to aquaculture practiced in marine environments.

The output, as reported, from aquaculture would supply one half of the fish and shellfish that is directly consumed by humans. However, there are issues about the reliability of the reported figures. Further, in current aquaculture practice, products from several pounds of wild fish are used to produce one pound of a piscivorous fish like salmon.

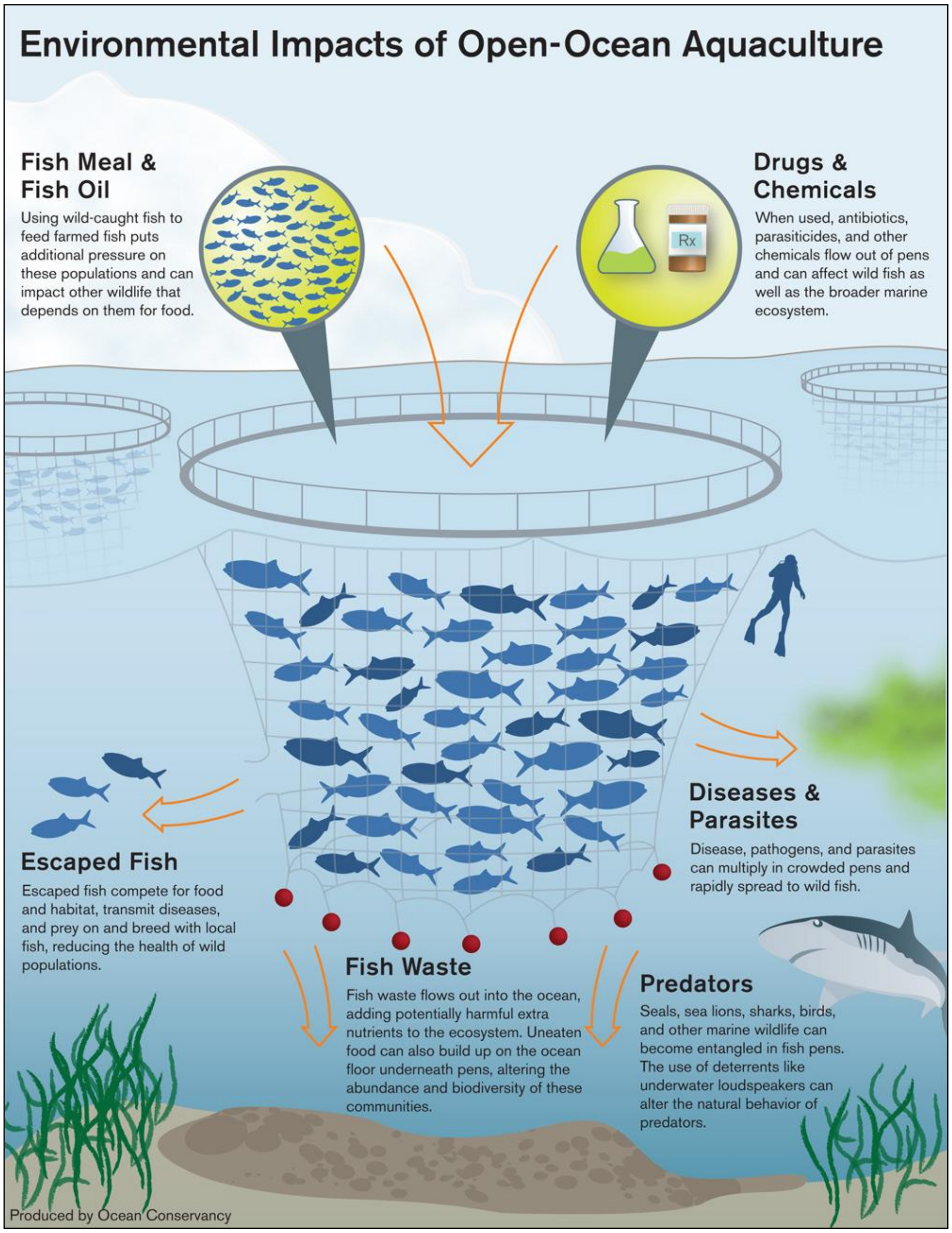
Particular kinds of aquaculture include fish farming, shrimp farming, oyster farming, algaculture (such as seaweed farming), and the cultivation of ornamental fish. Particular methods include aquaponics, which integrates fish farming and plant farming.

Mariculture is the term used for the cultivation of marine organisms in seawater, usually in sheltered coastal waters. In particular, the farming of marine fish is an example of mariculture, and so also is the farming of marine crustaceans (such as shrimps), molluscs (such as oysters) and seaweed.

Integrated Multi-Trophic Aquaculture (IMTA) is a practice in which the by-products (wastes) from one species are recycled to become inputs (fertilizers, food) for another. Fed aquaculture (e.g. fish, shrimp) is combined with inorganic extractive (e.g. seaweed) and organic extractive (e.g. shellfish) aquaculture to create balanced systems for environmental sustainability (biomitigation), economic stability (product diversification and risk reduction) and social acceptability (better management practices).

"Multi-Trophic" refers to the incorporation of species from different trophic or nutritional levels in the same system. This is one potential distinction from the age-old practice of aquatic polyculture, which could simply be the co-culture of different fish species from the same trophic level. In this case, these organisms may all share the same biological and chemical processes, with few synergistic benefits, which could potentially lead to significant shifts in the ecosystem. Some traditional polyculture systems may, in fact, incorporate a greater diversity of species, occupying several niches, as extensive cultures (low intensity, low management) within the same pond. The "Integrated" in IMTA refers to the more intensive cultivation of the different species in proximity of each other, connected by nutrient and energy transfer through water.

Ideally, the biological and chemical processes in an IMTA system should balance. This is achieved through the appropriate selection and proportions of different species providing different ecosystem functions. The co-cultured species are typically more than just biofilters; they are harvestable crops of commercial value. A working IMTA system can result in greater total production based on mutual benefits to the co-cultured species and improved ecosystem health, even if the production of individual species is lower than in a monoculture over a short term period.



Sometimes the term "Integrated Aquaculture" is used to describe the integration of monocultures through water transfer. For all intents and purposes however, the terms "IMTA" and "integrated aquaculture" differ only in their degree of descriptiveness. Aquaponics, fractionated aquaculture, IAAS (integrated agriculture-aquaculture systems), IPUAS (integrated peri-urban-aquaculture systems), and IFAS (integrated fisheries-aquaculture systems) are other variations of the IMTA concept.

ACTIVITY: EAT 'EM AND WEEP: PROBLEMS INVOLVING COMMERCIAL FISHING

Our project focuses on the impact of commercial fishing on the marine environment. Because humans rely on the sea as an important source of food and resources, they tend to overexploit its precious commodities. Many species of animals and plants are endangered due to the destructive nature of methods used for harvesting. Three major issues threatening marine species include over-fishing (catching more fish than can be reproduced), habitat destruction (destroying of the marine enviornment through human use), and by-catch (unwanted species of marine life that is caught). We intend to show how fishing practices create these problems and the effects that they have on fish populations. Through three different projects, we hope to help children better understand the negative effects of commercial fishing, raise their awareness of the need to conserve marine environments, and develop safer and better ways to obtain ocean resources.

This project focuses on issues of human impact on the marine environment. It specifically investigates the problems associated with habitat destruction, by-catch, and overfishing. Through these three activites, students will examine how these practices impact fish populations and habitats.

DURATION: 1 hour

OBJECTIVES

- Familiarize students with the idea of overfishing and its long-term effects on population sizes of various fish species
- Help students understand how fishing practices cause destruction to the marine environment
- Educate students about the problems involving by-catch and the harm it does to that are not targeted for the fishing industry

MATERIALS

Overfishing Activity
- dowel rods
- rulers
- dixie cups
- Swedish fish (candy fish, app. 1-2 lbs.)
- tape

Habitat Destruction Activity
- fish

- aquarium
- plastic aquarium plants (50)
- different colored jacks (20)
- small fish nets
- sanded/rocky bottom

By-catch Activity

- various small-sized plastic fish
- marine animals
- large bucket
- dixie cups

Background Information

Human impact on the marine environment extends to many areas and is frequently very detrimental. In particular, the fishing industry affects both target (wanted) and by-catch (non-wanted) species as well as threatening the stability of many habitats. By-catch includes any marine organisms which are inadvertently captured and/or killed through fishermen's activities. It can range from something as small as a snail to dolphins and porpoises. The proportion of by-catch species to target species is frequently as great as 100:1. The target species itself also suffers due to constant overfishing, which disallows the population to sustain its numbers through reproduction. Because populations are fished above their maximum sustainable yields (highest number fishermen can catch of one species without causing population desecration), they can be driven to extinction over time. Finally, habitat destruction occurs during fishing processes such as trawling (form of fishing where a net is dragged on the ocean bottom). Thus human impact extends far beyond the species that are targeted for consumption and threatens the entire marine ecosystem.

Preparation

Engage: Prior to beginning the three conservation activities, have students list all the marine species that they consume. In small groups, allow them to brainstorm about the ways in which fishing could be harmful to the marine environment outside of these species.

Preparation: Prior to class, the instructor should collect the required materials and familiarize themselves with the goals and background information supplied for the activities. Also, it is recommended to set up each activity in different corners of the room to avoid congestion. Overfishing activity: collect all materials. Habitat destruction activity: set up tank with rock/sand and plants, set up jacks randomly in rocks, fill with water. By-catch activity: place fish in bucket.

Procedure

Activity 1: Overfishing

1. Each student should tape dowels to table and tape two dixie cups to ends of rulers.
2. Label one cup "consumption" and one cup "population"
3. Ruler acts as balance on dowel rod
4. Each student starts out with 20 fish
5. Each student is allowed to choose however many fish they want in the consumption cup
6. For remaining fish, multiply that number by growth rate number 1 (given by teacher)...this represents the number of offspring produced by remaining population
7. Place new fish into "population" cup
8. Compare to see if it is balanced
9. Repeat with different growth rates

Activity 2: Habitat Destruction

1. Each jack is considered a target species and is worth 10 points
2. Each student will get 2 minutes to grab as many jacks as possible with the fish nets
3. Each plant knocked over is valued at -5 points
4. Determine final scores

Activity 3: By-catch

1. Each student receives a cup
2. A large bucket containing the fish is placed above the students' heads
3. Bucket should contain 20% target species compared to number of bycatch
4. Each student scoops out a cupful of plastic fish
5. One specific fish (target fish) will be valued at 5 points
6. The remaining species (by-catch) will be valued at -2 points
7. Determine final scores

Questions

How does reproduction rate relate to maximum sustainable yield?

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Is it possible to obtain the target species without disturbing the environment?

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Is the number of target species caught worth the price paid for the amount of by-catch?

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Are there better ways to obtain target species than the ones represented in the activities?

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CONCLUSION

The students should be able to discuss the pros and cons that are associated with fishing practices. Understanding reproductive rate and maximum sustainable yield can be tested by quizzes on calculating population increases or decreases based on the reproductive rate.

Activity: Fishing Population Activity

Duration: 1 hour

Objectives:

- Can define population.
- Can graph changes in a population over time.
- Can see how available resources determine the number and type of organisms that an environment can support.
- Can see how humans impact natural resources.
- Can identify common natural resources that humans impact.
- Can devise strategies to manage natural resources.

Materials

- Copy of Tragedy of the Commons handout for each student.
- 1 carton goldfish crackers
- 1 bag M&Ms (if sweets are not allowed, any small food item will work, grapes, raisins, cheerios, almonds, etc.)
- 1 bag peanut M&Ms
- 1 jar salted peanuts
- 1 roll masking tape or scotch tape per group of 4 students
- 1 paper plate per group of 4 students
- 1 napkin or paper towel per student
- 2 drinking straws per student
- Optional: 4 plastic spoons for transferring fish from the teacher's stocks to the student oceans

Procedure

1. Begin class with a discussion of fishing. What kinds of fish do you eat? What do you know about where fish come from and how they are caught? Who has ever gone fishing before?

2 .Introduce today's activity. Students will become fishermen and women for the day. These are the criteria/rules for the game:
4 fisherpersons will be fishing in each ocean (a paper plate). You cannot touch, tip or move the ocean!

Each fisherperson will be given 2 fishing poles (straws) and a net (a short length of tape) to fish with. There should be NO fishing with hands! Each fisherperson will also

get a boat (a napkin) onto which any fish that are caught should be placed. Fish that fall out of the boat onto the table do not count!
You will be fishing in your ocean for 4 years. Each year you will have 30 seconds to bring in your catch.

There are 4 different kinds of fish in the ocean. Each is worth a certain amount of money on the market. Goldfish are worth $3, Peanut Fish are worth $5, M&M Fish are worth $5, and Peanut M&M Fish are worth $10.

You must earn at least $5 of income each year to stay in business. However, you should try to earn as much money as possible.

At the end of each year, the fish have a chance to reproduce. For every 2 fish of that species, they will make 2 baby fish. Fish mate in pairs. Single fish don't reproduce.

The fish exist in a food web and need to have food in order to survive. Goldfish eat seaweed of which there is always a lot in the ocean. Peanut Fish and M&M Fish eat Goldfish; there must be at least 1 Goldfish in the ocean for these fish to survive. Peanut M&M Fish eats both Peanut Fish and M&M fish; there must be at least 1 Peanut Fish and 1 M&M fish in the ocean for these fish to survive.

3. Pass out the data tables and handout. Have one person from each group collect a plate, 8 straws, 4 napkins and a roll of tape for the members of their group. Students may use the straws and tape to create any fishing device they want. The key is to get fish out of the ocean and safely onto their boat.

4. Meanwhile, the teacher should go to each ocean and start off each ocean with: 4 peanut M&Ms, 4 peanuts, 4 M&Ms and 4 goldfish. If students discuss strategy at this time, let them. But have them do it spontaneously rather than instructing them to discuss strategy with their group.

5. When all oceans are stocked and groups are ready, the teacher should say "GO" and give students 30 seconds to fish. When the teachers says "STOP" all fishing poles must be put down.

6. Students should fill in their data tables with the number of each species of fish that remains in the ocean, the number and value of their catch, and the income earned by each fisherperson in their group. Once their tables are filled out, they can eat their catch!

7. As they fill in the tables, go around and adjust the number of fish in each ocean for the next round. Remember, there must be a food source and 2 fish of that species for them to reproduce and survive.

8. Repeat steps 5-7 three more times until there have been 4 years of fishing.

9. You may want to have students work on the worksheet questions at this time. The first 3 questions are good places to have students think about their own ocean before comparing the results between groups. You can also save the worksheet for homework or for after a group discussion.
10. Have each group report to the class the final number of fish remaining in their oceans after year 4. Some oceans may be completely empty of fish. Others may have figured out a way to fish sustainably so that there are many more fish than when they started. Discuss the various strategies the different groups used (or didn't use) to manage their oceans.

11. Introduce the concepts of overfishing, environmental collapse, the tragedy of the commons, sustainability, and resource management as they become relevant to the discussion.

12. Discuss other common resources that suffer from a tragedy of the commons and think about strategies that we can use to manage those resources responsibly.

Resources

http://nsgl.gso.uri.edu/masgc/masgch00001.pdf

http://marinediscovery.arizona.edu/lessons/gobies/Templates/index.html

http://www.sustainingriverlife.org.au/Riversandpeople/52Sustainablerecreationalfishing.aspx

http://www.agrowknow.org/wiki/index.php?title=Fishing_Population_Activity

http://en.wikipedia.org/wiki/Fishery

http://www.fao.org/fishery/en

http://www.nmfs.noaa.gov/fishwatch/management.htm