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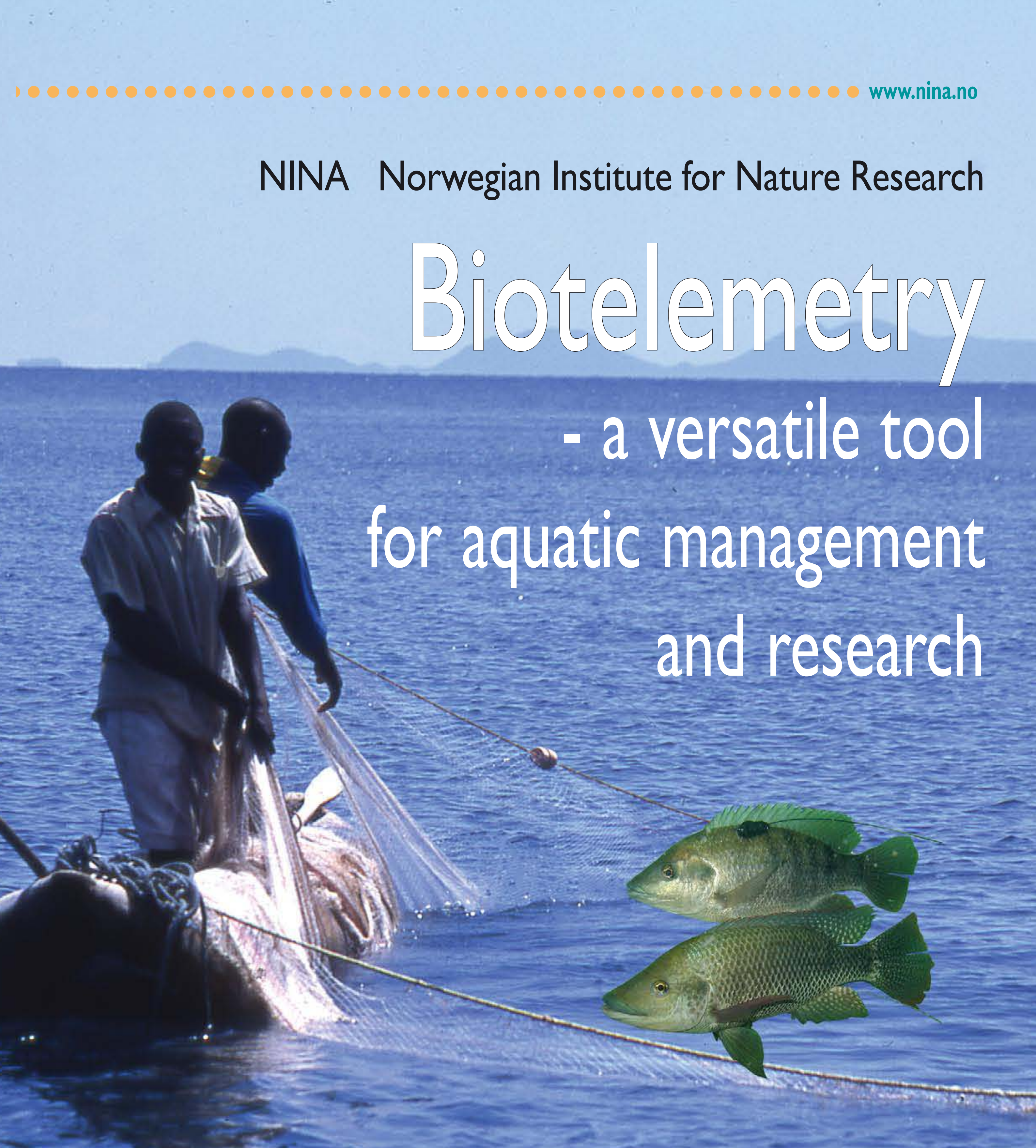
NINA Norwegian Institute for Nature Research

Biotelemetry

- a versatile tool for aquatic management and research



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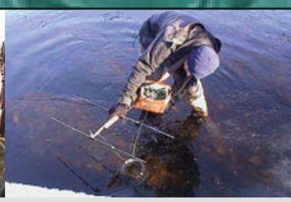
TEAMWORK



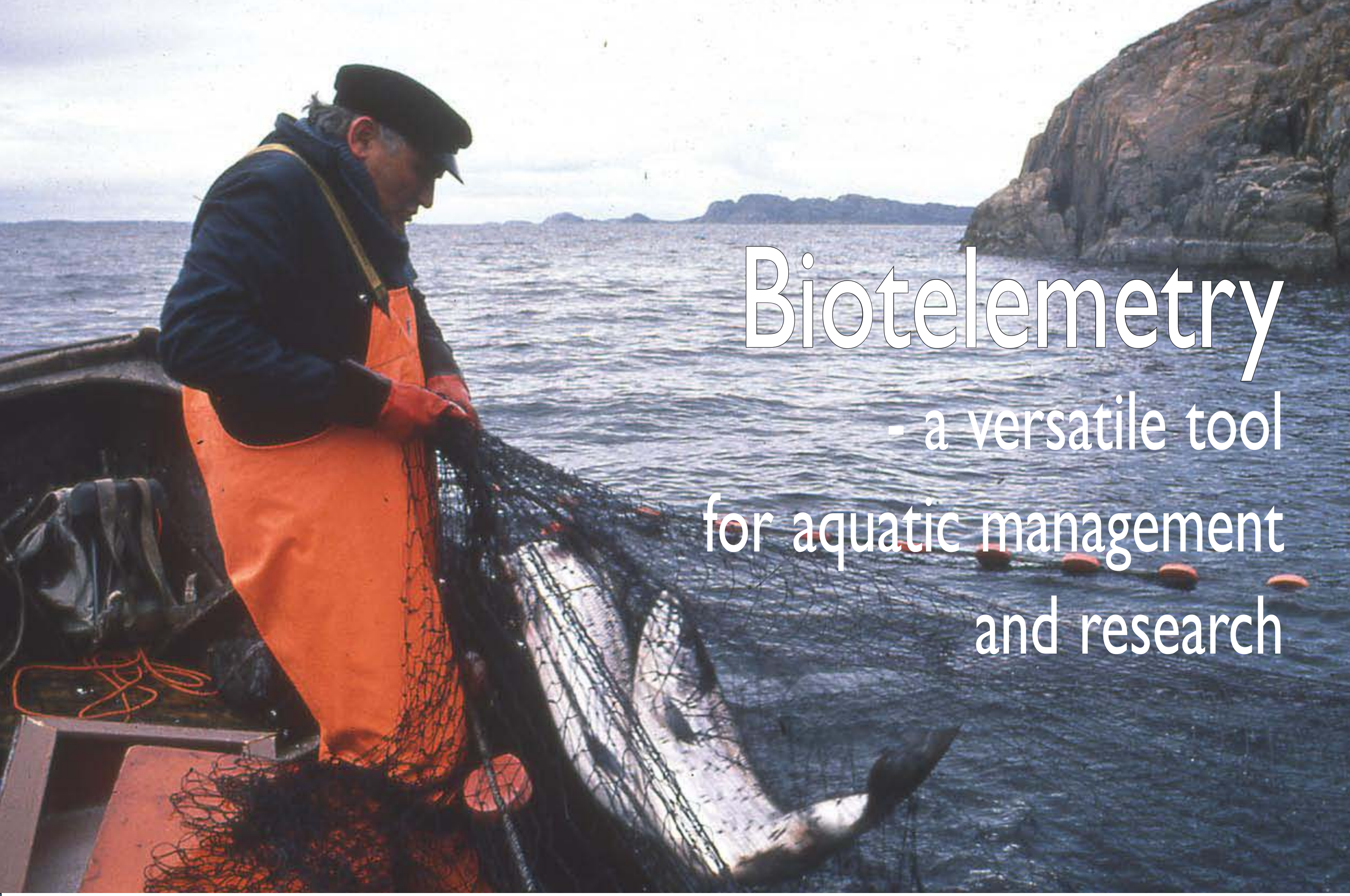
ENTHUSIASM

INTEGRITY

QUALITY

Cooperation and expertise for a sustainable future

photo: Tor Næsje, Eva Thorstad, Bruce Paxton



Biotelemetry

- a versatile tool for aquatic management and research

photo: Roar Lund

Sustainable and optimal management of the aquatic resources are globally important responsibilities. In this context, management agencies, industries and human societies are facing many and serious challenges in a rapidly changing environment with increasing demands and pressure on the aquatic environment and organisms. Today, important areas for aquatic research are effects of human activities and encroachments on the aquatic resources, sustainable management of the resources, development of economically viable and environmentally friendly aquatic industries, and conservation of biodiversity in accordance with international conventions.

The mission of the Norwegian Institute for Nature Research (NINA) is to be a leading institute in the work to produce knowledge on sustainable use and management of natural resources. NINA has a broad competence within the central aspects of aquatic research, and over the last two decades it has been a priority to build up a comprehensive competence regarding the use of aquatic biotelemetry in order to provide the best information and advice to management agencies, industries and civil societies. Today, NINA is one of the leading institutes in the area of aquatic biometry, with projects and cooperation all over the world. Due to broad knowledge in the different fields of aquatic research, NINA is able to address a variety of management issues in the best possible way.

The aim of this brochure is to review the immense prospects of biotelemetry as a versatile tool for aquatic management and research.

Norwegian Institute for Nature Research (NINA) is the leading institute for applied ecological research in Norway and is responsible for long-term strategic research and commissioned applied research to underpin implementation of conventions, decision-support systems, management tools, public awareness and conflict resolution. The Institute employs a staff of 152 and provides well equipped laboratories and facilities at seven sites throughout Norway. In 2005 the total number of NINA-projects was 700, with an operating income of 152 mill NOK (€ 19 mill), and 556 publications were produced. The Institute has a broad ecological expertise covering the gene, population, species, ecosystem and landscape level, in terrestrial, freshwater, and coastal marine environments. In addition, NINA addresses interdisciplinary issues involving both ecologists and social scientists. The institute also plays an important role in international research, both in Europe and elsewhere. NINA has broad experience in addressing natural and human aspects of resources and biodiversity management in developing countries and Eastern Europe, through collaborative research and consultant work, contributing actively to capacity building and technology transfer. NINA's activities cover resource assessment and monitoring, development of methodologies, environmental impact assessments, community-based resource management, and analysis of natural, anthropogenic and socio-economic aspects of biodiversity and resource management. The comprehensive and up-to-date scientific competence of NINA's staff guarantees high quality services in commissioned research and consultancy tasks.

NINA's mission

The mission of the Norwegian Institute for Nature Research (NINA) is to be a leading national and international research institute producing applied scientific knowledge as a basis for wise use and management of natural resources.

Our vision is that we will be at the forefront of research – both nationally and internationally – in the field of applied ecology. Our expertise will be in demand as society makes decisions regarding the use and management of nature.

Our tradition is to work in close collaboration with our clients and provide significant information to decision makers.

Our goal is to improve the excellence of our clients, and produce scientific products of high quality and relevance. We emphasize objectivity, independence and quality in research to maintain our scientific integrity.

NINA's work is directed towards environmental research with emphasis on the interaction between human society, natural resources and biodiversity. Through our research in natural and social sciences, and our collaborative networks in Norway and abroad, we aim to provide the best information and advice to management agencies, industry, and civil society, in all aspects of natural resource management and sustainable use of renewable resources.

photo: Arve Kjersheim

NINA's expertise

Optimal management and sustainable utilisation of natural resources in the aquatic and coastal environment requires access to relevant scientific information from a wide array of natural and social sciences available in NINA. This includes, e.g.:

- culture- and resource-geography, nature management, physiology, sociology, and anthropology
- terrestrial and aquatic zoology and botany
- project organization, and organization of work shops and conferences
- evaluating landscape and seascape ecology and development of ecological indices
- identifying, modelling and classifying aquatic habitats, and integrating such information into GIS
- extensive competence within remote sensing techniques and aquatic telemetry, including radio, acoustic and satellite telemetric methods
- analysing social and socio-economic aspects of resource use
- biodiversity, population and ecosystem research
- laboratory for genetical studies
- aquatic research stations with facilities for both small and large scale experiments

photo: Odd Terje Sandlund

What is biotelemetry?

In its broadest sense, telemetry can be defined as the art or science of conveying information from one location to another. Telemetry is the use of telecommunication for wireless transfer of information. In biological sciences, the term biotelemetry usually refers to the use of electronic tags transferring information about an individual to a remotely placed observer, either by radio or acoustic signals. Since aquatic biotelemetry was pioneered in the 1950's, the technological progress has been immense and during the last two decades a multitude of biotelemetry methods have been developed.

photo:Tor Næsje

Taking advantage of the rapid advances in biotelemetry, scientists are able to equip their research animals with amazingly small transmitters, and track their movements and behavior in impressive detail with the aid of equally advanced receivers and data loggers. The type of telemetry system most suitable for aquatic research will depend on the environmental conditions in the area of interest. These conditions include freshwater, estuaries and saltwater or open ocean environments. To provide the best possible results, it is imperative that the choice of methodology is based on solid knowledge and experience within the field.

Signal types

The different physio-chemical properties of freshwater and sea water causes radio signals to be transmitted best in freshwater, whereas the use of acoustic signals is the prevailing option in marine environments. The most frequently used tracking method for most freshwater studies is therefore radio telemetry, while acoustic telemetry is required in saltwater and estuarine environments. In some cases acoustic telemetry is also used for freshwater applications, particularly in water with high conductivity and/or in applications where depths exceed 12-15 meters. A hybrid tag has also been developed, transmitting radio signals in freshwater and acoustic signals in sea water.

The conveyed signals can either be pulsed or digitally encoded. Conventional telemetry involves the use of pulsed signals, - the familiar "beep-beep-beep". Pulsed systems provide individual identification of research subjects through the use of frequency separation combined with a variety of pulse rates. By contrast, digitally encoded tags transmit a distinct and unique numerical code that separates it from all other tags, even those transmitting on the exact same frequency. In fact, thousands of different coded tags can be deployed on any one frequency.

Transmitter size, range and longevity

The size of the organism, the desired signal range and the transmitter longevity determines the size of the transmitter tag, both when utilizing radio and acoustic signals. Large individuals can be equipped with large, long-lasting tags with a long range, while small tags must be used for smaller animals. By using the smallest available tags, it is possible to monitor the behavior of fish only a few centimeters in length. The longevity and range of the tags vary according to the size of the power supply, and long-lasting tags may be active for years. The range of radio signals may under good conditions be several kilometers, and tracking from airplanes is a routine in many telemetry studies.

photo:Tor Næsje

Transmitter types

Type	Typical application in aquatic management and research
Radio tags	Monitoring of position and behavior in freshwater systems
Acoustic tags	Monitoring of position and behavior in marine and estuarine systems, and in deep freshwater lakes
Sensor tags	Collection and transfer of physical and physiological data by the use of advanced sensor technology in all aquatic systems
GPS tags	Monitoring of gross movements of larger animals, like whales, sharks and sea turtles by utilizing the GPS system
DST tags	Recording of instant environmental data for subsequent computer download after tag retrieval in all aquatic systems
PIT tags	Precise identification and positioning of small animals over short distances in all aquatic systems

Transmitter types

Radio and acoustic transmitters that convey pulsed signals have traditionally been the primary choice for aquatic management and research, but the use of **digitally encoded tags** has become more common over the last decade. Both radio and acoustic tags can be equipped with various sensors that allow the recording of **environmental and physiological variables**. The tags can, for instance, be equipped with sensors for measurement of external and physical parameters like temperature, salinity and depth. Other sensors allow measurement of internal and physiological parameters like muscle activity and heart rate. The latter types of sensors are helpful in situations where detailed information about the internal state of the organism is required. The use of such sensors is often referred to as physiological telemetry.

Another effective way to monitor an aquatic animal may be to equip it with a **GPS tag**. By using the Navstar Global Positioning System (GPS), such tags provide accurate means of monitoring animal movements. A requirement for using GPS tags is that the tagged animals regularly break the water surface, to allow the tag to communicate with satellites. Furthermore, GPS tags are large and their use is therefore restricted to larger aquatic animals like whales, sharks and sea turtles.

Other tag types include **data storage tags** (DST or archival tags) and **passive integrator tags** (PIT tags). DST tags can store large amounts of information (temperature, depth, salinity) in a small processor within the tag. The stored information can later be directly downloaded to a computer after tag retrieval or conveyed wirelessly to a remote receiver (CHAT-technology). DST tags are particularly useful when wireless transfer of information is difficult or the probability of recapturing the tagged animal is high. PIT tags are tiny identification chips which are injected into specimens for permanent identification. The chip is read by means of a reader which provides a unique code. The chip is passive, i.e. does not have an internal power source. The advantage of PIT tags is their small size (8 mm), while the disadvantage is the short reading distances (less than 1 m).

Transmitter attachment

Telemetry transmitters can be attached on the exterior of the animals (external tags) or be implanted into the organism (internal tags). In fish, external transmitters are usually attached below the dorsal fin, while in other groups of aquatic animals such tags are often attached with collars or glue. External attachment is intended for animals that will be damaged by implanting a transmitter and whose habitats do not contain e.g. weeds to entangle the transmitter. An internal tag is surgically implanted into the body cavity through a small incision which is closed

photo: Tor Næsje

with sutures. Acoustic tags are usually not equipped with antennas, whereas an internal radio tag may have an antenna that is coiled inside the body cavity or exits the body cavity through a small incision in the side of the fish. A coiled antenna is used when there is a possibility that the external antenna could become tangled, while a trailing antenna is used when a longer signal range is required. Use of internal tags is advantageous in cases where an externally mounted tag may affect the behavior of the animal or increase catch mortality. Transmitters can also be implanted into the stomach of fish using an esophageal insertion tube. When using esophageal radio transmitters the antenna exits the fish from the corner of its mouth. This method is primarily used on salmonids that enter fresh water to spawn and no longer ingest food.

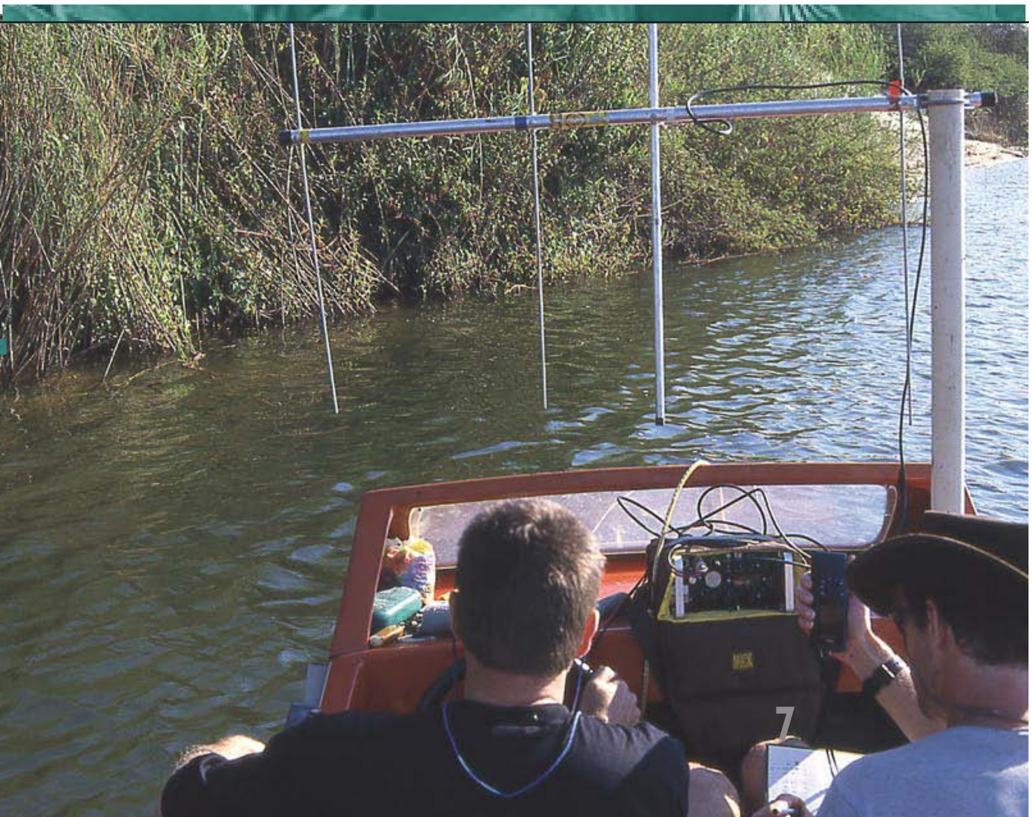
Training is required to surgically tag fish with transmitters. The fish is anaesthetized before surgery, and after surgery the recovery time is short and the mortality is usually negligible.

Data collection and analyses

Radio telemetry systems commonly utilize aerial antennas of various designs to establish "listening" zones to detect signals, whereas acoustic telemetry systems use hydrophones for the same purpose. There is a multitude of receiver types varying from straightforward manual receivers to advanced data collection computers, which combines data logging, data interpretation and automatic receiver control in a single unit.

Traditional **manual tracking**, on foot, by boat, car or airplane is often employed in studies of gross movements, migratory patterns, location of spawning grounds, etc. Tracking may either be done by manually searching for signals on all frequencies assigned, or with the aid of a scanning receiver that automatically listens at each frequency for a small period of time. **Fixed data logging stations** automatically record and store the signals from tagged animals within their detection range. In such applications, the receiver can be deployed to automatically scan for all frequencies in use. The use of fixed data collection computers with automatic logging of three or more connected hydrophones can allow exceptionally detailed and simultaneous three dimensional positioning of many individually tagged marine animals by cross-bearing analyses. Fixed station logging is preferred to manual data collection when an individual remains in the same area over time or when it visits a specific and predefined area.

photo: Tor Næsje



Why biotelemetry?

Biotelemetry is a valuable and unique methodological approach for aquatic management and research and provides data and information not available with other methods. It may be used to monitor behavior, abundance, habitat use and physiology of most types of mobile organisms, including aquatic mammals, fishes and crustaceans.

The great advantage of biotelemetry is that unique, fundamental and individual biological data can be gathered in a non-invasive manner, without disturbing the animal, repeatedly and over long distances and periods. Unlike terrestrial animals, aquatic organisms live in surroundings that normally are inaccessible for humans for longer periods of time. Therefore, it has been difficult to do individually based studies of animals in their natural environment. Traditional approaches like scuba diving, video filming and observations under semi-natural conditions have provided valuable biological knowledge, but these methods are in many ways limited by the human physiology, water properties and difficulties linked to recreate natural conditions in laboratories. Therefore, biotelemetry is often the best way to study e.g.:

- where animals reside, their position and presence
- movement, behavior and migration patterns
- habitat utilization and preferences
- swimming speed and duration
- temporal and spatial activity patterns
- home range and area use
- individual variations within species
- physical environmental parameter demands and preferences (e.g. temperature, salinity and depth/pressure)
- behavioral responses to changes in the environment
- physiological parameters, e.g. muscle use and heart rate
- effects of manmade constructions on animal behavior
- effects of human activities on animal behavior, survival and productivity
- interactions between different species
- effects of management measures

Use of aquatic biotelemetry

Human impacts

Habitat destruction
Human activities may alter or destroy aquatic habitats. Examples are hydro power regulations and irrigation schemes for agriculture, which often impact negatively on fish movements, migrations and behaviour. Biotelemetry can be used to obtain knowledge about the impacts and how to restore habitats in the best possible way, because it allows investigators to quantify human influence through the study of changes in animal behaviour and physiology. Biotelemetry may for instance be used to identify and study the effects of human made obstacles and encroachments for fish migrations between feeding, reproduction and nursing habitats. Since biotelemetry allows evaluation of problems from the animal's perspective, it is an excellent tool for assessing anthropogenic effects in aquatic habitats.

Effects of pollution
Pollution is perhaps the most serious negative anthropogenic factor on the aquatic environment. Changes in fish behaviour are often seen as an early indicator of pollution. Behavioural changes may have several secondary adverse effects, like suppressed reproduction and foraging leading to reduced production. Pollution might also affect the physiological status of animals. Biotelemetry can thus be used to detect, predict and document the effects of pollution on aquatic animals at an early stage, through providing detailed knowledge on behaviour and physiology.


photo: Roar Lund


photo: Roar Lund

Fish-ways
It is well documented that human activities often result in reduction or extermination of local fish stocks. Biotelemetry has a considerable potential to validate the effect of actions undertaken to re-establish or strengthen fish stocks. Fish-ways are frequently constructed to improve the passage of fish past hydro power dams or other human made constructions in rivers. Biotelemetry studies may validate the efficiency of fish-ways, for instance by confirmation of whether the fish are able to use the fish-way, or by estimating the effect on fish energetics imposed by such constructions. Information obtained by biotelemetry studies can also be used for improving fish-way design.

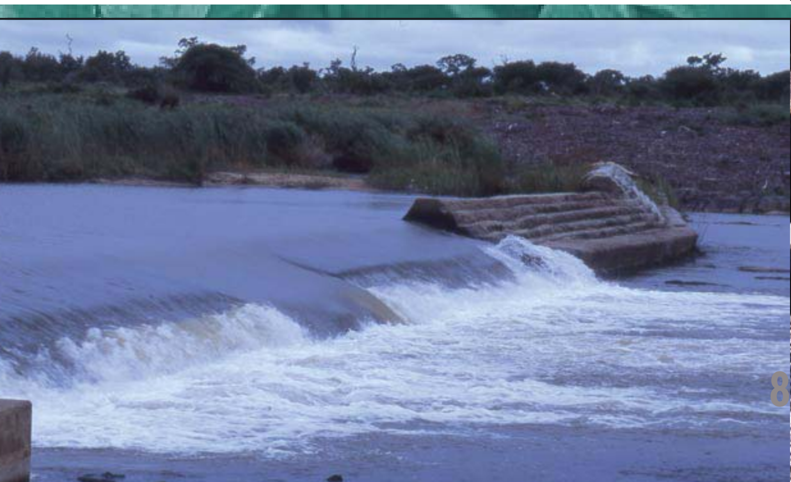
Resource management

Optimal exploitation
Exploitation of aquatic resources is of immense importance for the global society through providing food and employment. It is therefore important that the efficiency of the fisheries is optimal and sustainable. Biotelemetry may provide important knowledge for improving fisheries strategies. Information about habitat utilization, fish abundance and migrations will greatly improve the output of large scale industrial activities and small scale subsistence fisheries, both in industrial and less developed regions of the world.

In many cases, fish stocks are the target for both commercial, subsistence and sports fisheries. Achieving an acceptable and fair balance between conflicting interests requires sound knowledge of the abundance, habitat use, migration, and population dynamics of targeted stocks. Biotelemetry may often be the only method to obtain essential information on several of these parameters.

Management of recreational fisheries
Angling is a valuable activity, both in social and economi terms. A sustainable recreational fishery depends on a sound and viable fish stock and a positive public perception of the fishery. Biotelemetry provides information about fish abundance and recruitment potential by allowing examination of fish behaviour, including habitat use and migration. Furthermore, telemetry studies may reveal whether or not "catch and release" is an effective and ethically justified management approach, through providing survival estimates and

photo: Eva Thorstad



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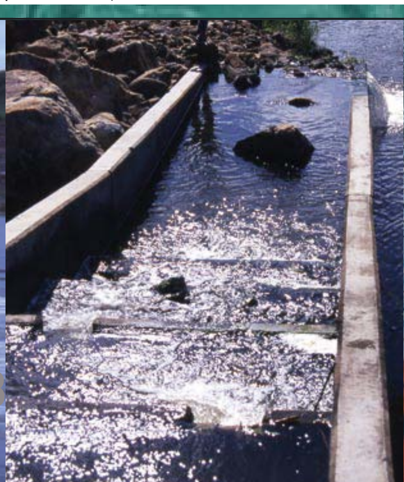

photo: Jon-Håvar Haukland

quantitative information regarding the physiological status of the fish.

Critical factors for sustainable management

The aquatic resources are not infinite and overexploitation is an universal problem. Development of goal oriented and sustainable management strategies are therefore of utmost importance for preserving the aquatic resources for future generations. The development of management strategies depends on detailed and reliable biological knowledge. Biotelemetry will in this context be a valuable tool by providing information related to habitat utilization, foraging patterns, population distribution, causes of mortality, and recruitment and production potentials.

Enhancement of overexploited stocks

Overexploited populations can be enhanced, not only through sustainable management of existing stocks, but also by restocking, which implies that animals are cultured with the purpose of being reintroduced to their native environment. Unfortunately, restocking has proved to be difficult due to high mortality and impaired reproductive ability of the released animals. Biotelemetry will allow researchers to estimate mortality rates and to determine the causes of mortality. Telemetry studies of behaviour and physiology in the spawning areas could also reveal the causes for impaired reproductive success.

Aquaculture

Optimization of production

The aquaculture industry is undergoing a rapid development on a global scale, and the future social and economical significance of cultured aquatic organisms will be immense. It

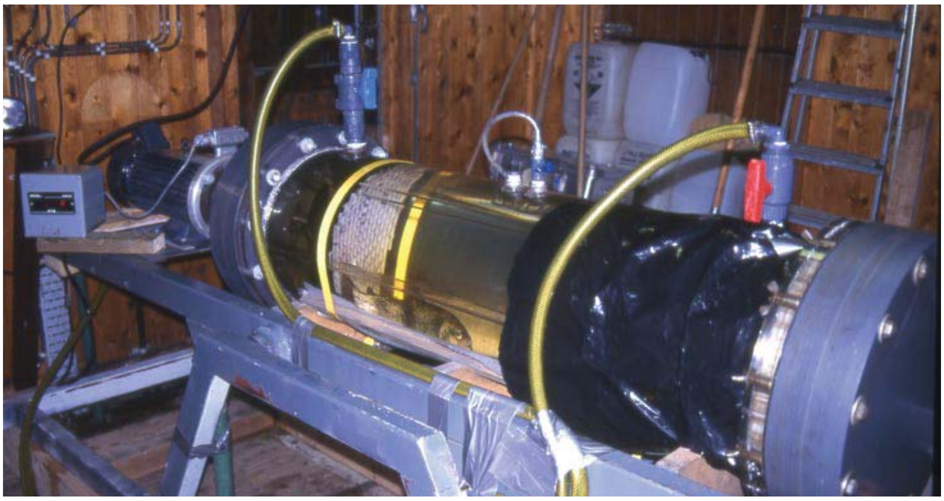

photo: Eva Thorstad

is thus important to increase the efficiency of the production methods. Culture conditions need to be adapted to the reared animals and different environments, and production costs must be minimized. Biotelemetry may be an important tool in acquiring the essential biological and technological knowledge to achieve this goal.

Biotelemetry is currently used in aquaculture research projects, for instance to develop intelligent monitoring systems that detect and respond to fish hunger, and to develop fish health monitoring systems. Physiological telemetry may also provide information about the internal state of the fish, which in turn will allow prediction of stress levels, flesh quality and energetics under varying environmental conditions. Hence, the use of biotelemetry may greatly contribute to optimization of aquaculture.

Environmental effects of aquaculture

Unfortunately, aquaculture may also lead to environmental problems, and it is imperative to minimize such impacts while still maintaining economic sustainability. Examples of negative environmental effects of aquaculture are escapement of farmed fish with subsequent negative impacts on local species, and transfer of diseases from farmed fish to wild stocks. Biotelemetry studies allow assessment of interactions and competition between farmed and wild species, and development of mitigation strategies. Furthermore, information of habitat utilization and migration of wild species in relation to the location of farms will allow modelling of infection-free or "safe" geographical areas for aquaculture.

Fish welfare

Maintenance of animal welfare is an important aspect in aquaculture, and positive consumer attitudes may in the future probably depend on a documented optimal state of well-being of the cultured animals. It is therefore important to establish production protocols that maintain animal welfare in all stages of the production process. Biotelemetry may provide important biological information for the development of justified and knowledge-based production methods, because it allows examination of problems from the animal's perspective. Telemetry is a useful alternative for obtaining information about the behaviour and physiology of the animals under a "real life" rearing situation.

photo: Eva Thorstad

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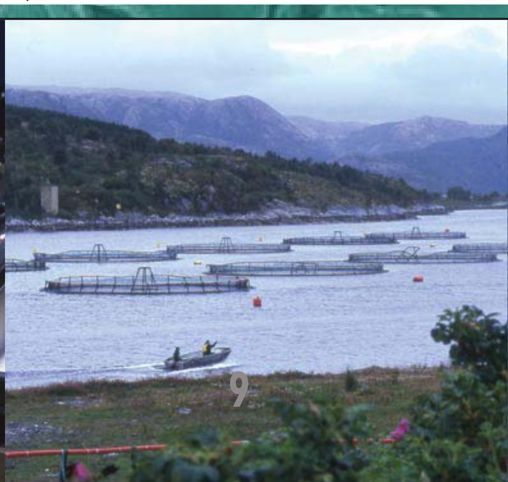

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Conservation

Biodiversity conservation

The development and expansion of human societies impose serious impacts on biodiversity. Biotelemetry studies may generate information on habitat use, movement patterns, behavioural and physiological response to stimuli, and energetics of aquatic species. Such information is essential for managers and scientists who aim to improve or protect species and ecosystems, forming the basis for quantifying species interaction and competition, effects of environmental factors, and influence of anthropogenic factors and practices.

Interactions between introduced and native species

Humans have during the last century made countless efforts of "improving" ecosystems by introducing non-native species. This has almost exclusively resulted in negative ecosystem effects. Considerable efforts have been made to clarify the consequences of introduction of non-native species and to develop mitigation strategies. Such efforts rely on detailed and basic biological knowledge, both of the native and the introduced species. Biotelemetry studies may illustrate the consequences of introductions and validate effects of mitigation actions by providing data on distribution and habitat use of the introduced species and interactions between native and non-native species under natural conditions.

Evaluation of conservation measures

Knowledge based conservation measures are important to protect biodiversity. Examples are removal of introduced species, reintroduction of eradicated populations and establishment of sanctuaries and conservation areas. Planning and evaluation of such measures are particularly difficult in aquatic environments due to problems with obtaining reliable and detailed basic biological information. Because biotelemetry allows collection of detailed biological data under natural settings, it can be used to quantify effects of conservation measures. It is for instance possible to utilize data on animal movements and migration to predict whether sanctuaries are adequate with respect to sanctuary size, location, and habitat composition.

NINA's competence in aquatic biotelemetry

The Norwegian Institute for Nature Research (NINA) has a broad and multidisciplinary competence within aquatic management and research. As a supplement to the traditional methodologies within the field, NINA has through the last 15 years developed a world leading competence with regard to aquatic biotelemetry. NINA has worked with aquatic biotelemetry both in Norway and several other countries and continents. The work has focused on a wide range of topics within basic, applied and management related research and has been carried out in freshwater, marine, and estuarine ecosystems in temperate, sub-tropic and tropic climate. Almost thirty species have been tagged and monitored successfully under a wide range of environmental conditions. The reference list below indicates the diversity of NINA's competence in aquatic biotelemetry. NINA will also in the future strongly focus on further development of the use of biotelemetry as a supplement to more traditional methodologies in aquatic management and research.

Our goal is to provide the best information and advice to management agencies, industry and societies in all aspect of natural resource management and sustainable use of resources.

photo: Odd Terje Sandlund

photo: Tor Næsje

Aquatic Telemetry Publications, Norwegian Institute for Nature Research (NINA)

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TELEMETRY

Foto/illustrasjoner: T. F. Næsje, C. Hay, I. Uglem, E. Thorstad, E. Olderøyen

Arctic grayling (*Thymallus thymallus*)

Elf (*Potamatomus saltatrix*)

Lake trout (*Salvelinus namaycush*)

Northern pike (*Esox lucius*)

Mozambique tilapia (*Oreochromis mossambicus*)

Redbreast tilapia (*Tilapia rendalli*)

Threespot tilapia (*Oreochromis andersonii*)

Lumpsucker (*Cyclopterus lumpus*)

Common carp (*Cyprinus carpio*)

African pike (*Hepsetus odoe*)

White steenbras (*Lithognathus lithognathus*)

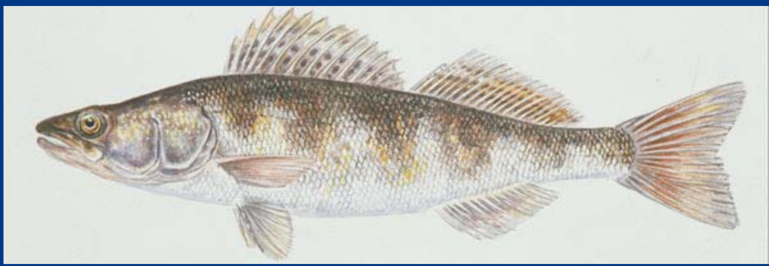
Spotted grunter (*Pomadasys commersonnii*)

White stumpnose (*Rhabdosargus globiceps*)

Atlantic cod (*Gadus morhua*)

Brown trout (*Salmo trutta*)

Pink happy (*Sargochromis giardi*)



Pikeperch (*Stizostedion lucioperka*)

Tigerfish (*Hydrocynus vittatus*)

Eel (*Anguilla anguilla*)

Dusky grouper (*Epinephelus marginatus*)

Pollack (*Pollachius virens*)

Nembwe (*Serranochromis robustus*)

Arctic char (*Salvelinus alpinus*)

Atlantic salmon (*Salmo salar***)**

Sharptooth catfish (*Clarias gariepinus*)

Greenhead tilapia (*Oreochromis macrochir*)

Humphback largemouth (*Serranochromis altus*)

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