Chapter 7. Glossary of Ecological Terms

Information Sources

The terminology used in chapters 1 through 6 is common in fishery science and quantitative ecology. The list of science terms identified in this glossary focuses not only on the common vocabulary used but also the uncommon and specialized terminology used in this report and its appendices. Each is accompanied by a definition that best reflects the meaning conveyed by the authors. A number of online resources and scientific references were consulted in preparation of the glossary. In many instances, the terms relate to fish population dynamics and quantitative concepts and, in these cases, the primary scientific references have been cited. The web sites used to develop definitions for more descriptive biological terminology include (1) A Glossary of Ecological Terms (http://www.terrapsych.com/ecology.html); (2) The Nature Education Knowledge Project (http://www.nature.com/scitable/knowledge); (3) Encyclopedia Britannica (https://www.britannica.com/); (4) FishBase (http://www.fishbase.org/); (5) Merriam-Webster Online (http://www.merriam-webster.com/); and (6) The Free Dictionary (http://www.thefreedictionary.com/). An extensive glossary of fishery science terms is presented in Mecklenburg and others (2002). Where appropriate, the definitions are presented with special attention to their application to meaning in the Chukchi and Beaufort Seas.

Science Terms

Abundance Generally, there are three types of abundance measures: total number of animals in a population (absolute abundance), number of animals per unit area (density), and abundance and density of one population to another (relative abundance). Because temporal variation in a population is often described in density and biomass parameters, the distinction between biomass and other abundance measures is important. Biomass, expressed as mass per unit area, or mass per volume, reflects the quantity of resources incorporated by the population (that is, bioenergetics) and as such, is an indicator of its relative role in the ecosystem (Odum, 1985).

Age The length of time during which a being or thing has existed; the number of years of life completed (fishery statistics). Age estimation is a fundamental part of studies of the life history of fish and a key area in the monitoring, assessment, and management of fish stocks because age determined parameters underlie the population-dynamics models used for fish stock assessments. The age-determined parameters include age profiles and age at first maturity, and, when considered with length and weight measurements, provide valuable information about stock composition, age at maturity, life span, mortality, and stock production (Ricker, 1975).

Age at first maturity (t_m) Mean or median age at first maturity (that is, age at which 50 percent of a cohort spawn for the first time). Values are estimated from population parameters in the von Bertalanffy Growth Model (VBGM)[1] (Ricker, 1975).

Age and growth Basic information about the age and growth of a species and the environmental area inhabited by that species is foundational to effective fishery management. Habitat is the natural environment that influences and is used by a species population. The relations between length and weight and size and age form the basis for population dynamics (that is, population growth and production models) and quantitative analysis of environmental effects. Importantly, the relation between total length (L) and total weight (W) for nearly all species of fish is expressed by the equation (Ricker, 1975):

$$W = aL^b \text{ or } \ln W = \ln a + b \ln L \tag{1}$$

where

W	is weight, in kilograms;
L	is length, in centimeters;
a	is y-intercept; and
b	is slope.

[1]The von Bertalanffy Growth Model is also expressed as the von Bertalanffy Growth Function (VBGF) and von Bertalanffy Growth Equation in the scientific literature.

A well-known growth model is the VBGM, which is based on a bioenergetics expression of fish growth converts length-frequency data into age composition (see, for example, Essington and others, 2001). The model expresses length (*L*) as a function of the age of the fish (*t*):

$$L_t = L_\infty\left(1 - e^{-k(t-t_0)}\right) \text{ or } L(t) = L_\infty * \left[1 - exp\left(-K*(t-t_0)\right)\right] \quad (2)$$

where

- L_t is the length at time t; t_0 the hypothetical age of the fish at zero length;
- K is the growth coefficient, the rate at which L_1 approached expressed as the rate (per year) at which L_∞ is approached (also see "Carrying capacity"); and
- L_∞ is the asymptotic length, the mean length a given stock would reach if it were to growth indefinitely.

Estimation of growth parameters (K, L_∞, t_0) of the VBGM are good indicators of stock condition and health. The right hand side of the equation contains the age, *t*, and some parameters. They are: "L_∞" (read "*L-infinity*"), "*K*" and "t_0" (read "*t-zero*"). Different growth curves will be created for each different set of parameters; therefore, it is possible to use the same basic model to describe the growth of different species simply by using a special set of parameters for each species.

Age structure The distribution of ages, or classes of ages, of individuals of a population. The presence of separate cohorts in fish populations may reflect adaptations in life strategies to cope against year to year variability in environmental conditions (Ricker, 1975).

Ammocoetes The larval stage of the primitive lamprey, known as an ammocoetes larva. Resembling a small eel, the larval lamprey can remain concealed in the sediments of rivers and estuaries from 7 to 17 years. Burrows are detectable as funnel shaped depressions, and in shallow, clear, flowing springs and streams, the ammocoetes larva will often expose their heads orienting their buccal cavities and gills into the current. Throughout the larval stage, there is a passive downstream migration of ammocoetes leading to maturity, and in some species, parasitism.

Amphidromy (of a migratory fish) that travels between freshwater and salt water, but does not travel to breed.

Anadromy (of a migratory fish) that lives in the sea and breeds in fresh water.

Arctic realm One of 12 marine realms as designated by the World Wildlife Federation and The Nature Conservancy. It includes the coastal regions and continental shelves of the Arctic Ocean and adjacent seas, including the Arctic Archipelago, Hudson Bay, and the Labrador Sea of northern Canada, the seas surrounding Greenland, the northern and eastern coasts of Iceland, and the eastern Bering Sea.

Axon An axon (from Greek, axis) also known as a nerve fiber, is a long, slender projection of a nerve cell, or neuron, that typically conducts electrical impulses away from the neuron's cell body. The function of the axon is to transmit information to different neurons, muscles, and glands.

Axoplasm Axoplasm is the cytoplasm within the axon of a neuron (nerve cell). Neural processes (axons and dendrites) contain about 99.6 percent of the cell's cytoplasm, and 99.7 percent of that is in the axons.

Baseline Initial collection of data, which serves as a basis for comparison with the subsequently acquired data.

Behavior Traditional fishing methods, scientific surveys, population modeling, and fishery management strategies are dependent upon a fundamental understanding of fish behavior. Behavioral research develops information about the relationships between fish behavior and environmental variables (physical and biological), and how this influences distribution, survival, and recruitment processes. Species have evolved particular behaviors to cope with environmental temperature and light, foods and predators, and reproduction.

Biodiversity Biological variety of the kind that preserves species and their DNA. Other definitions are (1) the number of species in an ecosystem, (2) the diversity between ecosystems, and (3) the diversity of entire regions. Depleted biodiversity leads to population crashes, declines in genetic variability, and extinctions.

Biogeography Biogeography is the study of the distribution of species and ecosystems in geographic space and through geological time. Organisms and biological communities vary in a highly regular fashion along geographic gradients of latitude, elevation, isolation, and habitat area.

Biogeographic province Provinces, as defined in biogeographic classification schemes, are nested within the realms.

> *Provinces are large areas defined by the presence of distinct biotas that have at least some cohesion over evolutionary time frames. Provinces will hold some level of endemism, principally at the level of species. Although historical isolation will play a role, many of these distinct biotas have arisen as a result of distinctive abiotic features that circumscribe their boundaries. These may include geomorphological features (isolated island and shelf systems, semienclosed seas); hydrographic features (currents, upwellings, ice dynamics); or geochemical influences (broadest-scale elements of nutrient supply and salinity)* (Spalding and others, 2007, p. 575).

The BOEM Arctic Planning Areas are nested within the Arctic realm and the boundaries that include Chukchi and Beaufort Sea provinces. The Beaufort Sea province includes continental coast and shelf waters of the United States and Canada.

Brackish In the Arctic, brackish typically refers to salinity conditions of 10–25 practical salinity units (psu). Warm (5–10 °C) brackish waters have estuarine-like qualities (Craig, 1989a).

Carrying capacity (*K*) In nature, population growth must eventually slow, and population size ceases to increase. As resources are depleted, population growth rate slows and eventually stops, known as logistic growth. The population size at which growth stops is generally called the carrying capacity (K), which is the number of individuals of a particular population that the environment can support. At carrying capacity, because population size is approximately constant, birthrates must equal death rates, and population growth is zero. Growth rate $K\,(1 - L\,(t)/L_{\infty})$ decreases with time as the length of the fish reaches asymptotic length (Ricker, 1975).

Chukchi borderlands The gateway to the Arctic Ocean, located 600 miles north of the Bering Strait and 800 miles south of the North Pole. From Jakobsson and others (2008, p. 527):

> *The Chukchi Borderland is comprised of a group of generally less than 1000 m deep, north-trending ridges that surround the extensional Northwind Basin (Figure 2) (Hall, 1990). The easternmost of these ridges is the Northwind Ridge, which is deeper than its western neighbours and is characterized by an exceptionally steep slope towards the Canada Basin and a gently rounded to flat topped ridge crest. The Chukchi Spur–Chukchi Plateau composite ridge lies on the western side of the Northwind Basin and has a wide (>140 km at 78° N) flat topped crest mainly shallower than 600 m (Figure 2(a)). In addition to the large Northwind Ridge and Chukchi composite ridge, several much smaller ridges rise above the floor of the Northwind Basin.*

Location of existing fish sampling and related catch characteristics is available in Mecklenburg and others (2014).

Colonization The spreading of a species into a new habitat. Successful colonization, as used in this report, implies the success of a reproductive event in the newly occupied habitat.

Compensation (density dependent processes) Population processes such as survival, growth, reproduction, and movement are considered density dependent if their rates change as a function of population abundance (Ricker, 1975). Processes that limit population growth at high abundances (for example, slower growth, increased emigration, and lower survival) or increase numerical growth at low population abundances (for example, faster growth, increased immigration, and higher survival) are examples of direct density dependence or compensation. Direct density dependent processes operate as a negative feedback and tend to stabilize population abundance.

Crepuscular feeder Crepuscular feeding occurs primarily at twilight (that is, during dawn and dusk). This is opposed to diurnal and nocturnal feeding behaviors, which occur respectively during hours of daylight and dark.

Dendrite Dendrites are the branched projections of a neuron that act to propagate the electrochemical stimulation received from other neural cells to the cell body, or soma, of the neuron from which the dendrites project. Electrical stimulation is transmitted onto dendrites by upstream neurons (usually their axons) through synapses located at various points throughout the dendritic tree. Dendrites play a critical role in integrating these synaptic inputs and in determining the extent to which action potentials are produced by the neuron.

Depensation (density independent processes) If population processes, such as survival and growth, decrease at low population abundances or increase at high abundances, they are referred to as inverse density dependence or depensation (Ricker, 1975). Inverse density dependent processes operate as a positive feedback and tend to destabilize populations.

Diadromy Migration of fish in either direction, from fresh to seawater or the reverse.

Ecosystem A biotic community and its surroundings, part inorganic (abiotic) and part organic (biotic), the latter including producers, consumers, and decomposers.

Ecological niche Describes the relational position of a species or population in an ecosystem. More formally, the niche includes how a population responds to the abundance of its resources and enemies (for example, by growing when resources are abundant and predators, parasites and pathogens are scarce) and how it affects those same factors (for example, by reducing the abundance of resources through consumption and contributing to the population growth of enemies by falling prey to them). The abiotic or physical environment also is part of the niche because it influences how populations affect, and are affected by, resources and enemies. The description of a niche may include descriptions of the organism's life history, habitat, and place in the food chain.

Endemism The ecological state of a species being unique to a defined geographic location, such as an island, nation, country or other defined zone, or habitat type; organisms that are indigenous to a place are not endemic to it if they are also found elsewhere.

Epipelagic Of, relating to, or constituting the part of the oceanic zone in which enough light penetrates for photosynthesis.

Extralimital (pertaining to a species) Not found within a given geographical area.

Eurythermic The animal is adaptable to a wide range of temperatures in the environment.

Food and feeding The numerical assignment of an organism to a trophic level has evolved to include ecological insight about a species position and interactions within a food web or ecosystem (Odum and Heald, 1975). In classic food web studies (Lindeman, 1942)[2], five (T1-5) trophic levels were recognized by ecologists. Lower trophic levels classified as producers (T1) and herbivores (T2), and higher trophic levels and primary and secondary carnivores (T3 and T4, respectively) and apex consumers (T5). Analysis of stomach contents often is used to associate a species with a specific level, intermediate standing between levels, or multiple levels. Recent models of trophic interactions (for example, Christensen and Pauly, 1992; Pauly and Watson, 2005) include a food-based fractional component in trophic level analysis to quantify the relative importance of prey in the consumers diet as well as the role of primary production. Model results present trophic level designations as continuous numbers ranging from 1 to 5. Age-related variations in foods habits are known in marine fish and thus, in reality, trophic level status will change over time. In most instances, deficiencies in life-history information have limited existing analyses to trophic level determinations based on combined data sets for juvenile and adult life stages. Although imperfect, the fractional analysis is meant to improve ecosystem understanding and energy flows because it more realistically addresses the complexities of consumer feeding behaviors (omnivory and feeding across multiple trophic levels) and predator-prey relationships. To illustrate, the mean trophic level for Blackline Prickleback (*Acantholumpenus mackayi*) is 3.1 (±0.31). This mid food web value is indicative of a primary carnivore that feeds across trophic levels, in this case on lower level herbivores. The trophic level values reported herein are as reported in FishBase (Froese and Pauly, 2012).

Generation time The average age (t_g) of parents at the time their young are born. In most fishes, L_{opt} (derived as a growth parameter in the VBGM) is the size class with the maximum egg production. The corresponding age (t_{opt}) is a good approximation of generation time in fishes. It is calculated using the parameters of the VBGM as $t_g = t_{opt} = t_0 - \ln(1 - L_{opt} / L_{inf}) / K$. Note that in small fishes (<10 cm) maturity is often reached at a size larger than L_{opt} and closer to L_{inf}. In these cases, the length class where about 100 percent (instead of 50 percent) first reach maturity will contain the highest biomass of spawning fishes, usually resulting in the highest egg production. As an approximation for that length class, most fish most fish are assumed to have reached maturity at a length that is slightly longer than L_m, namely: $L_{m100} = L_m + (L_{inf} - L_m) / 4$, and generation time is calculated as the age at L_{m100}. This is applied whenever $L_m >= L_{opt}$.

Gonochoristic The state (gonochorism) of having just one of at least two distinct sexes in any one individual organism.

[2]Some scientific literature refers to trophic levels T1-5 as I-V.

Growth The study of growth means the determination of the body size as a function of age (Ricker, 1975). Therefore, all stock assessment methods work essentially with age composition data. 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. The VBGM is widely to estimate of productivity parameters.

Specific growth rate (K) is given by:

$$K = (\ln w_t - \ln w_o) / t \tag{3}$$

where

w_t is the final weight and w_0 the initial weight,
t is equal to the number of days considered, and
K is assumed to be constant.

Hence, the individual growth is described by an exponential expression, relating the weight of the fish to time.

Growth model A primary interest of fisheries biologists is to estimate rates of fish population growth and understand the processes and factors that influence growth. Age and growth information is critical for research addressing questions about basic ecological relations and for managing fisheries. In the latter case, growth information is frequently used to populate assessment models with vital rates and age-specific length, weight, fecundity, and vulnerability to exploitation.

Additionally, information on growth may be used to estimate the age of fish based on size. Given the importance of understanding growth, much effort has been expended to understand factors that influence growth, to develop models to describe observed growth patterns, and to estimate the parameters of those models.

The decision about which growth model to use is important because most ecological models deal with transfer of energy or matter along the trophic chain. Growth can be constant or change during development periods. Although initial and final weights estimated with different models may be similar, growth curves as well as the total amount of energy or matter consumed over time may vary considerably during the growth period. It is suggested that the Gompertz or the parabolic growth models seem to be more appropriate for the description of young fish growth. For older fish, the VBGM equation or some modified form adjusted to seasonal change is preferable (Gamito, 1998).

Intrinsic rate of increase (r_m) The rate of increase in populations that reproduce within discrete time intervals and possess generations that do not overlap. The r_m is calculated as number of births minus number of deaths per generation time (reproduction rate less the death rate). Values greater than zero indicate that the population is increasing, the higher the value, the faster the growth rate. A population that has intrinsic rate of increase of zero is considered to have a stable age distribution (neither growing nor decreasing in numbers).

A growing population has more individuals in the lower age classes than does a stable population, and a decreasing population has more individuals in the older age classes than a stable population (Musick, 1999).

Iteroporous A reproductive strategy (iteroparity) in which the species is characterized by multiple reproductive cycles over the course of a lifetime.

***K*-selection** Species in stable environments tend to live longer and produce fewer, and sometimes larger, offspring. (*K* is the constant for carrying capacity in terms of population growth.)

Lateral line A system of sense organs in aquatic vertebrates, mainly fish, used to detect movement and vibration in the surrounding water. The sensory ability is achieved by modified epithelial cells, known as hair cells, which respond to displacement caused by motion and movement and transduce these signals into electrical impulses through excitatory synapses. Lateral lines serve an important role in schooling behavior, predation, and orientation.

Length (*L*) The length-frequency of a fish population is a key determinant in analyses of status and trends (Ricker, 1975). The length distributions of fish in samples give the simplest index of the composition of the stock from which the catch was taken. (Weight measurements are also required for determination of length-weight relationships and condition analysis.) Length measurements are reported as standard length, total length, and fork length by fishery investigators.

- **Standard length (SL)** refers to the length of a fish measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the mid-lateral part of the hypural plate. This measurement excludes the length of the caudal fin.
- **Total length (TL)** refers to the length from the tip of the snout to the tip of the longer lobe of the caudal fin, usually measured with the lobes compressed along the midline. It is a straight-line measure, not measured over the curve of the body.
- **Fork length (FL)** refers to the length from the tip of the snout to the end of the middle caudal fin rays and is used in fishes in which it is difficult to tell where the vertebral column ends.

Life span (t_{max}) Life span is a central aspect of life history diversification. The parameter t_{max} is the approximate maximum age that fish of a given population would reach. It is calculated as the age at 95 percent of L_∞ using the parameters of the VBGM. Life span is frequently estimated from maximum age and size data (Ricker, 1975).

Life span depends on the organism's survival schedule and is often associated with fecundity. The combination of survival and fecundity fitness components constitutes the basis for understanding the evolution of life histories. The theory of *r*- and *K*-selection expects that life histories can evolve toward short or long life spans because of variation in ecological factors such as resource availability. Resource limitations impose trade-offs between different fitness components (for example, reproductive effort compared with individual growth rate) that are expected to translate into different demographic patterns. For example, as life span increases, the importance of fecundity for overall population dynamics is progressively replaced by that of survival.

Limiting factors All living things need food, water, shelter, and space to survive. As long as organisms have all of these things available to them their population will continue to grow. However, populations cannot grow forever. Some form of environmental resistance will stop the growth of a population (Ricker, 1975). The form of environmental resistance is called a limiting factor because it limits the population. However, limiting factors also may increase a population. In nature, population growth must eventually slow, and population size ceases to increase. As resources are depleted, population growth rate slows and eventually stops (known as logistic growth). The population size at which growth stops is generally called the carrying capacity (*K*), which is the number of individuals of a particular population that the environment can support. At carrying capacity, because population size is approximately constant, birthrates must equal death rates, and population growth is zero.

Limitations to population growth are either density-dependent or density-independent. Density-dependent factors include disease, competition, and predation. Density-dependent factors can have either a positive or a negative correlation to population size. With a positive relationship, these limiting factors increase with the size of the population and limit growth as population size increases. With a negative relationship, population growth is limited at low densities and becomes less limited as it grows.

- Density-dependent factors may influence the size of the population by changes in reproduction or survival (for example, food availability—effects on fecundity and [or] habitat condition)
- Density dependent factors also may affect population mortality and migration.

Factors that decrease population growth can be defined as environmental stress including limitations in food, predation, and other density-dependent factors. However, many sources of environmental stress affect population growth, irrespective of the density of the population. Density-independent factors, such as environmental stressors and catastrophe, are not influenced by population density change. Although the density-dependent factors are often biotic, density-independent factors are often abiotic. These density-independent factors include food or nutrient limitation, pollutants in the environment, and climate extremes, including seasonal cycles such as monsoons. Catastrophic factors such as fires and hurricanes also can affect population growth (Monterio, 2002).

Some important density-independent factors include:

- The quality of nutrients (for example, food quality, and amount of particular plant nutrients) in an environment affects the ability of an organism to survive, grow, and reproduce.
- Pollutants also contribute to environmental stress, limiting the growth rates of populations.
- Environmental catastrophes such as oil spills, fires, earthquakes, volcanoes, and floods can strongly affect population growth rates by direct mortality and habitat destruction.

Logistic population growth The geometric or exponential growth of all populations is eventually limited by food availability, competition for other resources, predation, disease, or some other ecological factor. If growth is limited by resources such as food, the exponential growth of the population begins to slow as competition for those resources increases. The growth of the population eventually slows nearly to zero as the population reaches the carrying capacity (K) for the environment. The result is an S-shaped curve of population growth known as the logistic curve (Ricker, 1975).

Myomeres The blocks of skeletal muscle tissue found commonly in chordates. They are commonly zig-zag, W- or V-shaped muscle fibers. The myomeres are separated from adjacent myomere by connective tissues and most easily seen in larval fishes. Myomere counts are sometimes used for identifying specimens because their number corresponds to the number of vertebrae in the adults.

Microphthalmia A developmental disorder of the eye that literally means small eye. One (unilateral microphthalmia) or both (bilateral microphthalmia) eyes may be involved.

Myosin structure Myosins are a family of Actin Motor Protein that are Adenosine triphosphate (ATP)-dependent motor proteins and are best known for their role in muscle contraction and their involvement in a wide range of other eukaryotic motility processes. They are responsible for actin-based motility. All myosins have head, neck, and tail domains with distinct functions.

Natural mortality (M) Natural mortality is a parameter in most fish stock assessment models (Ricker, 1975). Natural mortality can occur through predation or non-predation events such as senescence and disease. It is generally accepted that the natural morality is high during larval stages and decreases as the age of fish increases, approaching a steady state. The rate then increases exponentially when the fish nears maximum age. Natural mortality also may vary with size, sex, parasite load, density, food availability, and predator numbers. However, in most cases, a single value—usually 0.2—for M is assumed for stock assessments.

Neritic Shallow marine waters extending from mean low water to 200-meter depths.

Neuromast The major unit of functionality of the lateral line is the neuromast. The neuromast is a mechanoreceptive organ that allows the sensing of mechanical changes in water. There are two main varieties of neuromasts in animals, superficial or freestanding neuromasts and canal neuromasts. Superficial neuromasts are located externally on the surface of the body, whereas canal neuromasts are located along the lateral lines in subdermal, fluid filled canals. Each neuromast consists of receptive hair cells whose tips are covered by a flexible and jellylike cupula. See “lateral line.”

Otophysic A connection between the swimbladder and the inner ear that enhances the hearing capability in various types of fish.

Oviparous Fishes producing eggs that hatch outside the body of the mother.

Poikilotherm An organism whose internal temperature varies with the temperature of its surroundings.

Paedmorphic Of, relating to, or resulting from the retention of juvenile characteristics by an adult.

Phylogenetic relationships In biology, phylogenetics is the study of evolutionary relationships among groups of organisms (for example, species and populations), which are discovered through molecular sequencing data and morphological data matrices. The result of phylogenetic studies is a hypothesis about the evolutionary history of taxonomic groups: their phylogeny.

Population distribution Variation of population density over a particular geographic area.

Population dynamics Major abiotic and biotic factors that tend to increase or decrease the population size, age, and sex composition of a species.

Populations or stocks The subdivision of species into local populations and the adaptive nature of genetic differences between these populations are interlinked by the ecological and genetic processes that subdivide and determine the discreteness of these stocks. Genetic discreteness implies some restriction of gene flow and spatial and temporal mechanisms of isolation. Differences in genetic stock structure reflect behavioral processes and adaptation within the species particular life history strategy.

Management at the stock-level is a cornerstone of conservation biology. In fisheries, the stock refers to the part of the fish population that is under actual or potential use. Population dynamics describes the ways in which a given population grows and shrinks over time as controlled by birth, death, and emigration or immigration. The population levels of exploited marine fish stocks are regulated through many underlying processes. Biological and environmental conditions as well as exploitation rate and pattern determine the balance between the increase in stock size due to recruitment and growth and losses caused by fishing and predation mortality. Critical parameters for population dynamics evaluations include stock size, age structure, recruitment, and growth (Ricker, 1975).

Relative abundance The contribution a species makes to the total abundance of the fishery community (Miller and Lea, 1976). It is a measure that provides an index of the number of individuals present, but not the actual numbers. Relative abundance terms, such as “abundant,” “common,” or “rare” often are used to express the general population status of a given species, but are most useful when they are defined by something that is measured or estimated in a manner that makes comparison meaningful. The definitions used in individual studies conducted in Chukchi Sea vary greatly and often reflect the differences in sampling gears, geographical localities and habitats sampled, time of sampling, and statistical approach. Thus, attempts to tie reported indices of abundance from catch summaries of individual studies (that is, species composition or catch-per-unit effort data) proved too challenging initially for this analysis, especially for the more poorly known fauna.

Recruitment The reaching of a certain size or reproductive state. For fisheries, recruitment usually means addition of new fish to the vulnerable population by growth from smaller size categories (Ricker, 1975).

Reproduction (Reproduction mode, chapter 3) The reproductive strategies of marine, amphidromous, and anadromous fishes demonstrate sharp contrasts related to their adaptation to cold Arctic conditions. Marine species generally have shorter lives, grow more quickly, and achieve earlier maturity than the anadromous counterparts. The low abundance of many species suggests tendencies for niche generalists, rather than specialists, animals that feed at lower trophic levels, and whose population may be more affected by density independent factors. For most Arctic species, marine and anadromous-like, population or stock information about the population characteristics (for example, sex ratios, age-at-maturity, and fecundity) that affect reproductive potential does not exist. Little is known about spawning times and locations or mating behaviors of marine species, and what is known has come from data collection outside the study area (chapter 3).

Resilience In ecology, resilience traditionally refers to the ability of a biotic community to sustain or return to its former state after a disturbance. The rate of recovery is a measure of resilience determined by the population processes involved in restoring abundance to healthy, sustainable, or pre-disturbance levels (Musick, 1999). Resilience also is thought of as a measure of the amount of change or disruption that is required to transform a system from being maintained by one set of mutually reinforcing processes and structures to a different set of processes and structures.

The competing definitions emphasize different aspects of stability. The practical application of resilience concepts requires substantial information about population status and trends (for example, intrinsic rate of population growth), biological interactions, genetic relationships, and effects of natural and anthropogenic stressors.

The American Fisheries Society proposed a method to classify a population’s resilience (vulnerability to extinction) using VBGM parameters and other life history traits (Musick, 1999). In the two-tiered approach a population in is initially assigned to one of four productivity categories. The second part of the vulnerability assessment examines recent trends in population size and further classifies the productivity categories according to observed rates of decline. This approach to studying population resilience is a first approximation of extinction risk. This means that a population that is determined to be vulnerable merits further study or status review.

In the first step, the five most important productivity parameters evaluated are (in order of importance): (1) intrinsic rate of growth (r_m, expressed as an instantaneous or annual percentage), (2) growth coefficient (K), (3) fecundity (number of eggs per year), (4) age at maturity (t_m), and (5) maximum age (t_{max}) (table 7.1). The intrinsic rate of increase is considered to be most important because its calculation incorporates all of the other parameters. Musick (1999) and others note that this parameter is the most difficult to estimate and is usually not available. As such, when information on r_m is available, it takes precedence in assignments to a productivity category. Age at maturity is the next most important parameter because it often is correlated with the growth coefficient (K) and maximum age. Musick (1999) noted that although fecundity also is a key indicator, it needs to be properly assessed in light of demographics features of the population, especially maximum age. Many fish populations exhibit a direct correlation between age or size and fecundity. Because of this, Musick (1999) recommended using fecundity-at-first-maturity to assess resilience.

As a rule, in the absence of an estimate of r_m, the fish population should be classified according to the lowest productivity category for which data are available (table 7.2).

Table 7.1. Productivity parameters proposed to the American Fisheries Society for classifying resilience of marine fish populations.

[Adapted from Musick (1999). **Life history parameter:** r_{max}, intrinsic rate of increase; K, growth coefficient; t_m, age at maturity; t_{max}, maximum age. <, less than; >, greater than]

Life history parameter	Productivity category			
	High	Medium	Low	Very low
r_{max} (1/year)	>0.5	0.16–0.50	0.05–0.15	<0.05
K (1/year)	>0.3	0.16–0.30	0.05–0.15	<0.05
Fecundity (1/year)	>10,000	100–1,000	10–100	<10
t_m (years)	<1	2–4	5–10	>10
t_{max} (years)	1–3	4–10	11–30	>30

Table 7.2. Decline thresholds as a function of resilience/productivity and population decline.

[Adapted from Musick (1999). **Observed population decline**: Threshold is percentage of rate of decline in numbers or biomass of mature individuals in a marine fish population over the longer of 10 years or 3 generations]

Decline thresholds	
Productivity category	**Observed population decline**
High	0.99
Medium	0.95
Low	0.85
Very Low	0.70

As an example, a fish with high fecundity (>10^4), but late maturity (5–10 years), and long life span (>30 years), would be classified under the Very Low Productivity category. Generally, populations having VBGM growth coefficients (K) less than 0.10 and (or) intrinsic rates of increase (r_{max}) less than 10 percent per year may be especially vulnerable.

Once a population's productivity category is established, the second tier of the assessment considers rates of population decline (table 7.2). Population trends are analyzed over the longer of two periods: 1 decade or 3 generations. Information about decline (from Musick, 1999) is based on (1) population decline observed, estimated, inferred, or suspected in the past, or (2) population decline projected or suspected in the future based on (a) direct observation; (b) an index of abundance appropriate for the taxon; (c) a decrease in area of occupancy, extent of occurrence, and (or) quality of habitat; (d) actual or potential levels of exploitation; or (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites.

Richness Species richness is the number of different species represented in an ecological community, landscape, or region. Species richness is simply a count of species, and it does not take into account the abundances of the species or their relative abundance distributions. [3]

R-Selection Rapid growth and occupation through early reproduction, short life spans, low biomass, and many offspring.

Salinity The concentration of salts dissolved in water, measured in parts per thousand (‰) or practical salinity units (psu). Seawater averages 34 psu. Arctic salinities typically range from 27 to 32 psu. Ocean salinity is generally defined as the salt concentration (for example, sodium and chloride) in sea water. Salinity is most frequently measured in practical salinity units, a unit based on the properties of seawater conductivity, which is equivalent to parts per thousand or to grams per kilogram.

Semelparous Refers to a strategy whereas reproduction or breeding occurs only once in a lifetime.

Stock size (in weight) The weight of a fish stock or of some defined portion of a fish is known as biomass. Biomass is indicative of energy flows and the relative importance of a particular species to an assemblage or community level of organization. The established relations between fish length and weight are critical to the development of other key population parameters (Ricker, 1975).

Temperature Temperature is arguably the most important environmental variable to fish; Reynolds (1977, p. 734) describes this importance thusly:

> *Temperature serves as a proximate factor (cue, guidepost, sign stimulus, or directive factor) affecting locomotor responses of fishes. Although temperature can also serve as an ultimate ecological factor, as in behavioral thermoregulation, nonthermal factors may in some cases provide the ultimate adaptive or ecological value of a temperature response; some examples are habitat selection, intraspecific size segregation, interspecific niche differentiation, isolating mechanisms, predator avoidance, prey location, escape reactions, and migrations (thermoperiodic, diel, seasonal, spawning). Conversely, nonthermal variables such as light intensity or water depth may act as accessory proximate factors in thermoregulation. In spawning migrations, thermal requirements of eggs and larvae may take precedence over the (often different) preferenda or optima of adults. Although thermal responses of fishes are largely innate and species specific, ontogenetic and other changes can occur. Since temperature can serve as an unconditioned reinforcer in operant conditioning, thermal responses are not limited to simple kineses or taxes. Nonthermal factors such as photoperiod, circadian rhythms, currents, social and biotic interactions, stresses, infections, or chemicals can affect thermal responses, and may account for some lack of conformity between laboratory preferenda and field distributions and behaviors.*

Trophic level The step in a nutritive series, or *food chain, of an ecosystem. The organisms of a chain are classified into these levels on the basis of their feeding behavior*. The first and lowest level contains the *producers*, green *plants*. The plants or their products are consumed by the second-level organisms—the *herbivores*, or plant eaters. At the third level, primary *carnivores*, or meat eaters, eat the herbivores; and at the fourth level, secondary carnivores, eat the primary carnivores. These categories are not strictly defined, as many organisms feed on several trophic levels; for example, some carnivores also consume plant materials or carrion and are called *omnivores*, and some herbivores occasionally consume animal matter. A separate trophic level, the *decomposers*, or transformers, consists of organisms such as bacteria and fungi that break down dead organisms and waste materials into nutrients usable by the producers.