Chapter 2

Principles of Crustacean Taxonomy

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It is very important to know the living organisms around us. A species may occur in nature in many different forms (like sexes, larvae and morphs). Over one and half million species of animals have been described and it is estimated that about 3 to 10 million species still await discovery. It is therefore, necessary to put such a large number of species into definite groups so that their identities and properties are established. The assignment of a name to an organism provides the only key to all the information available about that species and its relatives (instead of lengthy descriptions). Careful and accurate identification and classification are of vital importance and if one wants to acquire knowledge in scientific way, the organisms should be grouped into smaller units.

Crustacean diversity: Crustaceans exhibit 4th largest diversity among the animal groups on the planet and include many well-known commercially exploited groups such as the prawns, crabs, and lobsters. The number of named species of Crustaceans worldwide is estimated at approximately 50,000 to 67,000 but the potential number of species may range from as many as ten times to one hundred times that number. The Crustaceans show an enormous diversity of form, and a great range of size from microscopic species measuring as little as a tenth of a millimetre to giant crabs, lobsters, and isopods with a body size of up to 4 meters in length or breadth, and weighing up to 20 kilograms. By virtue of their highly prized edibility, the decapod crustaceans are arguably the most popular invertebrates. The numbers of "small" species may be comparable to those of insects on the land. *e.g.* isopods currently number approximately 5,800 marine species, but recent estimates suggest that as many as 50,000 species of isopods could exist on coral reef habitats alone (Kensley 1988), a figure close the current total for all Crustacea, while Wilson (2003) estimated a total of 400,000 deep-sea species.

Species of Decapod Crustaceans: Decapod crustaceans comprising of shrimps, crabs and lobsters are commercially the most important group. Chace (1951) estimated for the first time 8,321 species of decapod crustaceans distributed among 1,000 genera and recently De Grave *et* *al*. (2009) estimated total number of extant species of Decapoda at 14,756 in 2,725 genera. This implies that in the last 50 years, the number of described species has nearly doubled. However, we are a long way from knowing the true global diversity of decapods. The number of known fossil species currently stands at 3,300, and discoveries will continue as new localities are explored, more revisions are completed and museum collections are more thoroughly studied.

As far as shrimps or prawns are concerned there are 3,047 species in the world grouped in to 4 categories, namely Sergestoidea (94 species), Penaeiodea (94 species), Stenopodidae (60 species) and Caridea (2,517 species) (FAO, 1998). Most of the commercial shrimp species belong to the 5 penaeidean families Solenoceridae, Aristeidae, Penaeidae, Sicyoniidae and Sergestidae - and 3 caridean ones - Pandalidae, Crangonidae and Palaemonidae. Another 2 caridean families, Hippolytidae and Alpheidae, contain species of some economic interest in the Western Indian Ocean. The shrimp fauna of the latter area is grouped into 27 families, only 9 of which include species fished commercially or of potential interest. There are about 340 species of prawns throughout the world (Holthuis, 1980), out of which 62 were recorded from the Indian waters by George (1979) until 1975. Recently, Kathirvel and Thirumilu (2011) have enlisted a total of 105 species of shrimps in 13 genera under the family Penaeidae from Indian waters.

Taxonomy, Classification, Systematics and Nomenclature

Taxonomy is the practice and science of classification. The word taxonomy coined by A.P. de Candolle (1813) is derived from the Greek words *taxis* (meaning 'order' or 'arrangement') and *nomos* (meaning 'law' or 'science'). Taxonomy uses taxonomic units, known as taxa (singular taxon). Originally *taxonomy* referred only to classification of organisms but now it is used in wider sense to the *principles* underlying such a classification. Another term 'Systematics' is often used in taxonomy. It is the system of classification developed by Carl Linne' in 1735. Systematics is often incorrectly used as synonym to taxonomy. Taxonomy actually deals with the naming and classification of organisms and forms only a part of biological systematics called the science of biodiversity. Classification is placing organisms into groups on the basis of their relationships. Such relationships are associations based on contiguity, similarity or both (Simpson, 1961). Taxonomy includes classification and nomenclature but heavily leans on systematics for the concepts. In taxonomy the smallest unit of classification is called 'species'.

Systematics includes taxonomy, identification, nomenclature, classification, diversity and differences between the organisms and their evolutionary interrelationships. The information provided by taxonomic research is a fundamental basis for all fields of biology.

Levels of taxonomy

Taxonomical study comprises 3 stages: 1) **Alpha taxonomy**, which deals with the description of new species and its arrangement in comprehensive genera. 2) **Beta taxonomy**, which works out relationships at the species level and 3) **gamma taxonomy** which emphasizes intra-specific variations and their evolutionary relationships *i.e.* study of speciation. In actual practice it is difficult to study any species in isolation as the three levels of taxonomy overlap each other. There are only a few groups of animals (birds & butterflies) where taxonomy has reached up to gamma level. Work in majority of animal groups including crustaceans is at alpha and gamma levels.

Concept of species

Species is a Latin term meaning “kind” or “appearance”. Generally, the knowledge about different organisms comes from ‘differences’ or ‘similarity’ in their appearance. According to Carl Linne’ species were distinguished by their external appearance or morphology. Although this principle is widely used to distinguish most of the species, it can not be applied to many plants and animals, and in particular micro-organisms such as bacteria and virus. Although many researchers have attempted a comprehensive definition of ‘species’, it is difficult. Traditionally, a large number of specimens of a proposed species must be studied for unifying characters before it can be regarded as a species. A usable definition of "species" is essential for stating and testing biological theories and for measuring biodiversity.

Over two dozen definitions of species are in use amongst biologists, yet none is uncontroversial. Cuvier (1829) defined ‘species’ as the assemblage descended from common parent who resemble each other. Thompson (1937) defined it as a group of individuals distinguished by common properties and connected by descent and genetic relationship. Huxley (1942) defined it as a geographically definable group having interbreeding members or potential to interbreed in nature. Mayr (1957) reviewed the problem of species definition and suggested to consider 3 concepts.

1. *Typological species concept:* According to this concept, the species can be recognized by their essential characters which are expressed in their morphology. Species is a group which can be segregated by their physical characteristics, colour, size, habitat etc from the other organisms. It is therefore, also called the *morphological species concept*.
2. *Biological species concept:* According to this concept species is a group of interbreeding natural population that is reproductively isolated from other such groups. Thus, the species has three 3 separate functions: *(i)* It forms reproductive community which has a species specific genetic programme that ensures intra-specific reproduction *(ii)* it is an ecological unit in which individuals interact and share the same environment *(iii)* it is a genetic unit consisting of a large gene pool while individual is a small, temporary pool for a short period.
3. *Evolutionary species concept:* Biological concept fails when organisms are uniparental and reproduce asexually. Evolutionary species concept considers species as a lineage (ancestral-descendent sequence of populations) with its unitary properties evolving separately from others.

Most textbooks follow Ernst Mayr's definition of a species as: ***Groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups.*** In addition to true taxonomic species, there are many other kinds pertaining to ecological and evolutionary concepts.

- Sibling species: Groups of similar or closely related species which are reproductively isolated but morphologically identical species.
- Cryptic species: These are extremely different and often taxonomically unrelated species in which one species conceals and protects itself from the enemies by cryptic colouration.
- Sympatric species: very close species occupying the same geographic area.
- Allopatric species: Two or more related species normally inhabiting different geographical areas.

- Syntopic species: Two or more related species which occupy the same micro-habitat and possibly interbreed.
- Allotopic species: Two or more related species which do not occupy the same micro-habitat and do not interbreed.
- Continental species: Those living on large land masses.
- Insular species: Those living on isolated islands.
- Polytypic species: Consisting of two or more sub-species.
- Monotypic species: Species with no subspecies.

Some species are so widely distributed that they form many local populations. If these populations are sufficiently distinct from each other, they are called subspecies. Species which contain two or more subspecies are called polytypic; this concept of polytypic species is very important in classification of animals. Certain local species that had been described from various parts of the world can be combined in to species groups (allopatric species) because they were obviously more close to one another than to any other species and live in mutually exclusive geographical areas. When gaps in the ranges of allopatric species are explored, they can be included into a single polytypic species.

Stocks: While describing the exploited aquatic fishery resources the fundamental concept is 'stock'. A stock is a smaller unit of a species. The term stock is used to describe a population inhabiting a particular geographical area having same growth and mortality parameters. Therefore, stock is a discrete group of animals with little mixing with adjacent groups. Cushing defined stock as a population having single spawning ground to which adults return year after year. Larkin (1972) on the other hand, defines it as population which shares a common gene pool that is sufficiently discrete to warrant consideration of self perpetuating system that can be managed. Gulland (1983) states that unit stock is an operational matter *i.e.* subgroup of a species that can be treated as stock, if possible differences within the group and interchanges with other groups can be ignored. In Indian waters, although species such as *Parapeneopsis stylifera* occur all along the west coast (8°-20°N), certain biological characteristics (spawning season, sex-ratio, fecundity) and growth parameters of the populations differ considerable along the coastal waters which warrant existence of several local stocks.

Subspecies: It is a universal fact that all species vary and it is known since long that certain species split into subspecies and races. Linnaeus and Fabricius preferred to call them varieties. Subspecies is the lowest taxonomically nameable category and defined as geographically separate aggregate of local populations of the species. Or it is a group within the species with strong morphological differences combined with geographic, ecological, edaphic or physiological distinctiveness. The subspecies must be able to interbreed if given an opportunity to do so. Only professional taxonomists can make a decision that the two races of a species are taxonomically different. Geographical subspecies are synchronic aggregates of populations which are isolated during their mating but they would crossbreed freely and normally.

Demes: Demes are morphologically homogenous group of organisms which are either from a single locality or habitat. Simpson (1961) preferred calling them *Demes* while Mayr (1969) called them *Phena*; but these terms have no nomenclature status. It is a group of individuals so localized that they are in frequent contact with each other.

Variety: Under typological principles each species has fixed pattern and any variant from the pattern is called a variety. Originally proposed by Linnaeus, this term is abandoned from the zoological nomenclature.

Morphotype or Form: It is 'variety' in second sense and has no standing in the nomenclature.

Cline: Any variation having gradation within species was called by Huxley (1938) as cline. This morphological gradation must be a measurable character.

Superspecies: It is defined as a monophyletic group of closely related and largely or entirely allopatric species (Simpson, 1961). The doubtful populations which could not be kept in species or subspecies were kept under a new semi-species to mark their intermediate nature. These have no place in zoological nomenclature.

Binomial nomenclature

Nomenclature means allocation of names to the taxa. Naming the animals is the first and foremost task of a taxonomist. The system of naming species of living things is called binary nomenclature or binomial nomenclature. This system of naming was invented by Linnaeus and the rules of naming the animals are now laid down in the International Code of Zoological Nomenclature (ICZN).

- In the binomial system of naming each species name has two parts, the **genus** name and **species** name (also known as the specific epithet), e.g. *Parapeneopsis stylifera*, which is the scientific name of the kiddi (karikadi) shrimp.
- The first letter of the genus is always capitalized, while that of the species is not, even when derived from a proper noun such as the name of a person or place.
- Every binomial scientific name is either formed out of Latin or is a Latinized version of words from other languages.
- Conventionally, all names of genera and lower taxa are always *italicized* (underlined while writing), while family names and higher taxa are printed in plain text.
- Species can be divided into a further rank, e.g. *Penaeus* (*Fenneropenaeus*) *indicus* H. Milne Edwards, 1837 giving rise to a *trinomial name* for a subspecies (*trinomen* for animals, *ternary name* for plants). The binomial name of a species is commonly known as its Latin name. However, biologists prefer to use the term 'scientific name' rather than "Latin name", because the words used to create these names are not always from the Latin language, even though words from other languages have usually been Latinized in order to make them suitable for this purpose. Often the species names are derived from Ancient Greek words, or words from numerous other languages.
- Frequently species names are based on the surname of a person, such as a well-regarded scientist (e.g. *Aristeus alcocki* and *Penaeus silasi*), or are a Latinized version of a relevant place name (e.g. *Metapenaeus kutchensis* and *Metapeneiopsis andamanensis*). The names of binomen have opposite functions- the species name expresses distinctness while generic name the relationship.
- While using the scientific name of a species, biologists usually also give the authority (Author who described it for the first time) and the date (year) of the species description. Thus, the scientific name of Indian shrimp species is given as: *Penaeus indicus* H. Milne Edwards, 1837 in which the name "H. Milne Edwards" tells the reader who described the species for the first time and 1837 is the date (year) of the publication in which the

original description can be found. In this case, the name of the author is not put in a bracket because the species name '*indicus*' was originally given by "H. Milne Edwards" and it was not transferred from any another genus described for the species. But when the latest nomenclature *Fenneropenaeus indicus* (H. Milne Edwards, 1837) is used, the author's name is put under the bracket as the species has been transferred from the genus *Penaeus* to *Fenneropenaeus* (Perez Farfante and Kinsley, 1997). In such a case, the authority that created the genus *Fenneropenaeus* does not get credit in the binomial nomenclature.

Significance of binomial nomenclature

Binomial nomenclature is widespread and it avoids confusion that is created when common names are used to refer to a species. Common names often differ even from one part of a country to another part, and certainly vary from one country to another. In contrast, the scientific name can be used all over the world, in all the languages, avoiding confusion and difficulties of translation. Scientific names are the only internationally (universally) recognized standard way of referring to biological organisms. They facilitate communication among not only scientists but also trading partners who speak different languages. Without their use and standardization, no two people could really be sure what organism they were talking about without both having seen it.

The procedures associated with establishing binomial nomenclature tend to favour stability. Even though such stability as exists is far from absolute, it is still advantageous *e.g.* when species are transferred between genera (as not uncommonly happens as a result of new knowledge), the species descriptor is kept the same. Similarly, if what were previously thought to be distinct species are demoted from species to a lower rank, former species names may be retained as infraspecific descriptors. The scientific names of animals from subgenera and above are uninominal and written with a capital letter. The ICZN stipulates standardized endings for the taxa: e.g. superfamily (-oidea), family (-idea), subfamily (-inae), tribe (-ini). This can be illustrated by classification of shrimps:

Phylum: Arthropoda
Class: Crustacea
Subclass: Malacostraca
Series: Eumalacostraca
Superorder: Eucarida
Suborder: Dendrobranchiata
Infraorder: Penaeidea
Superfamily: Penaeoidea
Family: Penaeidae
Subfamily: Penaeinae

Rules of Nomenclature

Typification: Designation of a nomenclatural type is called typification. It is the means by which scientific names are allocated to the taxa. A 'type' is a zoological object on which the original published description of a name is based. Once designated, the 'type' cannot be changed (not even by the original author) excepting the plenary powers of ICZN. Although Linnaeus never designated any specimen as 'type'; his descriptions were based on a single specimen and he substituted old specimens with the new ones. This practice continued in Europe for quite some time resulting in confusion in tracing the original specimens. The zoological code ruled for typification in 1901 for the future work. There are 41 different type series but commonly recognizes types categories are:

1) *Holotype*: A single specimen selected by the author of a species to give full description as a true type. A holotype must be labelled containing following data: Locality, date, size, sex, developmental stage, name of the host (if epizoic or parasitic) and name of the collector. It should be deposited in a recognized museum and assigned a registered number.
2) *Syntype*: Specimens from which the primary type (Holotype or Neotype) is selected.
3) *Paratype*: A specimen cited in the original description other than the holotype.
4) *Allotype*: It is a specimen of the opposite sex to the type.
5) *Apotype*: A specimen, not the type upon which a subsequent or supplementary description or figure is based on. It is also called *hypotype*.
6) *Topotypes*: Specimens identified as of special origin.

7) *Genotype*: The species which is designated as the type species of a genus upon which it is based.
8) *Geotype*: Specimen from the type locality.

***Abbreviation of species*:** Books and articles sometimes intentionally do not identify species fully and use the abbreviation "sp." in the singular or "spp." in the plural in place of the specific epithet: for example, *Metapenaeus* sp. This commonly occurs in the following types of situations: The authors are confident that some individuals belong to a particular genus but are not sure to which exact species they belong. The authors use "spp." as a short way of saying that something applies to many species within a genus, but do not wish to say that it applies to all species within that genus. If scientists mean that something applies to all species within a genus, they use the genus name without the specific epithet. In books and articles, genus and species names are usually printed in *italics.* If using "sp." and "spp.", these should not be italicized.

Name change and instability in nomenclature: One of the drawbacks with binomial system is its instability. Genera are often split or clubbed together and species are frequently shifted from one genus to another. Such changes reduce the efficiency of zoological nomenclature as a reference system. However, ICZN has flexibility to have such changes.

Michener (1964) proposed to freeze the original scientific names of a new species for all times by connecting the generic and specific names with a hyphen. This avoids the problem of homonymy, changes of generic and specific combinations and changes of specific endings to agree with gender of generic name. But it creates confusion in cases where the species have been transferred from one genus to other. The problem is aggravated further if the species belonging to altogether different family is transferred.

Use of parentheses: The author's name is put in parentheses when the species is transferred form one genus to other retaining its original author and date. It is called new combination. *e.g. Hemilea bipars* (Walker, 1862) Hardy, 1959. This means that Walker described the fruit fly species *bipars* originally in some genus but Hardy in 1959 transferred it to its correct genus *Hemilea*. This example gives the names of original authors as well as the one who transferred it.

Use of such double citation is purely optional under ICZN. Generally, original author in such cases is omitted to avoid double citation.

Under the Zoological code, the use of the citation of author's name and date in square bracket indicates that the name has been taken from indirect source (other than the original). In citing synonyms, square brackets are also used to include statement of misidentification.

Synonymy: Two or more names belonging to the same taxon are called synonyms. When there are number of synonyms for a species only the oldest one is valid by the Law of priority (ICZN). The oldest one is taken as the proper name and called senior synonym while the rest are treated as junior synonyms. The synonyms pose a great problem for the taxonomists. These are created due to lack of knowledge of the existing literature or not understanding the amount of variation a species may possess Many a times same species is described by two or more authors by different names without knowing that variations within the species. It is estimated that more than half of the synonyms are due to underestimation of the individual variations. It was reported that there were 251 species of fresh water mussel (*Anodonta* spp) which were actually variants of merely two species. However, synonymy provides considerable amount of information available in the literature.

Homonymy: The names which are spelt in an identical manner but based on different types are called homonymes. The ICZN rules that if two or more homonyms are found, only the oldest one (Senior homonym) is used while the rest are excluded. This may occur when identical based on different types are used at the same rank, e.g. subspecies in a species, species in a genus, and so on. The family-group names differing only in suffix are also considered synonyms. However, identical species names placed in different higher groups are not considered as homonyms i.e. *Noctua variegata* (Insecta) and *Noctua variegata* (Aves). The existence of two or more names based on different types is called *homonymy*.

Use of punctuation: Punctuation marks such as comma and colon are very important while writing scientific names. There should be no punctuation between the species name and the author's name and the year; if there such punctuations they have significance e.g. when *Penaeus monodon* Fabricius 1798 is written without comma between the species name and the author's name, it means Fabricius gave the specific name *monodon* and he is the original authority. When a comma between the species name and the author's name is inserted it would mean that the author is not the original discoverer but only quoting the taxa. and the year other authors make use of already published name and it is necessary to refer to such subsequent users of the name, they are authors of junior names (i.e. junior synonyms or repetition of already published ones). They should be cited after the original name but separated from it by a colon or semi-colon, never by a comma or full stop.

Priority: This is a controversial part of the zoological nomenclature but a basic law of ICZN to promote stability. Whenever two names belonging to the same taxon are discovered, the validity of one is decided by the law of priority. This means the valid name is the oldest (taken from the published records) with few exceptions. The authority of a name in family, genus or species is not changed on its elevation or reduction in rank within the group.

Advances in taxonomy at molecular level

Alpha taxonomy, and so biodiversity assessment remains today mainly based on morphological characters. Since morphology is complex and non-neutral, it may lead to under- or over-estimation of species diversity. Today's technology for sequencing DNA and barcoding have paved a way to molecular taxonomy at more objective level. For highly diversified crustaceans, sequencing of two mitochondrial genes, COI and 16 S rRNA have been found useful for correlation between taxonomic ranks and molecular divergence (Lefe'bure *et al*., 2006). DNA barcoding requires defining for each taxonomic group a set of molecular synapomorphies that can be used as taxonomic tags.

Cryptic species are common in crustaceans (Burton and Lee, 1994; de Bruyn *et al*., 2004). Crustaceans are also particularly abundant in extreme habitats which have tendency of morphological convergences leading to biodiversity under estimation. For these reasons crustaceans constitute a group for which DNA taxonomy could be highly valuable.