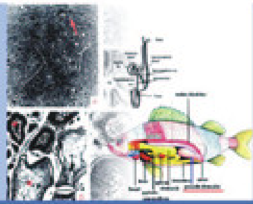

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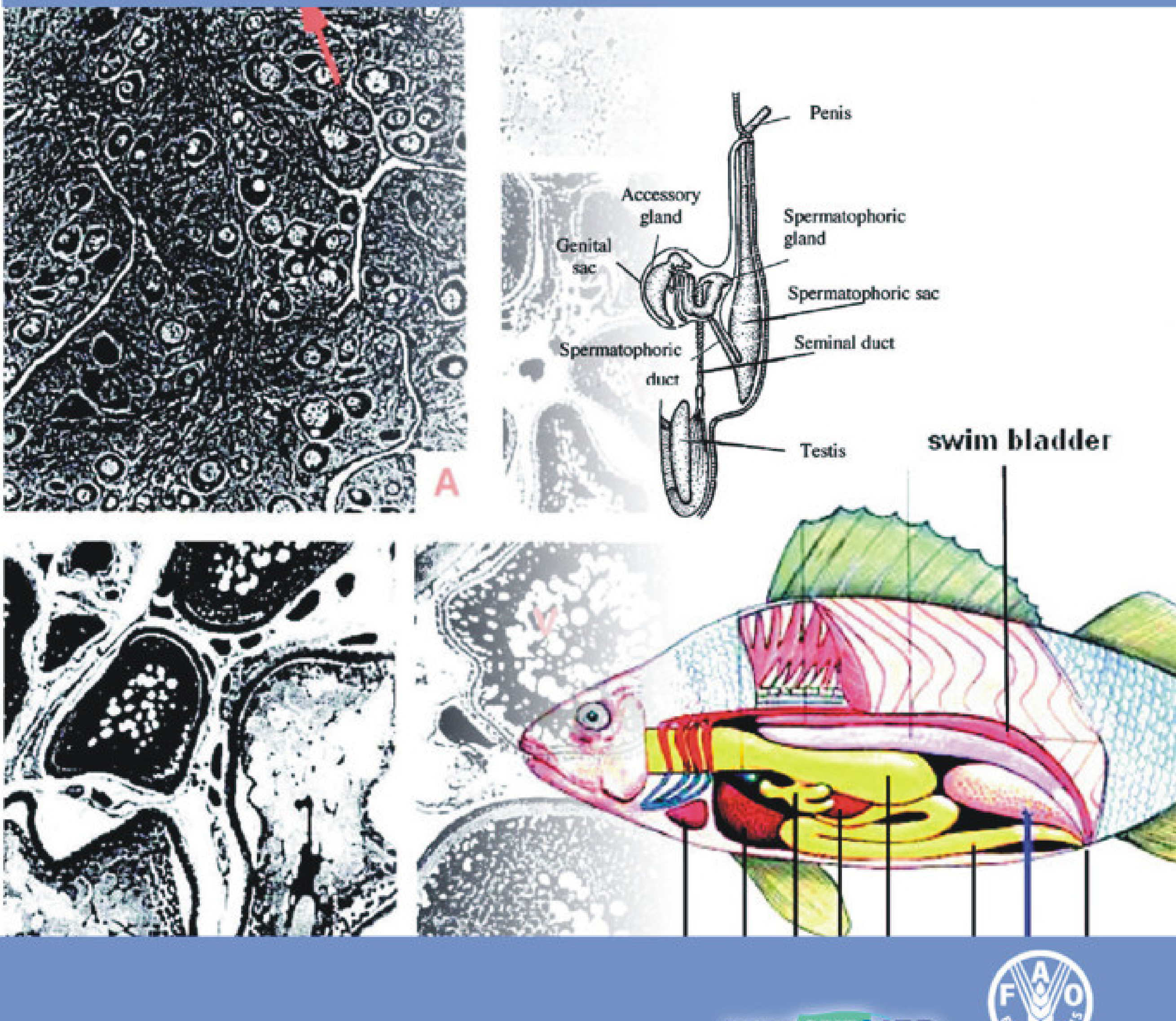
MEDSUDMED - TECHNICAL DOCUMENTS

Field manual on macroscopic identification of maturity stages for the Mediterranean fishery resources



MEDSUDMED
FAO FIAT PANIS

ASSESSMENT AND MONITORING OF THE FISHERY RESOURCES AND ECOSYSTEMS IN THE STRAITS OF SICILY

MiPAAF

MedSudMed

GCP/RER/010/ITA

Field manual on macroscopic identification of maturity stages for the Mediterranean fishery resources.

MedSudMed Technical Documents
GCP/RER/010/ITA/MSM-TD-21

Rome (Italy) December 2008

Preface

The Regional Project "Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily" (MedSudMed) is executed by the Food and Agriculture Organization of the United Nations (FAO) and funded by the Italian Ministry of Agriculture, Food and Forestry Policies (MiPAAF).

MedSudMed promotes scientific cooperation among research institutions in the four participating countries (Italy, Libyan Arab Jamahiriya, Malta and Tunisia) for the continuous and dynamic assessment and monitoring of the state of the fisheries resources and the ecosystems in this area of the Mediterranean.

Research and training are supported to increase and use knowledge on fisheries ecology and ecosystems, and to create a regional network of expertise. Particular attention is given to the technical coordination of the research among the countries, which should contribute to the implementation of the Ecosystem Approach to Fisheries. Consideration is also given to the development of an appropriate tool for the management and processing of data related to fisheries and their ecosystems.

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GCP/RER/010/ITA Publications

MedSudMed Project publications are issued as a series of Technical Documents (GCP/RER/010/ITA/MSM-TD-00) related to meetings, missions and research organized by or conducted within the framework of the Project.

Comments on this document would be welcomed and should be sent to the Project headquarters:

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Preparation of this document

This document is the Report of the Training Course on Macroscopic Identification of Maturity Stages for the Mediterranean Fishery Resources (Tajura, Libya, 9–11 July 2006) organized by the FAO MedSudMed Project (*Assessment and Monitoring of the Fishery Resources and the Ecosystems in the Straits of Sicily*).

Acknowledgements

The Project would like to thank Mr Ray C. Griffiths and Mr Luca Ceriola for their kind assistance in the technical editing of the draft version of this document.

N. Ungaro.
Field manual on macroscopic identification of maturity stages for the Mediterranean fishery resources.
MedSudMed Technical Documents No 21. GCP/RER/ITA/MSM-TD-21, Rome, 2008. 34 pp.

ABSTRACT

The MedSudMed Training course on macroscopic identification of maturity stages for the Mediterranean fisheries resources, Tajura, Libya, 9–11 July 2006 was primarily intended for the scientists of the Marine Biology Research Centre (MBRC) and focused on the macroscopic identification of maturity stages of demersal fishery resources. The objective was to teach the basic techniques for the processing of samples and macroscopic identification of maturity stages for different species of fish. More specifically, background information on maturity stages of demersal fishery resources, including basic notions and terminology, was provided. The course also included a general description of the reproductive organs of the main fishery resources (fishes, crustaceans and cephalopods), an analysis of slides illustrating the macroscopic identification of maturity stages in the Mediterranean species, a description of and comments on the maturity scales currently available. Practical exercises were organized with fresh samples of *Sardinella aurita*, *Scomber japonicus* and *Spicara flexuosa*, and simple techniques, algorithms and exercises to retrieve data on reproductive features (macroscopic) were taught. Following the biological analysis, simple elaboration of the resulting data was performed. All the participants in the course showed interest in the topics and some of them proposed the development of collaboration and new studies on the fish species distributed in the Libyan waters.

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Introduction

The technical manual was prepared and edited according to the terms of reference discussed and accepted by the MedSudMed Project Coordinator, the Project Fishery Monitoring Expert, the Head of Fishery Projects in the Marine Biology Research Centre (MBRC) of Tajura, Libya, and the Lecturer of the Course:

1. Gather and evaluate the available background information on the subject (scientific papers, maturity scales, etc.).

2. Provide a comprehensive overview of the techniques and scales used for the macroscopic identification of maturity stages.

3. Train the scientists in selection and dissection of fresh samples, identification of external signs of sexual maturity, extraction and analysis of reproductive organs and identification of maturity stages using available scales.

The manual is divided into four sections, in accordance with the activities carried out during the training course.

1 Background information and general description of the reproductive organs of the main fishery resources (fishes, crustaceans and cephalopods).

Studies and analysis of fish maturity are among the most important topics for the assessment and management of fishery resources. Irrational exploitation of the natural populations can produce a decrease in the relative number of the adult (mature) specimens and changes in the fish physiology (leading to e.g. decrease in length- and age-at-maturity, sexual inversion, compensatory adaptations). Knowledge of the species' lengths at maturity, the spawning periods and the sex ratio (overall and by size-class) can improve the best practice in the sustainable management of fisheries, particularly with respect to the regulation of gear selectivity and the fishing seasons.

1.1 Fish gonad maturity

The main object of the studies on maturity is the gonad and its development which is continuous and can be monitored by macroscopic and microscopic observations. Ovary and testes change their aspect and their relative weight during maturation according to the species' physiology, growth and/or external factors (environment and season). Some environmental variables, such as water temperature, light intensity and photoperiod, influence biological sensors, such as the eye and the pineal gland. The biological sensors send biochemical messages to the hypothalamus, which allows the production of the gonadotropic hormones by the pituitary gland. The target organs of the gonadotropic hormones are the gonads (ovary and testes). At the same time, gonad development affects the fish physiology by the release of estrogenic and androgenic hormones (feed-back options). During the full maturation and the spawning periods some biological activities, such as feeding, decrease. The relationship among maturation, spawning and feeding in Mediterranean fishes is shown in Figure 1

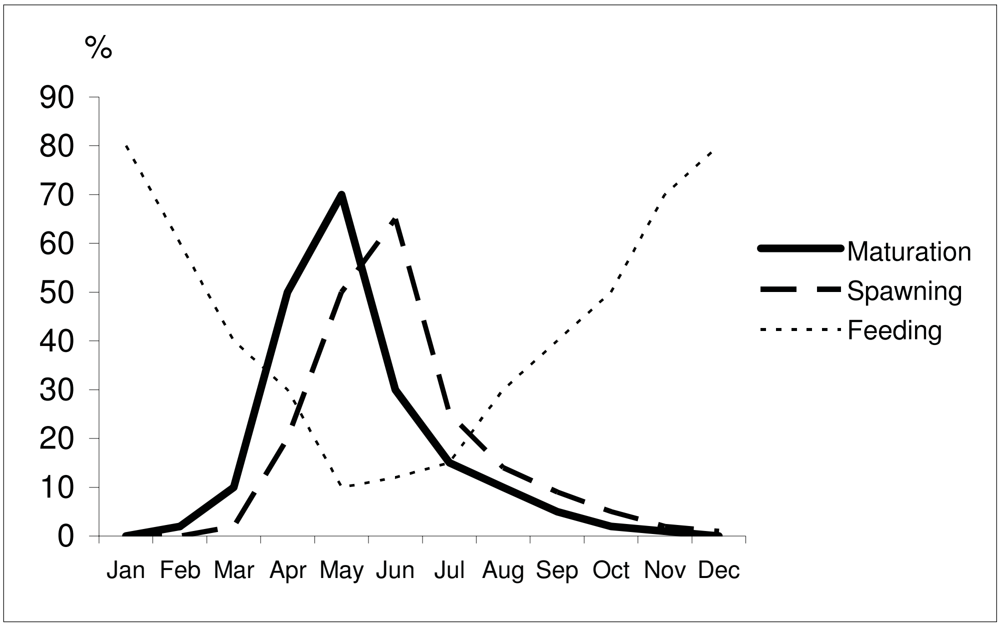


Fig. 1. Temporal relationship among maturation, spawning and feeding in Mediterranean fish species.

Gonad development, including changes in the volume, weight and shape, is marked by cellular modifications in the testis and ovary. The cellular modifications during the development of the testes are represented by the relative predominance of the different germinal stages: spermatogonia, spermatocytes, spermatids and spermatozoa. The cellular modifications during the development of the ovary are represented by the relative predominance and dimensions of the different germinal stages: oogonia, previtellogenic, vitellogenic and mature oocytes. Some examples of the different maturations stages at the microscopic level are shown in Figures 2 and 3.

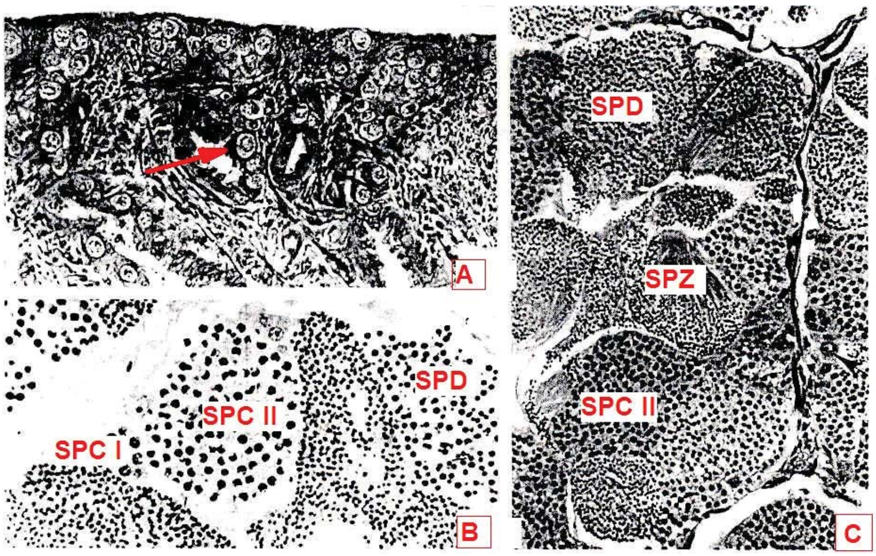


Fig. 2. Developmental stages in the testis of the Mediterranean amberjack (*Seriola dumerili* Risso). **A.** spermatogonia (*arrow*) in the lobule wall of an immature fish. **B.** *SPC I* and *SPC II* are spermatocytes at maturity stages I and II; *SPD* are spermatids in cysts in the lobule wall at stage III; **C.** *SPC II* spermatocytes at stage II; *SPD,* spermatids, and *SPZ,* spermatozoa (modified from Marino et al., 1995)

The cellular modifications and the development of the gonads in general affect some parameters, such as the gonad weight, as reported previously. The ratio between the gonad weight and the body weight (gutted or not) is conventionally called the "gonado-somatic index" (GSI). The value of the ratio is variable as a rule, depending on the fish length (age) and the season. The highest values of the GSI occur during the spawning season for species at the maturity length (age). The estimation of the gonado-somatic index by month can be useful for the identification of the spawning peaks during the year (if there are any).

Moreover, gonad development implies changes in gonad volume, shape, general aspect and colour. These features are adopted for the preparation of the macroscopic maturity scales, mostly based on the observations by eye of the different developmental stages of the testis or ovary. Of course, the validation of the stages by means of microscopic examination can improve the quality and the usefulness of the scales.

Defining the stage of sexual maturity of fish is also useful for the estimation of the length at first maturity. The length at first maturity is conventionally the size at which the 50% of the population attains an advanced stage of gonad development ($L_{m_{50\%}}$). The size (and age) at maturity is a species-specific value, as a rule, but it could be influenced by both environmental (i.e. temperature, food availability) and population (i.e. density) factors.

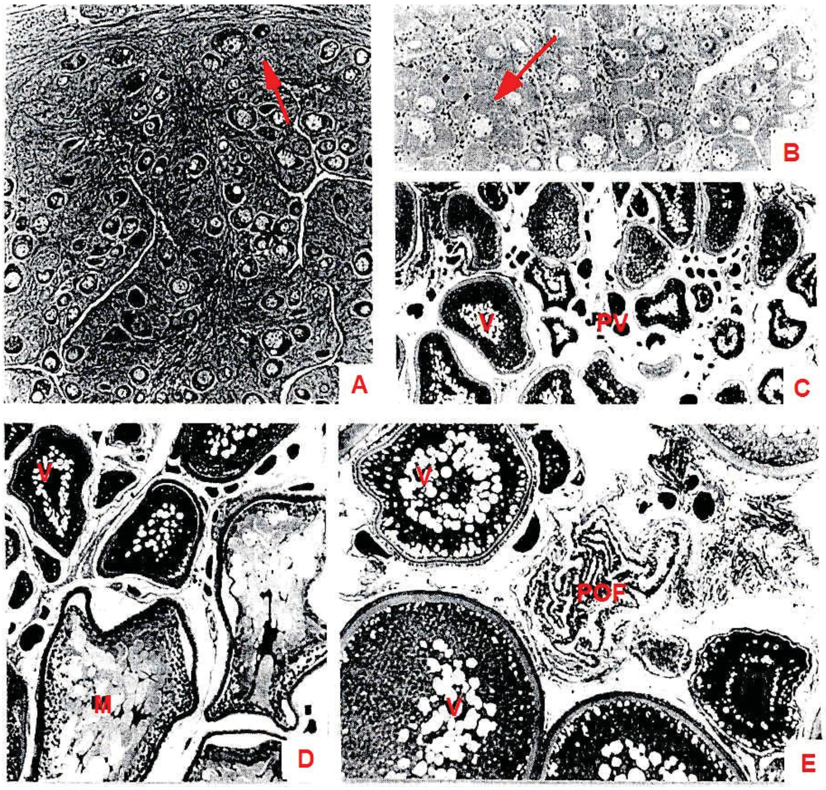


Figure 3. Developmental stages in the ovary of the Mediterranean amberjack (*Seriola dumerili* Risso). **A.** immature ovary; ovigerous folds contains nets of oogonia (*arrow*) and oocytes. **B.** perinucleolus-stage oocytes (*arrow*). **C.** maturing ovary, showing *PV* previtellogenic oocytes and *V* vitellogenic oocytes. **D.** mature ovary, showing *V* vitellogenic oocytes and *M* mature oocytes. **E.** a stage-V ovary, showing vitellogenic oocytes (*V*) and post-ovulatory follicles (*POF*) (modified from Marino *et al.*, 1995)

1.2 Basic concepts of fish maturity and related terminology

Some basic concepts and terminology are reported below by way of an introduction to fish reproduction biology:

- Oviparous species = egglayers
- Ovoviviparous species = incubate eggs and liberate young without providing any maternal source of nourishment other than that in the egg
- Viviparous species = nourish developing embryos
- Gonochoristic (diœcious) species = two separate sexes
- Hermaphroditic species = individuals produce both eggs and sperm
- Sequential hermaphroditic species = first male (protandrous) or first female (protogynous)
- Semelparous (monocyclic) species = spawn only once in their lifetime, die after spawning
- Iteroparous (polycyclic) species = spawn twice or more times during their lifetime
- Total (isochronal) spawner = the whole gonad matures and all the eggs or sperm are spawned in a single breeding period (short period, one week or so)
- Partial (heterochronal) spawner = the spawning period is protracted and the gonad can include eggs or sperm at different maturity stages.

1.3 The reproductive apparatus of the main animal groups in fishery resources

Figures 4–21 describe the reproductive apparatus of fishes, crustaceans and cephalopods, in order to facilitate the characterization of the gonads and the successive macroscopic sexual maturity stages.

Fish

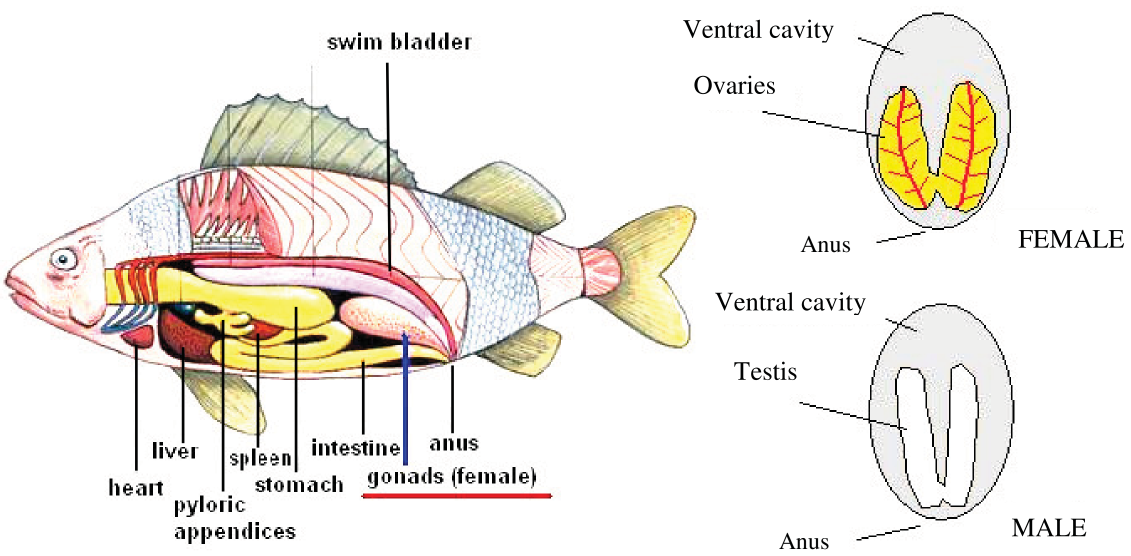


Fig. 4. Anatomy of a bony fish, showing placement and shape of the gonads.

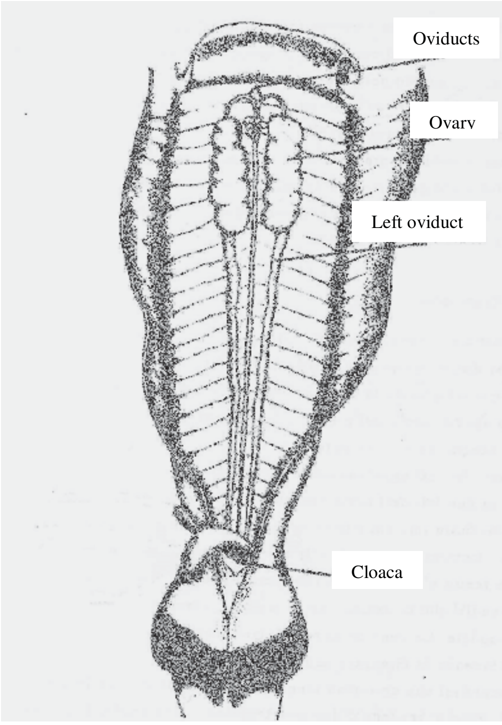


Fig. 5. Localization and shape of the ovary in a cartilaginous fish (modified from Peyrot and Vellano, 1973)

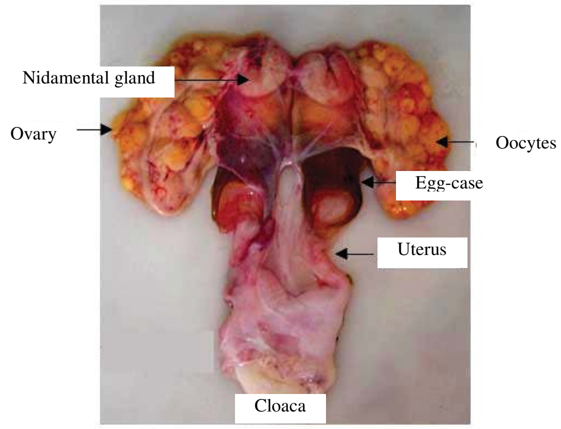


Fig. 6. Reproductive apparatus of female cartilaginous fish (picture by Dr. Fabrizio Serena, modified)

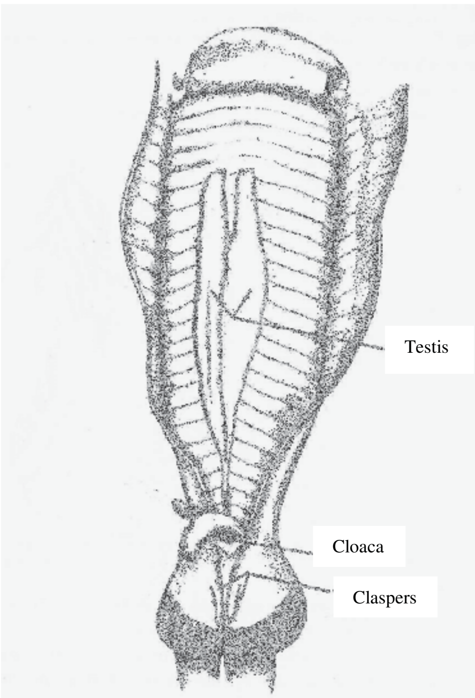


Fig. 7. Localization and shape of the testes in a cartilaginous fish (modified from Peyrot and Vellano, 1973)

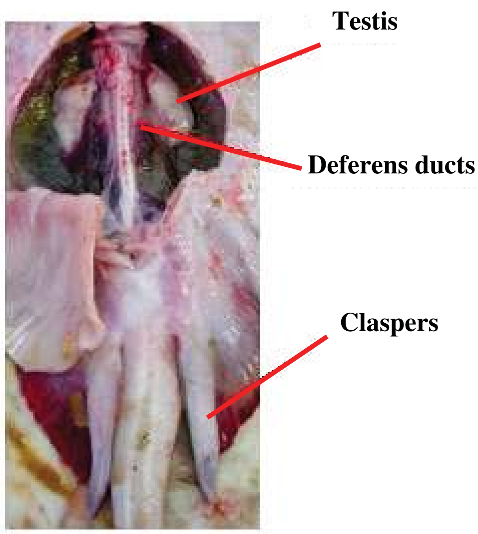


Fig. 8. Reproductive apparatus of a male cartilaginous fish (picture by Dr. Fabrizio Serena, modified)

Crustaceans

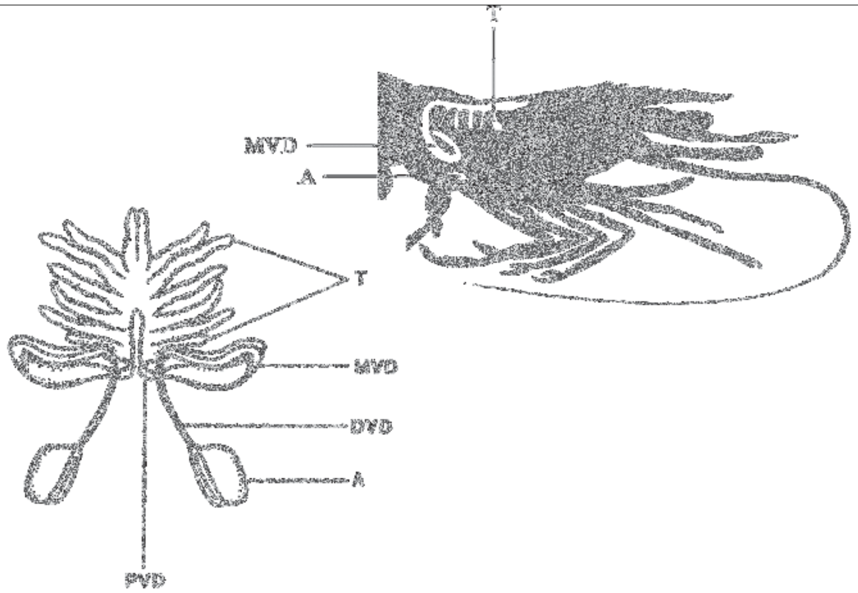
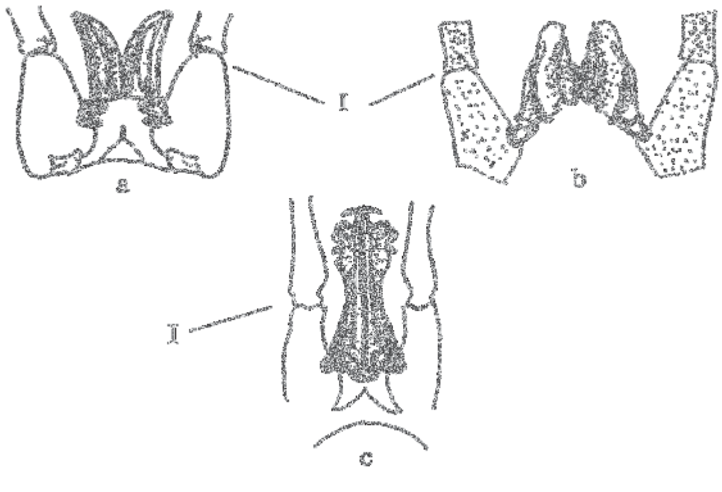
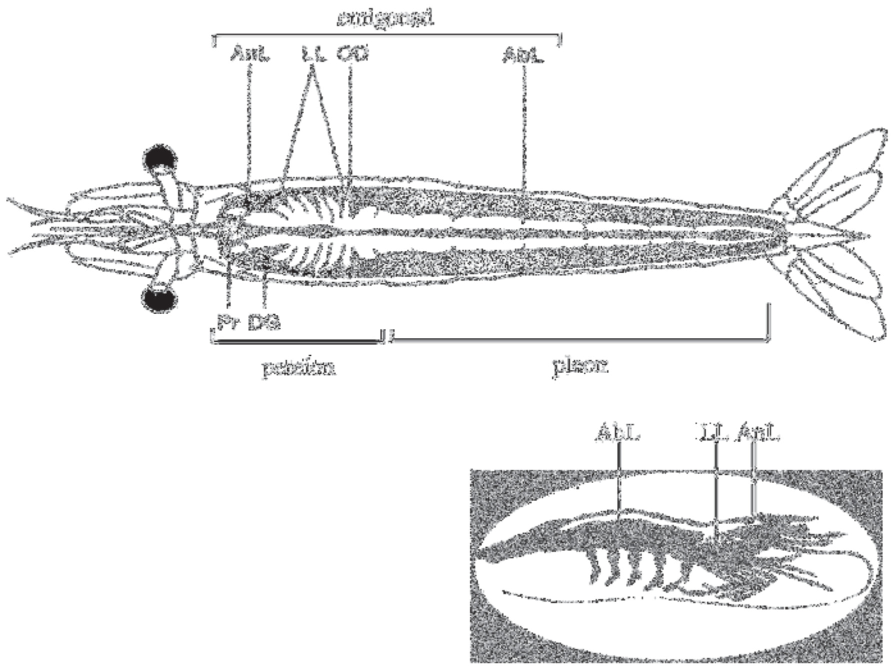


Diagram of the male reproductive system. *A* – terminal ampullae; *DVD* – distal vas deferens; *MVD* – median vas deferens; *PVD* – posterior vas deferens; *T* – lobe of testis (from Dall et al., 1990; modified)

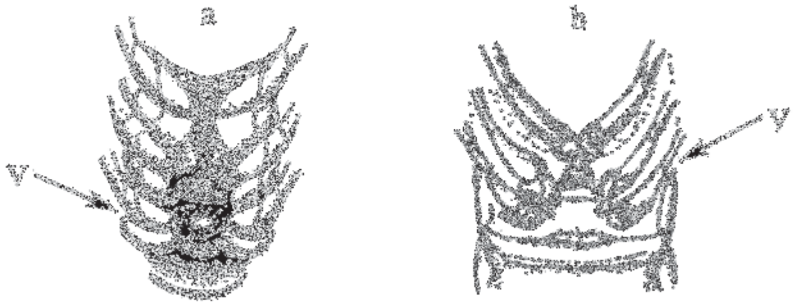


Petasma in: *Aristaeomorpha folicea* (**a**); *Aristeus antennatus* (**b**); *Parapenaeus longirostris* (**c**). *I* – first pair of pleopods. From Zariquey Alvarez, 1968; modified

Fig. 9. The reproductive apparatus in male crustaceans (schemes provided by Dr. Porzia Maiorano).



The female reproductive system. Dorsal and lateral views of the ovary. *AnL* – anterior lobe; *LL* – lateral lobes; *AbL* – abdominal lobe; *OD* – oviduct. *Pr* – proventriculus; *DG* – digestive gland (from Dall et al., 1990; modified)

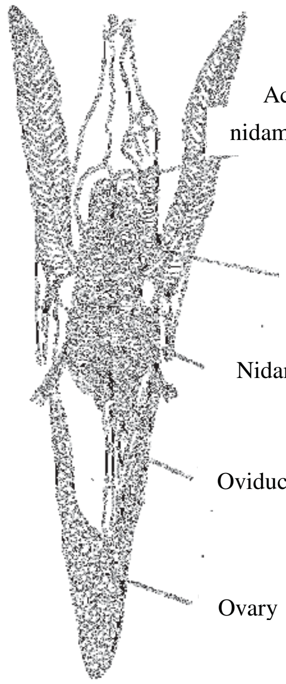


Thelycum in females of: *Aristaeomorpha folicea* (**a**); *Aristeus antennatus* (**b**); ventral view. *V* – fifth pair of pleopods. From Zariquey Alvarez, 1968; modified

Fig. 10. The reproductive apparatus in female crustaceans (schemes provided by Dr. Porzia Maiorano).

<u>Cephalopods</u>

Squids (loliginids)



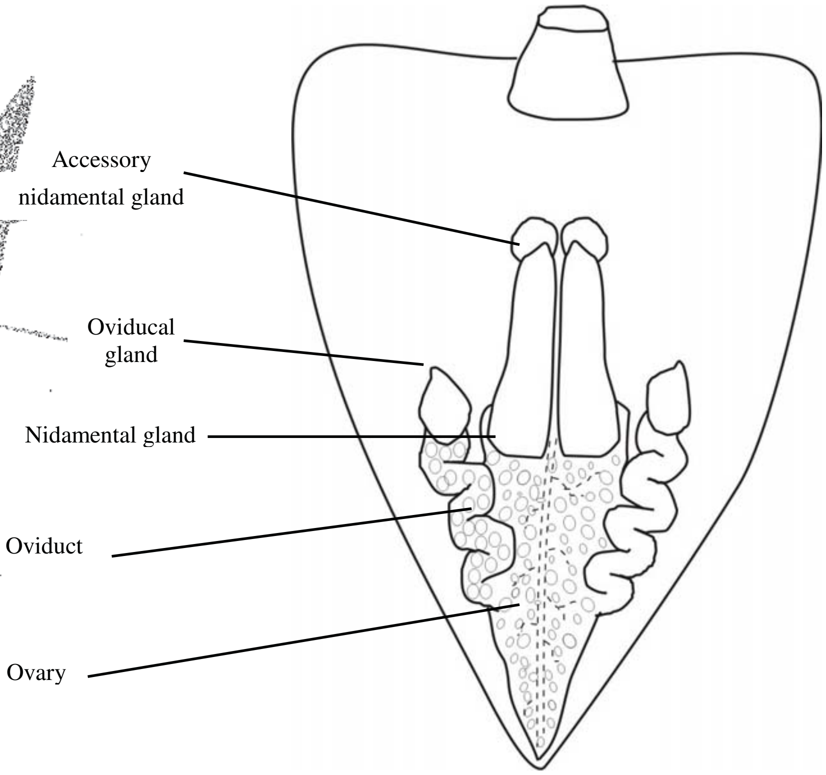
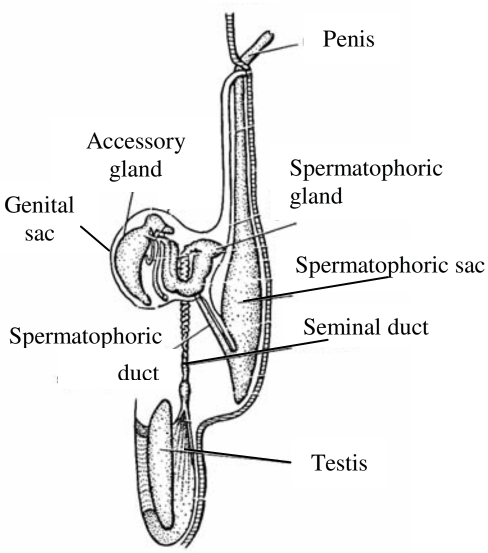


Fig. 11. The reproductive apparatus in the female loliginid squid (modified from Nesis, 1987)

Fig. 12. Diagram of the reproductive apparatus of female loliginid squid (drawing by Dr. Eugenia Lefkaditou)



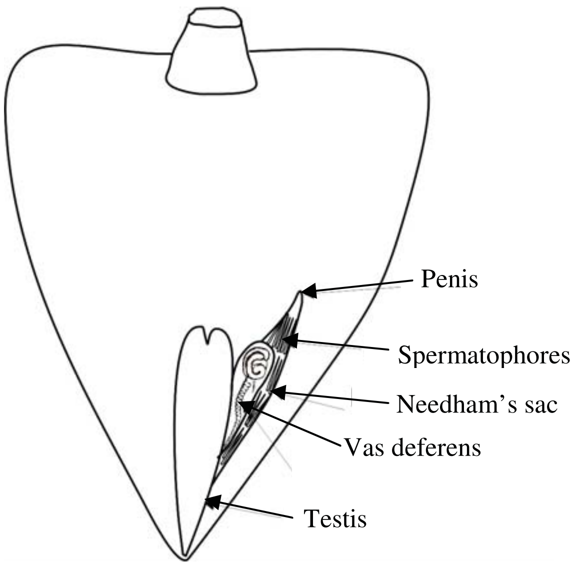


Fig. 13. The reproductive apparatus in the male loliginid squid (modified from Nesis, 1987)

Fig. 14. Diagram of the reproductive apparatus of male loliginid squid (drawing by Dr. Eugenia Lefkaditou)

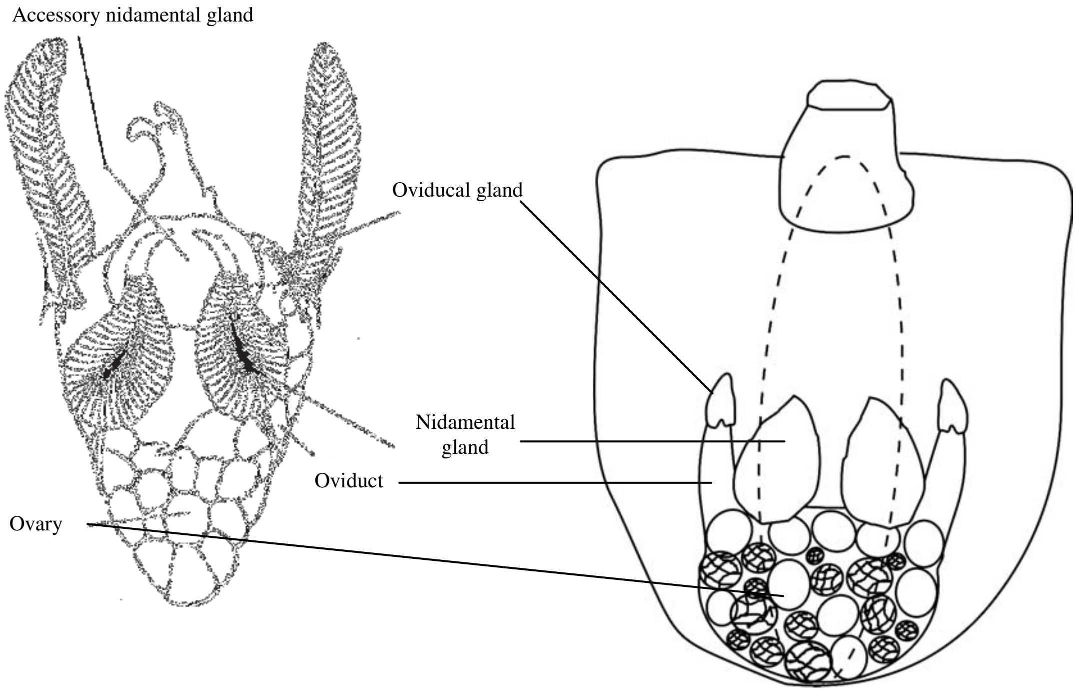


Fig. 15. The reproductive apparatus in the female cuttlefish (modified from Nesis, 1987)

Fig. 16. Diagram of the reproductive apparatus of female cuttlefish (drawing by Dr. Eugenia Lefkaditou)

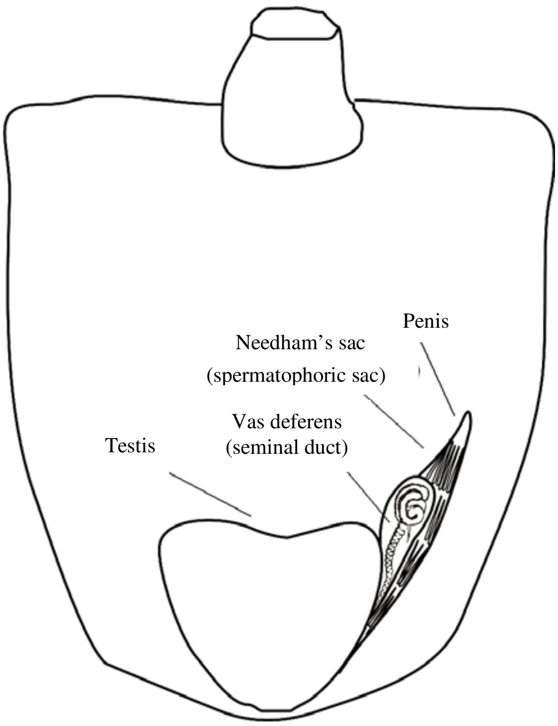


Fig. 17. Diagram of the reproductive apparatus of male cuttlefish (drawing by Dr. Eugenia Lefkaditou).

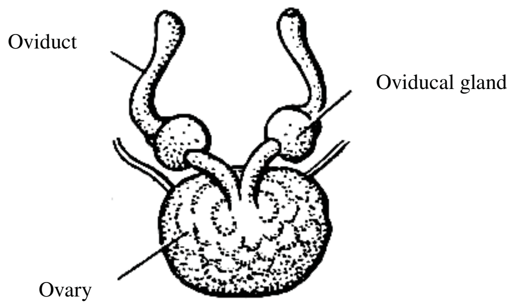


Fig. 18. The reproductive apparatus in the female octopus (modified from Nesis, 1987)

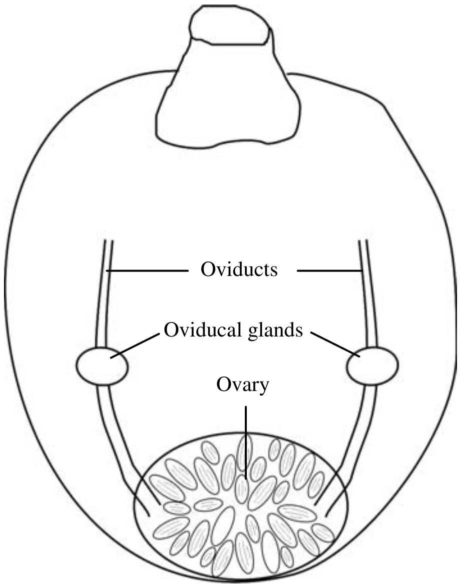


Fig. 19. Diagram of the reproductive apparatus of female octopus (drawing by Dr. Eugenia Lefkaditou)

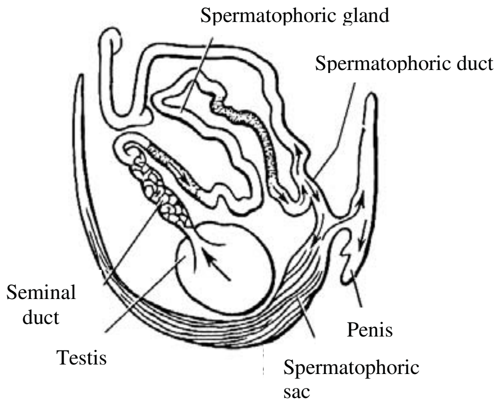


Fig. 20. The reproductive apparatus in the male octopus (modified from Nesis, 1987)

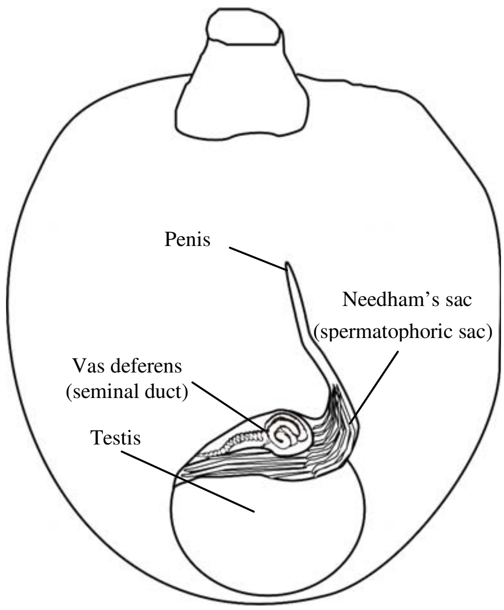


Fig. 21. Diagram of the reproductive apparatus of male octopus (drawing by Dr. Eugenia Lefkaditou)

2 The macroscopic maturity scales currently available and some information on the reproductive features of the most common species exploited by Mediterranean fisheries

2.1 Introduction

The macroscopic maturity stages corresponding to a scale of maturity are mostly based on the **general aspect**, **shape**, **relative dimension**, **position** and **colour** of the gonads, as shown in Figure 22.

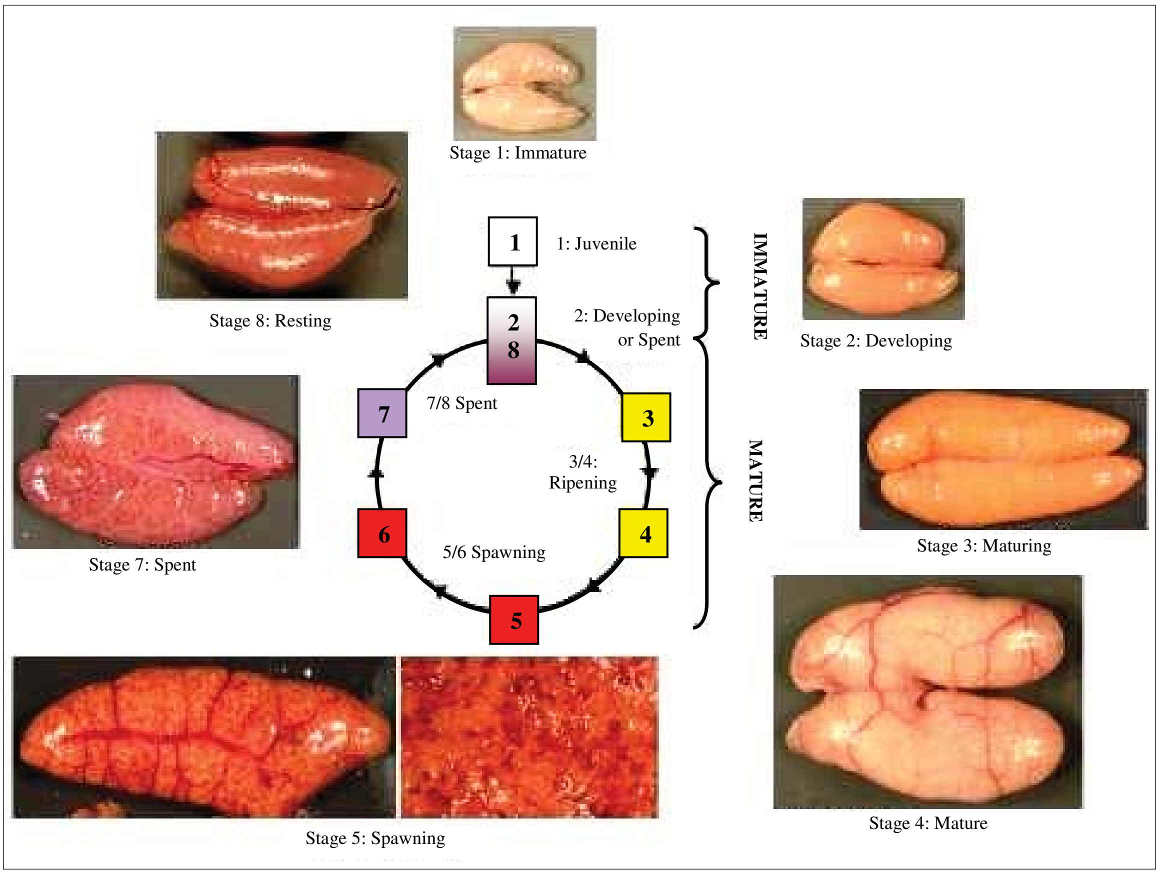


Fig. 22. An eight-stage macroscopic maturity scale: an example of visual representation (from www.marine.ie modified).

The macroscopic maturity scales have been (and will be) formulated in the light of the following two questions:

1. Do we need a unique maturity scale for all fish species?
2. Do we need a maturity scale for each fish species?

The first option (generalized scale) is mostly needed for field research on the assessment of multi-species fishery resources (e.g. MEDITS project)

The second option (mono-specific scale) is mostly useful for the study of the reproductive biology of a single species.

What are the risks in choosing the two options?

- Option 1. The scale can be too generalized, so there is a risk of failing to identify the classification of maturity stages in the different fish species; in fact, the development of gonads can vary according to fish species, genera and/or family
- Option 2. The scale can be useful for the species studied, but most of time it is not reliable for other species; it cannot be used for field projects aimed at the assessment of multi-species fishery resources.

Another question: What is the right number of macroscopic stages to be considered for the description of gonad development?

Of course, it depends on the fish species. Normally, a scale of three to eight stages (per sex) can be acceptable, but the best seems to be a scale of four to six stages.

The risk in the use of scales with a low number of stages is the loss of information. Moreover, for some species, the uncorrected interpretation of the scale and/or of the maturity stages can produce mistakes in the classification of maturity development (confusion among different stages), although scales with a small number of stages are more practical for field surveys.

The scales characterized by a large number of stages can help to achieve a better identification of the true development of the gonads. Unfortunately, such scales need more time and more attention when applied. So, they are time-consuming during extensive field surveys, when both a large number of species and individuals have to be analysed.

Given the foregoing reservations in the answers to the above-mentioned questions, the effort of the scientists has been and will be aimed at the preparation of maturity scales that are easy to use but as detailed as possible. Sometimes it is a very difficult task, because of the impossibility of meeting both these objectives.

2.2 The maturity scales currently available*

Most of the most common and best-known maturity scales are presently being used in the assessment of the Mediterranean fishery resources.

The "historical" scales are reported first.

* For sake of clarity, the original scales were edited without affecting the general meaning.

NIKOLSKI'S SCALE (teleosts)

Stage I. Immature: young individuals that have not yet spawned.
Stage II. Quiescent: gametes either have not yet started to develop or have already been discharged; the swelling of the gonad in the body cavity is complete; gonads are of very small size; eggs are not visible to the naked eye.
Stage III. Ripening: eggs visible to the naked eye; the gonad increases in weight very rapidly; testes change from being transparent to a pale rose colour.
Stage IV. Ripeness: gametes ripe; gonads have reached their maximum weight, but the gametes do not yet run out of the gonad when light pressure is applied.
Stage V. Reproduction: gametes run out of the gonad on the application of the lightest pressure to the thorax; the weight of the gonad rapidly decreases during spawning.
Stage VI. Spent: gametes extruded, and cavity of gonad swollen; gonad has the appearance of an empty sac, usually with a few eggs remaining in females, or sperm in males.

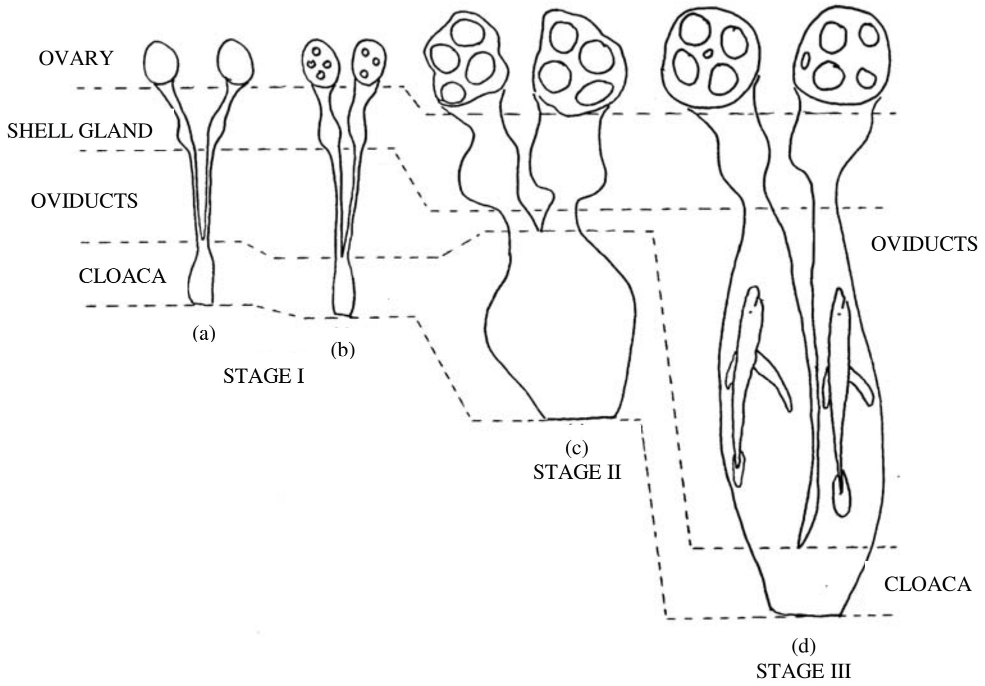
HOLDEN & RAITT: A FIVE-POINT MATURITY SCALE FOR PARTIAL SPAWNERS (teleosts)

Stage I. Immature: ovary and testis each about one third the length of the body cavity; ovaries pinkish, translucent; testis whitish; ova not visible to naked eye.
Stage II. Maturing: virgin and recovering spent: ovary and testis each about half the length of the body cavity; ovary pinkish, translucent; testis whitish, more or less symmetrical; ova not visible to naked eye.
Stage III. Ripening: ovary and testis each about two thirds the length of the body cavity; ovary pinkish-yellow colour with granular appearance, testis whitish to creamy; no transparent or translucent ova visible.
Stage IV. Ripe: ovary and testis each from two thirds to full length of the body cavity; ovary orange-pink in colour with conspicuous superficial blood vessels; large transparent, ripe ova visible; testis whitish-creamy, soft.
Stage V. Spent: ovary and testis each shrunken to about half the length of the body cavity; walls loose; ovary may contain remnants of disintegrating opaque and ripe ova, darkened or translucent; testis bloodshot and flabby.

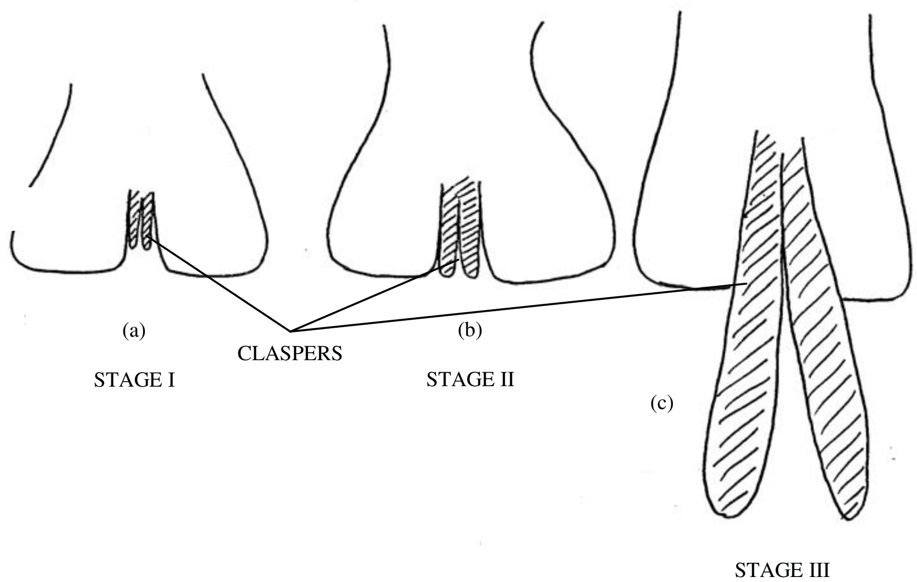
THE MAIER SCALE: AN EIGHT-POINT MATURITY SCALE FOR TOTAL SPAWNERS (teleosts)

Stage I. Virgin: sexual organs very small, situated close to vertebral column; testis and ovary transparent, colourless or grey; eggs not visible to naked eye.
Stage II. Maturing virgin: testis and ovary translucent, grey-red; length of gonads one half, or slightly more, of the length of ventral cavity; individual eggs can be seen with magnifying glass.
Stage III. Developing: testis and ovary opaque, reddish with blood capillaries, occupying about half of the ventral cavity; eggs visible to naked eye as whitish granular material.
Stage IV. Developed: testis reddish-white, no milt produced under pressure; ovary orange-red; eggs clearly discernible, opaque; testis and ovary occupy about two thirds of the ventral cavity.
Stage V. Gravid: sexual organs fill ventral cavity; testis white and drops of milt produced under pressure; eggs completely round, some already translucent and ripe.
Stage VI. Spawning: roe and milt run under slight pressure; most eggs translucent with few opaque eggs left in ovary.
Stage VII. Spent: not completely empty; no opaque eggs left in ovary.
Stage VIII. Resting: testis and ovary red and empty; a few eggs in state of resorption.

HOLDEN & RAITT: A THREE-POINT VISUAL MATURITY SCALE FOR ELASMOBRANCHS



Females



Males

More recent maturity scales:

STEHMANN MATURITY SCALE FOR ELASMOBRANCHS (1)

Oviparous sharks, rays and skates, and chimaeras

Males

A or 1 = immature, juvenile: claspers undeveloped as small, flexible sticks, being shorter than extreme tips of posterior pelvic fin lobes; gonads (testes) small, sperm ducts straight and thread-like.

B or 2 = maturing, adolescent, sub-adult: claspers becoming extended, longer than tips of posterior pelvic lobes, their tips (*glans*) becoming structured, but skeleton still soft and flexible; gonads enlarged, sperm ducts beginning to meander (coil) posteriorly.

C or 3 = mature, adult: claspers full length, external and internal *glans* structures fully formed; skeleton hardened so that claspers are stiff and free *glans* components are sharp; gonads greatly enlarged, sperm ducts meandering over their entire length and tightly filled with sperm.

D or 4 = active, copulating: *glans* clasper often dilated, its structures reddish and swollen; sperm flowing on pressure from cloaca and/or present in clasper groove or *glans*; sperm ducts largely as stage C/3, but may be less tightly filled, whereas seminal vesicle may be well filled. For oviparous sharks and chimaeras, this stage does not necessarily mean that the *glans* is spread open, but fleshy pads are obviously enlarged and sperm is present in clasper grooves.

Females – ovarian stages

A or 1 = immature, juvenile: ovaries small, their internal structure gelatinous or granulated; no oocytes differentiated or all uniformly small, granular; oviducts (uteri) narrow, thread-like.

B or 2 = maturing, adolescent: ovaries somewhat enlarged, walls more transparent; oocytes becoming differentiated to various small sizes; uteri largely as stage A/1, but may become widened posteriorly.

C or 3 = mature, adult: ovaries large and tight; oocytes enlarged, with some being very large; uteri enlarged and widening over nearly their entire length.

Females – uterine stages

D or 4 = active: a distinctly large-yolk egg present in one or both Fallopian tubes; no egg capsule yet visible in shell gland, or beginning formation of egg capsule at most.

E or 5 = advanced: large yolk-eggs in Fallopian tubes, or already passing through into egg capsules; egg capsules about fully formed in one or both oviducts, but still soft at upper end and located very close to Fallopian tubes.

F or 6 = extruding: completed, hardened egg capsules in one or both oviducts, more or less separated from Fallopian tubes; capsule surface covered with dense silky fibres; either no enlarged oocytes in Fallopian tubes, or one or two in position; if oviducts empty but still much enlarged and wide, capsules have probably just been extruded – this corresponds to either stage D/4 or E/5.

STEHMANN MATURITY SCALE FOR ELASMOBRANCHS (2)

Aplacental and placental viviparous sharks

Males

A or 1 = immature, juvenile: claspers undeveloped as small, flexible sticks, being shorter than extreme tips of posterior pelvic fin lobes; gonads (testes) small, whitish; sperm ducts straight and thread-like.

B or 2 = maturing, adolescent, sub-adult: claspers becoming extended, longer than tips of posterior pelvic fin lobes, their tips (*glans*) becoming structured, but their skeleton still soft and flexible; gonads enlarged, sperm ducts beginning to meander posteriorly.

C or 3 = mature, adult: claspers fully formed and stiff, eventually present cartilaginous hooks, claws or spines of *glans* free (unconnected) and sharp; gonads enlarged, well rounded, filled with flowing sperm and often reddish in colour; sperm ducts tightly coiled and well filled with sperm.

D or 4 = active: *glans* clasper often dilated and swollen, with free cartilaginous spine mostly erect; sperm flowing from cloaca under pressure on seminal vesicle and/or present in clasper groove.

Females - ovarian stages

A or 1 = immature, juvenile: ovaries small and their internal structure gelatinous or granulated; no oocytes differentiated or all uniformly small, granular; oviducts (uteri) narrow, thread-like.

B or 2 = maturing, adolescent: ovaries somewhat enlarged, walls more transparent; oocytes becoming differentiated to various small sizes; uteri largely as stage A/1, but may become widened posteriorly; ovaries at first maturity will not show *corpora lutea*, or a very few only, whereas ovaries of resting females prior to repeated reproduction will show *corpora lutea* in greater number.

C or 3 = mature, adult: ovaries large, well rounded; oocytes obviously enlarged, all to about the same size, can easily be counted and measured.

Females - uterine stages

D or 4 = developing: uteri well filled and rounded with seemingly unsegmented yolk content ("candle").

E or 5 = differentiating: uteri well filled and rounded with segmented content of large yolk balls, can easily be counted and measured. Embryos variously small, atop their huge yolk balls, larger ones with external gills and unpigmented (still "candle") (Stages D/4 and E/5 have for convenience been rather artificially separated and might be seen also as substages of one and the same stage D/4 or E/5).

F or 6 = expecting: embryos more or less fully formed, pigmented, external gills lost, yolk sacs obviously reduced; can be counted, measured and sexed easily.

G or 7 = post-natal, spent: ovaries at resting stage, similar to stages A/1 or B/2; uteri empty but still widened considerably over their full length, in contrast to stages A/1 or B/2.

ICES TELEOST MATURITY SCALE

1. VIRGIN. Male: testes very thin translucent ribbon lying along an unbranched blood vessel; no sign of development. Female: ovaries small, elongated, whitish, translucent; no sign of development.
2. MATURING. Male: development has obviously started, colour is progressing towards creamy-white and the testes are filling more and more of the body cavity, but sperm cannot be extruded with only moderate pressure. Female: development has obviously started, eggs are becoming larger and the ovaries are filling more and more of the body cavity, but eggs cannot be extruded with only moderate pressure.
3. SPAWNING. Male: will extrude sperm under moderate pressure to advanced stage of extruding sperm freely with some sperm still in the gonad. Female: will extrude eggs under moderate pressure to advanced stage of extruding eggs freely with some eggs still in the gonad.
4. SPENT. Male: testes shrunken, with little sperm in the gonads, but often some in the gonoducts which can be extruded under light pressure; resting condition firm, not translucent, showing no development. Female: ovaries shrunken with few residual eggs and much slime, resting condition firm, not translucent, showing no development.

ICES ELASMOBRANCH MATURITY SCALES (1)
Maturity stages for Rajidae, Chimeridae, Scyliorhinidae and oviparous sharks

Males
NE. Not examined
M1. Juvenile: claspers undeveloped, shorter than extreme tips of posterior pelvic lobes: gonads (testes) small, thread-like in shape.
M2. Adolescent, maturing: claspers more or less extended, longer than tips of posterior pelvic lobes, their tips (*glans*) more or less already structured, but skeleton still flexible, soft; gonads enlarged, sperm ducts (*ducti deferentes*) beginning to meander.
M3. Adult, mature: claspers full length, *glans* structures fully formed and skeleton hardened so that claspers are stiff; gonads greatly enlarged, sperm ducts meandering and tightly filled with flowing sperm.
M4. Active, copulating: *glans* clasper often dilated, its structures reddish and swollen; sperm flowing on pressure from cloaca and/or present in clasper groove or *glans*. For chimaerids, scyliorhinids and other oviparous species of shark, stage M4 does not mean that the *glans* is spread open; the fleshy pads are obviously enlarged and sperm is present in the clasper grooves.

Females
NE. Not examined
F1. Immature, juvenile: ovaries small, their internal structure gelatinous or granulated; no oocytes differentiated or all uniformly small, granular; uteri (oviducts) small and thread-like.
F2. Adolescent, maturing: ovaries enlarged and with more transparent walls; oocytes differentiated in various small sizes; uteri similar to stage F1.
F3. Adult, mature: ovaries large and tight; oocytes enlarged with some being very large; uteri enlarged and widening.
F4. Active, uterine stage: a distinctly large yolk-egg present in one or both Fallopian tubes; no egg capsule yet visible in shell gland, or beginning formation of egg capsule at most.
F5. Advanced, uterine stage: large yolk-eggs in Fallopian tubes, or already passing through into egg capsules; egg capsules about fully completed in one or both oviducts, but still soft at upper end and located very close to Fallopian tubes.
F6. Extruding, uterine stage: completely hardened egg capsules in one or both oviducts, more or less separated from Fallopian tubes; capsule surface covered with dense silky fibres within the shell integument; either no large oocytes in Fallopian tubes or one or two in position; if oviducts are empty but still much enlarged and wide, capsules have probably just been extruded – this corresponds to stages 4 or 5.

ICES ELASMOBRANCH MATURITY SCALES (2)
Maturity stages for ovoviviparous and viviparous sharks

Males
NE. Not examined
M1. Juvenile: claspers undeveloped sticks; gonads tiny and thread-like, whitish in colour sperm ducts straight.
M2. Subadult: claspers formed but soft, flexible; gonads enlarged; sperm ducts meandering.
M3. Adult: claspers fully formed and stiff; gonads well rounded, reddish in colour and filled with flowing sperm; sperm ducts tightly coiled.
M4. Active: *glans* clasper(s) often dilated and swollen; sperm flowing from cloacal papilla under pressure on belly, and/or present in clasper groove.

Females
F1. Juvenile, ovarian stage: ovaries small, gelatinous or granulated; eggs not yet fully differentiated, or uniformly small and granular; uteri thread-like.
F2. Ripening, ovarian stage: ovaries enlarged, walls transparent; eggs differentiated into various sizes; uteri similar to stage F1.
F3. Ripe, ovarian stage; ovaries large, well rounded; eggs enlarged, all about the same size, can easily be counted and measured.
F4. Developing, uterine stage: uteri well filled and rounded with unsegmented yolk content.
F5. Differentiating, uterine stage: uteri well filled and rounded with unsegmented content of yolk balls; embryos small, unpigmented and with large yolk sacs, but can be counted.
F6. Expecting, uterine stage: embryos fully formed and pigmented, yolk sacs obviously reduced, but can be counted and measured easily.
F7. Post-natal, uterine stage: ovaries at resting stage, similar to stage F1; uteri empty but still widened considerably in comparison to stages F1 or F2.

The MEDITS new (revised) generalized scales for the Mediterranean demersal species:

Bony fishes

SEX	GONAD ASPECT	MATURATION STATE	STAGE
U	Sex not distinguished by naked eye. Gonads very small and translucid, almost transparent. Sex undetermined.	**UNDETERMINED**	**0**
F	Sexual organs very small and usually shorter than 1/4 of the body cavity, situated close to vertebral column. Ovary transparent, colourless or grey. Eggs not visible to the naked eye.	**IMMATURE/VIRGIN**	**1**
M	Sexual organs very small and usually shorter than 1/4 of the body cavity, situated close to vertebral column. Testis transparent, colourless or grey.		
F	Small pinkish/reddish ovary shorter than 1/2 of the body cavity. Eggs not visible to naked eye.	**VIRGIN-DEVELOPING** *	**2a**
M	Thin whitish testis shorter than 1/2 of the body cavity.		
F	Pinkish-reddish/reddish-orange and translucent, ovary as long as about 1/2 of the body cavity. Blood vessels visible. Eggs not visible by naked eye.	**RECOVERING ***	**2b**
M	Whitish/pinkish testis, more or less symmetrical, as long as about 1/2 of the body cavity.		
F	Ovary pinkish-yellow in colour with granular appearance, as long as about 2/3 of the body cavity. Eggs are visible to naked eye through the ovaric tunica, which is not yet translucent. Under light pressure, eggs are not expelled.	**MATURING**	**2c**
M	Whitish to creamy testis long about 2/3 of the body cavity. Under light pressure, sperm is not expelled.		
F	Ovary orange-pink in colour, with conspicuous superficial blood vessels, as long as from 2/3 to full length of the body cavity. Large transparent, ripe eggs are clearly visible and could be expelled under light pressure. In a more advanced condition, eggs escape freely.	**MATURE/SPAWNER**	**3**
M	Whitish-creamy soft testis as long as from 2/3 to full length of the body cavity. Under light pressure, sperm could be expelled. In a more advanced maturity stage, sperm escapes freely.		
F	Reddish ovary shrunk to about 1/2 length of the body cavity. Flaccid ovaric walls; ovary may contain remnants of disintegrating opaque and/or translucent eggs.	**SPENT**	**4a**
M	Bloodshot and flabby testis shrunk to about 1/2 length of the body cavity.		
F	Pinkish and translucent ovary as long as about 1/3 of the body cavity. Eggs not visible to naked eye.	**RESTING ***	**4b**
M	Whitish/pinkish testis, more or less symmetrical, as long as about 1/3 of the body cavity.		

*: WARNING ! These stages could be confused each other.

Elasmobranchs (oviparous)

SEX	GONAD ASPECT	MATURATION STATE	STAGE
N	The specimens are not sexed.	**NOT DETERMINED**	**0**
F	Ovary is barely discernible, with small isodiametric eggs. Distal part of oviducts is thick-walled and whitish. The nidamental glands are less evident.	**IMMATURE/VIRGIN**	**1**
M	Claspers are small and flaccid and do not reach the posterior edge of the pelvic fins. Sperm ducts not differentiated. Testis small and narrow .		
F	Whitish and/or few yellow maturing eggs are visible in the ovary. The distal part of oviducts (uterus) is well developed but empty. The nidamental glands are small.	**MATURING**	**2**
M	Claspers are larger, but skeleton still flexible. They extend to the posterior edge of the pelvic fins. Sperm ducts well developed and eventually beginning to meander.		
F	Ovaries contain yellow eggs (large yolk eggs). The nidamental glands are enlarged and oviducts are distended.	**MATURE**	**3a**
M	Claspers extend well beyond the posterior edge of the pelvic fin and their internal structure is generally hard and ossified. Testis greatly enlarged. Sperm ducts meandering over almost their entire length.		
F	Ovary walls transparent. Oocytes of different sizes, white or yellow. Nidamental glands large. Egg-cases more or less formed in the oviducts (Extruding Stage).	**MATURE/EXTRUDING-ACTIVE**	**3b**
M	Claspers longer than tips of posterior pelvic fin lobes, skeleton hardened, with axial cartilages hardened and pointed. Sperm ducts largely as at stage 3a. Sperm flowing on pressure from cloaca (Active Stage).		
F	Ovary walls transparent. Oocytes of different sizes, white or yellow. Oviducts appear much enlarged, collapsed and empty. The diameter of the nidamental glands is decreasing	**RESTING**	**4**
M	Claspers longer than tips of posterior pelvic fin lobes, skeleton hardened with axial cartilages still hardened. Sperm ducts empty and flaccid.		

Cephalopods

SEX	REPRODUCTIVE APPARATUS ASPECT	EGGS SIZE (mm)	SPERMATOPHORES DEVELOPMENT	MATURATION STATE	STAGE
U	Sex not distinguished by naked eye. Sex undetermined.	Total absence of eggs.	Absence of spermatophores.	**UNDETERMINED**	**0**
F	Small, translucid and/or semi-transparent Nidamental Glands (NG) / Oviducal Glands (OG). Ovary is semi-transparent, stringy and lacking granular structure. Oviduct meander not visible.	*L. vulgaris & I. coindetii:* no eggs. *S.officinalis, E. moschata, E. cirrhosa, O. vulgaris:* very small eggs.	Absence of spermatophores	**IMMATURE = VIRGIN**	**1**
M	Testis small. Spermatophoric complex (SC) semi-transparent with not visible *Vas deferens*. Penis appears as a small prominence of SC.				
F	NG / OG enlarged. NG covering some internal organs. Whitish ovary with granular structure clearly visible, not reaching the posterior half of the mantle cavity. Oviduct meander clearly visible.	*L. vulgaris & I. coindetii:* no eggs visible to naked eye.. *S.officinalis: ø<2mm; E. moschata: ø <4mm; E. cirrhosa ø <2mm; O. vulgaris ø<1mm*	Absence of spermatophores	**DEVELOPING**	**2a**
M	Enlarged testis with structure not clearly visible. The *Vas deferens* whitish or white and the spermatophoric organ with white streak.				
F	Large NG covering the viscera below. Ovary occupies the whole posterior half of mantle cavity, containing reticulated oocytes of all sizes tightly packed and probably a few ripe ova at its proximal part. Oviducts fully developed but empty.	*L. vulgaris & I. coindetii*: maturing eggs visible to naked eye. *S.officinalis:* 2,1mm< ø<4mm; *E. moschata:* 4mm<ø<11mm; *E. cirrhosa:* 2mm<ø<5mm; *O. vulgaris:* 1mm<ø<2mm.	*L. vulgaris, I. coindetii* and *S.officinalis*: few immature spermatophores in Needham's sac. *E. moschata, cirrhosa, O. vulgaris*: few spermatophores, barely developed and not functional.	**MATURING**	**2b**
M	The *Vas deferens* white, meandering, enlarged. The Needham's sac (SS) with structureless whitish particles inside. Normally the Needham's sac is without functional spermatophores, but sometimes some immature/abortive ones could occur. The testis tight, crispy, with visible structure.				
F	Large NG as previously. Ovary containing higher percentage of large reticulated eggs and some large ripe ova with smooth surface. In Teuthoidea ripe ova in oviducts.	*L. vulgaris & I. coindetii*: amber-coloured and isodiametric eggs in oviducts and in part of the ovary (ø =2mm in *Loligo* and ø =1mm in *Illex*). *S.officinalis*: medium eggs (4,1mm< ø<6,0mm) and big eggs (6,1mm<ø<8mm). *E. moschata*: ø >11mm (striped eggs). *E. cirrhosa*: ø >5mm. *O. vulgaris*: ø >2mm.	Well developed spermatophores	**MATURE**	**3a**
M	Testis as before. Spermatophores packed in the Needham's sac.				
F	NG/OG large but soft and running. Ovary shrunken and flaccid, with only immature oocytes attached to the central tissue and a few loose large ova in the coelom. In Teuthoidea oviduct may contain some mature ova but is no longer packed.	Few large ova	Disintegrating spermatophores	**SPENT**	**3b**
M	Disintegrating spermatophores in the Needham's sac and the penis.				

Crustaceans

SEX	REPRODUCTIVE APPARATUS ASPECT	COLOURING OF FRESH OVARY	MATURATION STATE	STAGE
U	Sex not distinguished by naked eye. Sex undetermined	Translucid	**UNDETERMINED**	**0**
F	Ovary hardy visible in transparency. After dissection of the tegument, ovary is small and lobes are flaccid, stringy and poorly developed. *Aristaeomorpha foliacea* and *Aristaeus antennatus* no sphermatophores on thelycum.	Whitish or translucid	**IMMATURE = VIRGIN ***	**1**
M	Petasma is not much visible, there are no spermatic masses (hemi-spermatophores) on the seminal ampullae, located on side of the V pair of pereiopods. *A. foliacea* and *A. antennatus*: long rostrum.			
F	Ovary status to develop. Cephalic and lateral lobes are small but distinguishable by naked eye. Abdominal extensions are thin and just visible.	*A. foliacea*: flesh coloured. *A. antennatus: i*vory coloured with orange pink-violet dotting. *N. norvegicus*: cream. *P. longirostris*: creamy orange.	**VIRGIN DEVELOPING ****	**2a**
M	Petasma appears visible and nearly or completely joined, but there are no spermatic masses in the seminar ampullae. *A.. foliacea* and *A.. antennatus*: long or intermediate rostrum.			
F	Ovary status to re-develop. Cephalic and lateral lobes are small but distinguishable by naked eye. Abdominal extensions are thin and just visible. Occasionally presence of spermatophores in *A.. foliacea* and *A.. antennatus*.	*A. foliacea*: flesh coloured. *A. antennatus*: Ivory coloured with orange pink-violet dotting. *N. norvegicus*: cream. *P. longirostris*: cream orange.	**RECOVERING****	**2b**
M	Petasma appears completely joined, but there are no spermatic masses in the seminar ampullae. *A. foliacea and A. antennatus*: short rostrum.			
F	Ovary developed and occupies almost entirely the dorsal portion. The cephalic and lateral lobes are much developed and have a turgid consistence.	*A. foliacea*: light and dark grey. *A. antennatus*: light violet. *N. norvegicus*: light green. *P. longirostris*: light green or grey green.	**MATURING OR ALMOST MATURE**	**2c**
M				
F	Turgid ovary extends to the whole dorsal portion, covering the organs below. Lobes and extensions well developed, in particular the abdominal extension are much evident. Oocytes well visible.	*A. foliacea*: black. *A. antennatus*: violet. *N. norvegicus*: dark grey. *P. longirostris*: bright green or olive green.	**MATURE**	**2d**
M	Petasma is perfectly visible and completely joined. Spermatic masses in seminar ampullae. *A. foliacea* and *A. antennatus*: small rostrum.			
F	Resting ovary. Presence of spermatophores in *A. foliacea* and *A. antennatus*.	Uncoloured.	**RESTING ADULT***	**2e**
F	*N. Norvegicus*: eggs on pleiopods		**BERRIED**	**3**

*, ** : WARNING ! These stages could be confused each other.

Moreover, two examples of species-specific scales are reported below:

Maturity scale for the Mediterranean amberjack (*Seriola dumerili*) (from Marino et al., 1995).

	Maturity stage	Macroscopic appearance	Cytological characteristics
Female			
I	Immature	Small symmetric ovaries just recognizable as a female reproductive organ. Reddish-pink in colour.	Ovigerous folds partially fill the ovarian cavity. Nets oogonia and primary oocytes in chromatin nucleous stage are evident. Few perinucleolus stage oocytes are present. 'Balbiani bodies' appear in primary oocytes.
II	Developing	Symmetric transparent ovaries. Whitish-pink in colour.	Ovigerous folds completely fill the ovarian cavity. Perinucleous stage oocytes are predominant. Few oocytes undergo second growth phase.
III	Maturing	Granular, slightly asymmetric ovaries. Yellow-pink in colour. Opaque oocytes.	Two or more groups of coetaneous oocytes are always present. Few pre-vitellogenic oocytes in perinucleolus stage and lipid vescicles (stage 4 and 5) and protein granules (stage 6) oocytes are scattered through the ovary.
IV	Mature	Swollen ovaries with evident superficial blood vessels. Yellow-orange in colour. Large eggs, clearly visible.	Previtellogenic (stage 3), vitellogenic (stage 4, 5, 6 and 7) and hydrated oocytes (stage 8) are distributed along the ovigerous folds.
V	Partially ovulated		Within the ovarian stroma, almost two groups of different vitellogenic oocytes (occasionally stage 4, stage 5 and 6are mixedwith many post-ovulatory follicles (stage 9). No hydrated oocytes are present.
Male			
I	Immature	Symmetric, yellowish-red, string-like testes.	Testes lack a completed lobular organization. Four-five strings of lobules, cysts with spermatogonia, spermatocytes I and II and spematids are present.
II	Developing	Elongated whitish-yellow, ribbon-like testes.	Testes not yet completely organized. Germ cells in different developmental stage are present.
III	Mature	Elongated whitish, creamy testes.	Testes completely organized. All germ cell stages are present. Spermatozoa in the lumen of lobules are evident.
IV	Running-ripe	Elongated creamy-white and soft testes. Presence of milt.	Greatly enlarges lobules. Vas deferens is filled with spermatozoa.

Maturity scale for the Angler fish (*Lophius piscatorius*) (from Afonso-Dias and Hislop, 1996).

Stage	Females	Males
I, Virgin	The ovaries are very narrow (>2 cm broad), thin and ribbon-like. They are translucent and no individual oocyte clusters and vascularization can be seen. Their volume is negligible compared to that of the other internal organs.	The testes are long, narrow (<1 cm broad) and have a tubular-like structure. The medial seminiferous duct is distinct, being very pale with no visible vascularization. Their volume is negligible compared to that of the other internal organs.
II, Developing or recovering/ resting	The ovaries increase in length and, particularly, in width (2-4 cm broad). They become less translucent and there is visible vascularization. There are still no visible individual oocyte clusters. The volume occupied by the ovaries is roughly the same as that occupied by the intestine.	The flattened tubular-shaped testes increase in length and, especially, in width. Blood vessels become visible around the the medial seminiferous duct. Their volume is roughly half that occupied by the intestine.
III, Maturing	The ovaries increase considerably in width (>4 cm) and, particularly, in length. They are highly vascularized. Individual opaque oocyte clusters are visible, embedded in a gelatinous matrix. At this stage, the ovaries occupy most of the abdominal cavity.	The testes have a very firm texture and moderate to large amounts of milt are produced when they are dissected. The seminiferous duct is now highly vascularized. Stage III testes still occupy less volume than the intestine.
IV, Ripe	The ovaries are extremely long (>6 m) and wide (30cm) and occupy most of the body cavity. The bright orange oocyte clusters (1-2 mm) are easily visible and are embedded in a transparent gelatinous matrix. The ovaries are high vascularized.	Milt runs from the genital pore on slight pressure. The testes are extremely turgid and large amounts of milt are produced when they are dissected. Even at this stage. the testes still occupy less volume than the intestine (except in very large fishes, where the volumes are similar).
V, Spent	The ovaries are opaque and flaccid, with longitudinal striations. No oocyte clusters are easily visible to the naked eye. They are still very wide (10-15 cm) and highly vasculariszed.	The testes are very flaccid. Frequently, there are roseate/salmon-pink areas in the beige surface of the testis. Milt is often present in the seminiferous duct and also when dissected. The posterior edge is sometimes narrower than the anterior part of the gonad. At this stage, the testes are still highly vascularized in the vicinity of the seminiferous duct.

2.3 Some information on the reproductive features of the most common species exploited by Mediterranean fisheries

The table below reports some basic information on the reproduction of the most common species exploited by Mediterranean fisheries. The sexual behaviour, the main spawning period and the length at first maturity are listed for each species. Most of the information came from Fisher et al. (1987) and Relini et al. (1999).

Species	Reproductive behaviour	Main spawning period	Length at first maturity
FISH			
Aspitrigla cuculus	Gonochoristic species	winter-spring	14 cm TL
Boops boops	Hermaphroditic species (protogynous)	spring-summer	F = 12-13 cm TL; M = >15 cm TL
Chelon labrosus	Gonochoristic species	winter-spring	F = 35 cm TL; M = 27 cm TL
Conger conger	Gonochoristic species	summer	F = 200 cm TL; M = 50-75 cm TL
Coryphaena hippurus	Gonochoristic species	summer	45-55 cm SL
Dentex dentex	Gonochoristic species	late spring	F = 35 cm TL; M = 50 cm TL
Dicentrarchus labrax	Gonochoristic species	autumn-winter	25-35 cm TL
Diplodus annularis	Hermaphroditic species (protandrous)	spring-summer	9-10 cm TL
Diplodus puntazzo	Hermaphroditic species (protandrous)	spring-autumn	20-30 cm TL
Diplodus sargus	Hermaphroditic species (protandrous)	spring	F = 23 cm TL; M = 20 cm TL
Diplodus vulgaris	Hermaphroditic species (protandrous)?	summer-winter	18 cm TL
Engraulis encrasicolus	Gonochoristic species	spring-autumn	11-12 cm TL
Epinephelus aeneus	Hermaphroditic species (protogynous)	summer	F = 50-60 cm TL; M = >60 cm TL
Epinephelus costae	Hermaphroditic species (protogynous)	summer	F = 30-35 cm TL; M = >40 cm TL
Epinephelus marginatus	Hermaphroditic species (protogynous)	summer	F = 45-55 cm TL; M = >60 cm TL
Lepidorhombus boscii	Gonochoristic species	winter	22-24 cm TL
Lithognathus mormyrus	Hermaphroditic species (protandrous)	summer-autumn	F = 25-30 cm TL; M = 14-15 cm TL
Liza ramada	Gonochoristic species	autumn-winter	F = 25-30 cm TL; M = 25-27 cm TL
Lophius budegassa	Gonochoristic species	winter	65 cm TL
Lophius piscatorius	Gonochoristic species	winter	70 cm TL
Merluccius merluccius	Gonochoristic species	all year round	F = 25-30 cm TL; M = 22-26 cm TL
Mugil cephalus	Gonochoristic species	summer-autumn	F = 33-42 cm TL; M = 30-32 cm TL
Mullus barbatus	Gonochoristic species	late spring-early summer	11-13 cm TL
Mullus surmuletus	Gonochoristic species	late spring	13-16 cm TL
Mustelus mustelus	Gonochoristic species	summer	70-80 cm TL
Pagellus acarne	Hermaphroditic species (protandrous)	summer-autumn	F = 19-25 cm TL; M = 13-18 cm TL
Pagellus bogaraveo	Hermaphroditic species (protandrous)	summer-autumn	F = 25-30 cm TL; M = 22-25 cm TL
Pagellus erythrinus	Hermaphroditic species (protogynous)	spring-autumn	F = 14-15 cm TL; M = 17-20 cm TL
Pagrus pagrus	Hermaphroditic species (protogynous)	winter-spring	F = 30 cm TL; M = >30 cm TL
Phycis phycis	Gonochoristic species	winter-spring	35-40 cm TL
Pomatomus saltatrix	Gonochoristic species	spring-summer	30 cm TL
Prionace glauca	Gonochoristic species	spring-summer	170-280 cm TL
Raja clavata	Gonochoristic species	winter-spring	55-60 cm TL
Sarda sarda	Gonochoristic species	spring-summer	35-50 cm FL
Sardina pilchardus	Gonochoristic species	autumn-winter	15 cm TL
Sardinella aurita	Gonochoristic species	summer	14 cm TL
Sarpa salpa	Gonochoristic species	spring-autumn	20 cm TL
Scomber japonicus	Gonochoristic species	summer	28-32 cm TL
Scomber scombrus	Gonochoristic species	winter-spring	30 cm TL
Scorpaena porcus	Gonochoristic species	spring-summer	9-11 cm TL

Species	Reproductive behaviour	Main spawning period	Length at first maturity
FISH			
Scorpaena scrofa	Gonochoristic species	summer	13-16 cm TL
Seriola dumerili	Gonochoristic species	spring-summer	110-115 cm SL
Solea vulgaris	Gonochoristic species	winter-spring	25 cm TL
Sparus aurata	Hermaphroditic species (protandrous)	autumn-winter	M = 27 cm TL; F >30 cm TL
Spicara flexuosa	Hermaphroditic species (protogynous)	late spring	F = 12 cm TL; M = 16 cm TL
Spicara smaris	Hermaphroditic species (protogynous)	spring-summer	F = 12 cm TL; M = 14 cm TL
Thunnus alalunga	Gonochoristic species	summer-autumn	60-70 cm FL
Thunnus thynnus	Gonochoristic species	spring-summer	90 cm FL
Trachurus mediterraneus	Gonochoristic species	summer	23 cm TL
Trachurus trachurus	Gonochoristic species	spring-summer	22-25 cm TL
Trisopterus minutus capelanus	Gonochoristic species	winter-spring	12-13 cm TL
Umbrina cirrhosa	Gonochoristic species	summer	35 cm TL
Xiphias gladius	Gonochoristic species	summer	110-140 cm LJFL
Zeus faber	Gonochoristic species	spring-summer	40 cm TL
CRUSTACEANS			
Aristaeomorpha foliacea	Gonochoristic species	spring-autumn	30-35 mm CL
Aristeus antennatus	Gonochoristic species	spring-autumn	25-35 mm CL
Nephrops norvegicus	Gonochoristic species	all around the year	25-35 mm CL
Palinurus elephas	Gonochoristic species		65-70 mm CL
Parapenaeus longirostris	Gonochoristic species	spring-autumn	24-28 mm CL
Penaeus kerathurus	Gonochoristic species	spring-summer	40-45 mm CL
CEPHALOPODS			
Eledone cirrhosa	Gonochoristic species	spring-autumn	7.5-8 cm ML
Illex coindetii	Gonochoristic species	all around the year	F = 15 cm ML; M = 12 cm ML
Loligo vulgaris	Gonochoristic species	spring	F = 16 cm ML; M = 12 cm ML
Octopus vulgaris	Gonochoristic species	all around the year	F = 13 cm ML; M = 7 cm ML
Sepia officinalis	Gonochoristic species	spring-summer	F = 8-12 cm ML; M = 6-8 cm ML

3 Classification of the macroscopic maturity stages of some of the most common species exploited by Mediterranean fisheries

Some images showing anatomical features used in the determination of macroscopic maturity stages in the main groups of the Mediterranean demersal resources are here provided. The new MEDITS maturity scales have been used as a rule for the classification of the stages.

Bony fishes

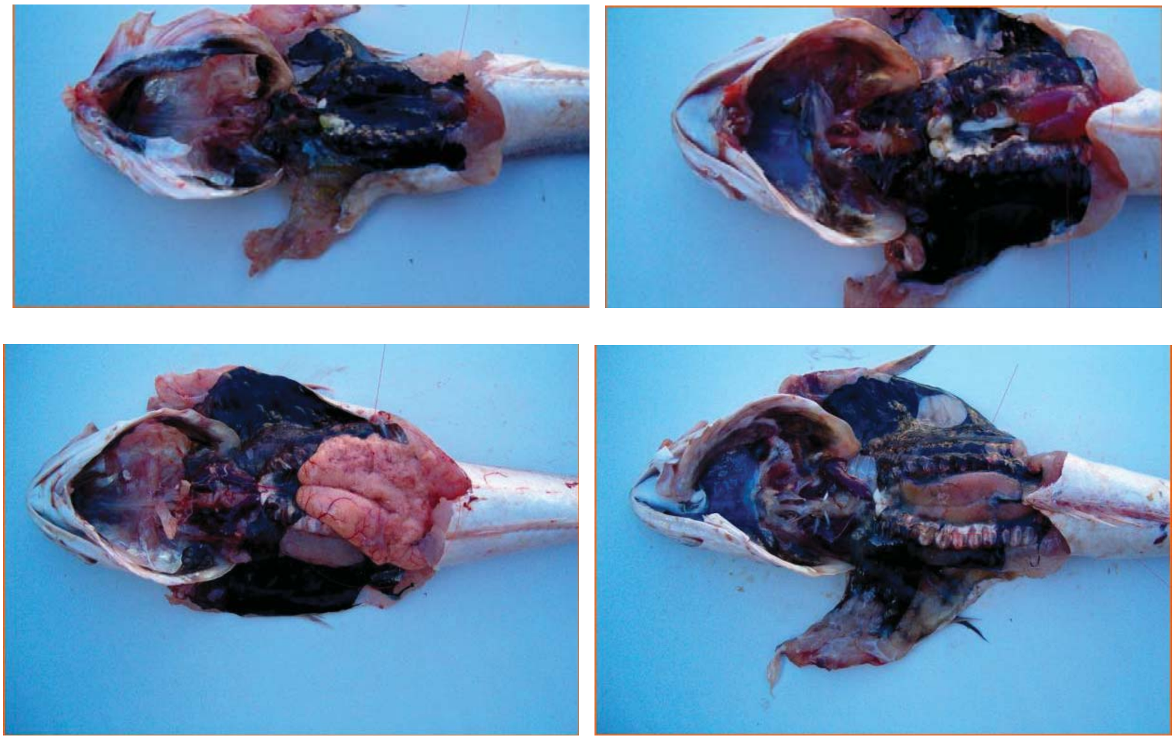


Fig. 23. *Merluccius merluccius*, females. From left to right and top to bottom: **virgin**, **developing**, **mature** and **spent** (picture by N. Ungaro).

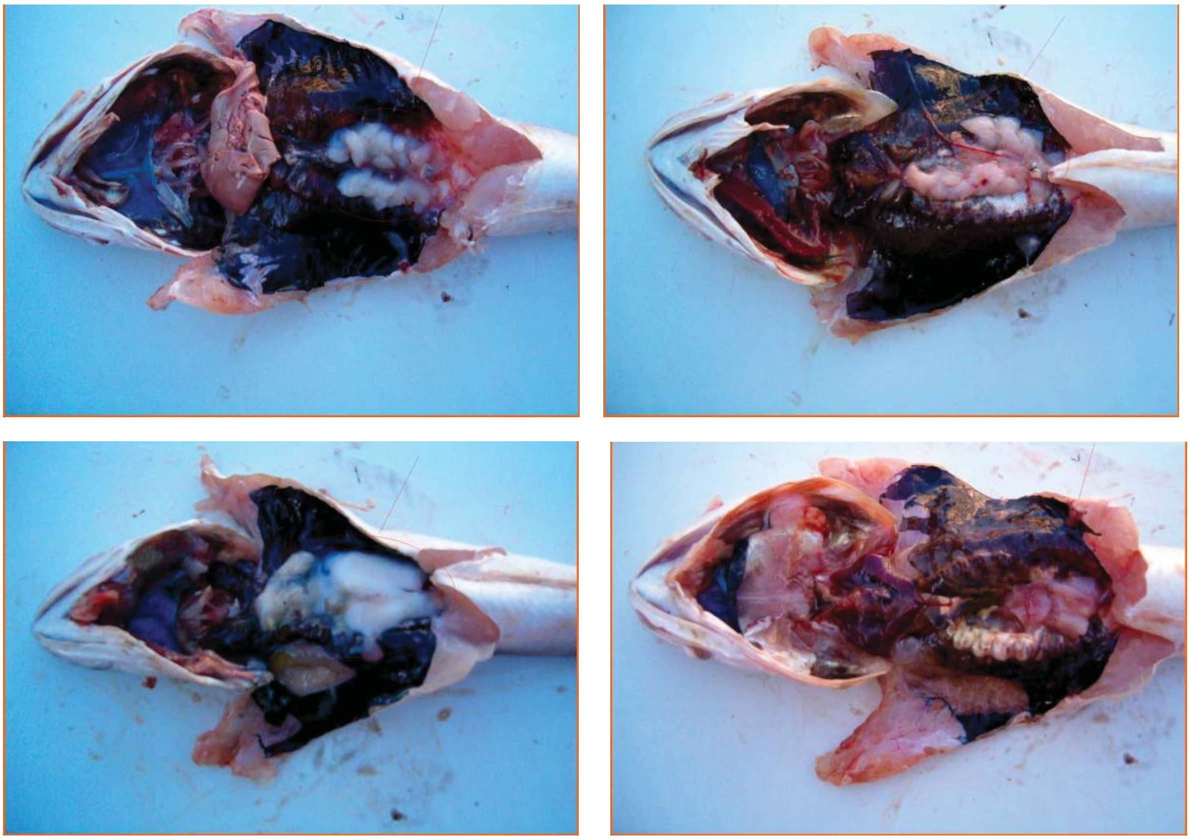


Fig. 24. *Merluccius merluccius*, males. From left to right and top to bottom: **recovering**, **maturing**, **mature** and **spent** (picture by N. Ungaro).

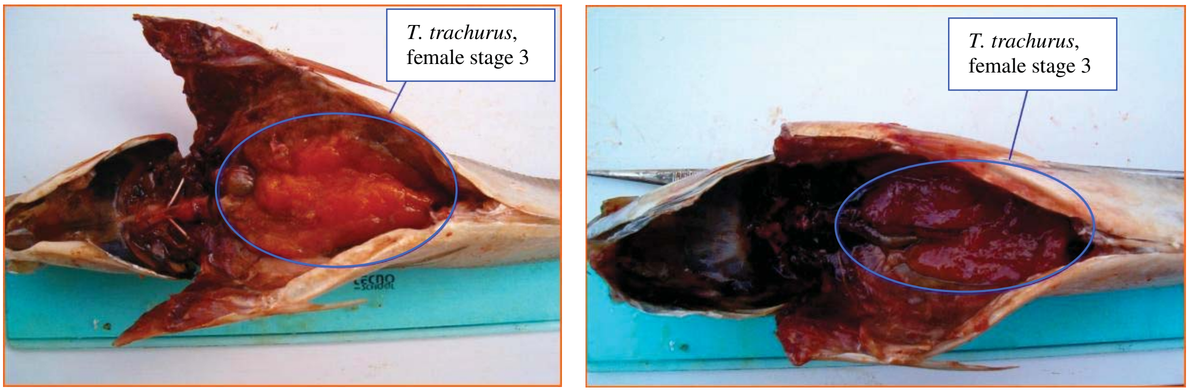


Fig. 25. *Trachurus trachurus*, females. From left to right: **mature** and **spent** (picture by N. Ungaro).

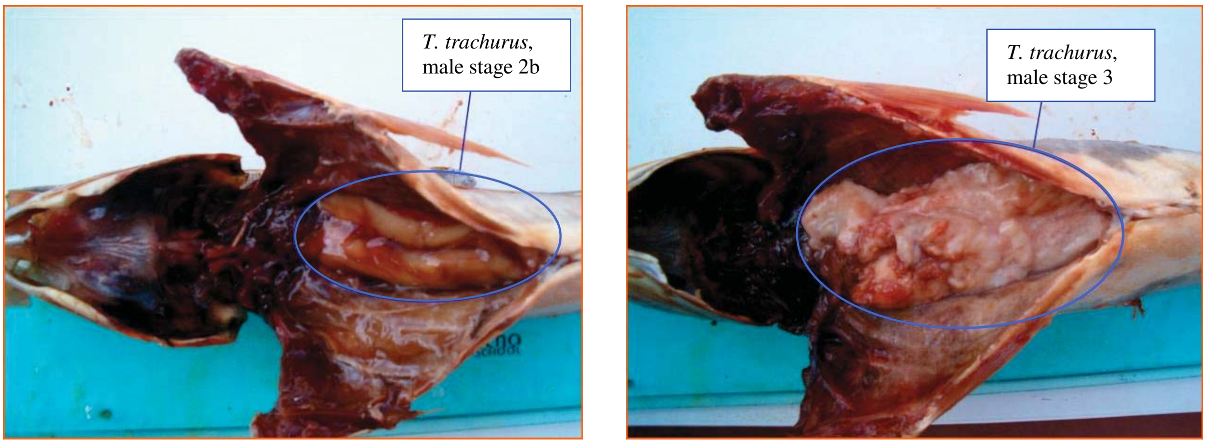


Fig. 26. *Trachurus trachurus*, males. From left to right: **maturing** and **mature** (picture by N. Ungaro).

Elasmobranchs

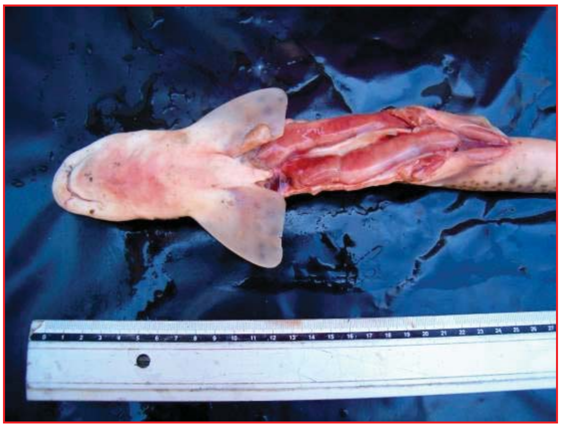


Fig. 27. *Scyliorhinus canicula*. From left to right: **mature** **female;** **maturing-mature** **male** (picture by N. Ungaro).

Cephalopods

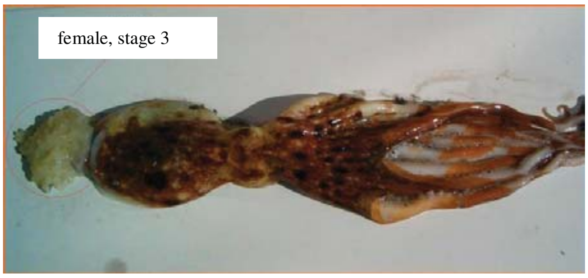


Fig. 28. *Eledone moschata*. From left to right: **mature** **female;** **mature** **male** (picture by N. Ungaro).

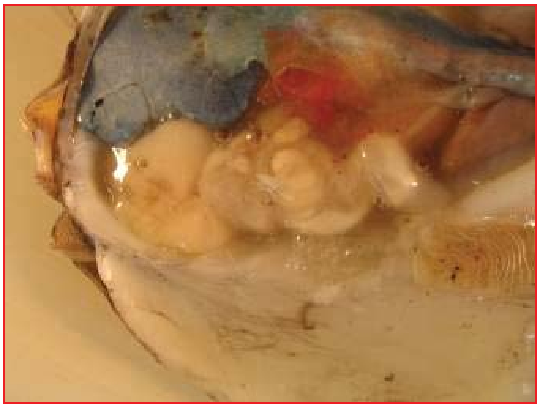


Fig. 29. *Sepia officinalis*. From left to right: **maturing-mature female; maturing-mature male** (picture by Cuccu-Davini).

Fig. 30. *Loligo vulgaris*. from up to down: **maturing-mature female; maturing-mature male** (picture by N. Ungaro).

Crustaceans

Fig. 31. *Aristeus antennatus*, females. From left to right: **immature; maturing; mature** (picture by Follesa-Davini).

Fig. 32. *Aristaeomorpha foliacea* females. From left to right: **maturing** and **mature** (picture by Follesa-Davini).

Fig. 33. *Parapenaeus longirostris*, females. From left to right: **maturing** and **mature** (picture by Follesa-Davini).

Fig. 34. *Nephrops norvegicus*, females. From left to right: **immature; maturing; mature** (picture by Follesa-Davini).

4 Estimation of the gonado-somatic index, the reproductive period and the lengths at maturity (50%, 25% and 75%)

4.1 The gonado-somatic index (GSI)

The gonado-somatic index is the ratio (percentage) between the weight of the gonad and the body weight, whole or gutted (GSI = gonad weight*100/body weight). If feasible, the utilization of the gutted body weight can provide more reliable values. The GSI can also be taken as the ratio between the weight of the gonad and the cube of the body length, as the typical length–weight relationship in fish is $W = a*L^3$, where *W* is body weight, *a* is a species-specific coefficient, and *L* is body length.

The GSI is a useful key to identify the maturation and/or spawning periods. For this purpose the monthly mean value of the GSI is estimated based on the largest possible number of specimens and, as far as possible, by sampling the whole length range of the population at sea. Moreover, in the estimation of the GSI the number of individuals per size-class should be balanced. The plotting of the monthly mean GSI values, including the corresponding standard deviation, gives some indication of the maturity stages throughout the year and the spawning period or periods.

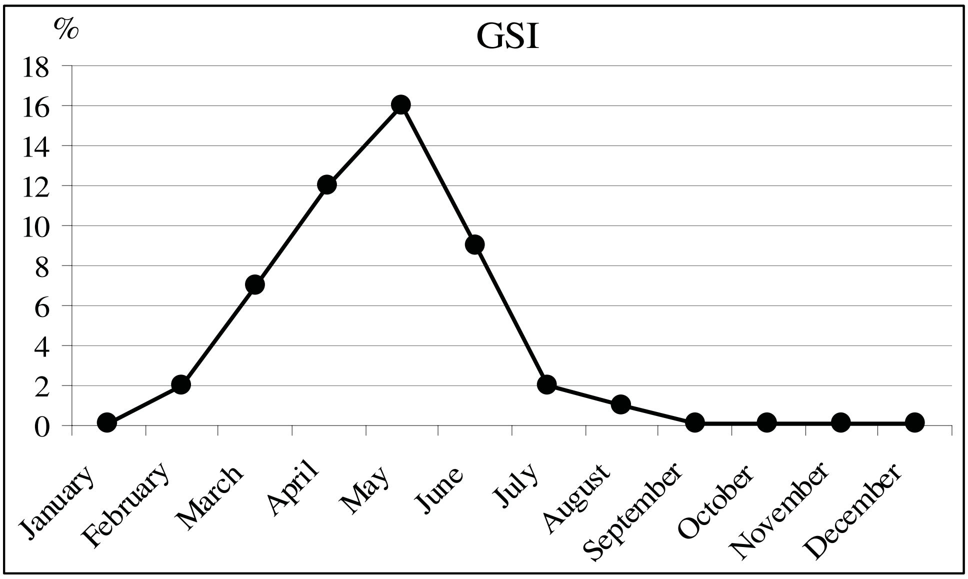


Fig. 35. An example of seasonal variation in the GSI

If the GSI value by size-class is calculated during the spawning season, a rough estimate of the length at first maturity can also be obtained.

4.2 The estimation of length at first maturity (50%, 25% and 75%)

The length at first maturity is conventionally the size at which the 50% of the population attains an advanced stage of gonad development ($L_{m_{50\%}}$). The mentioned parameter is a species-specific value as a rule, but it could be influenced by environmental (i.e. temperature, food availability) and by population (i.e. density) factors.

The data needed for the estimation of the size at first maturity came from the calculation of the percentages of mature specimens per size-class (number of mature individuals/total number per size-class). The number of individuals in each size-class has to be sufficient (a minimum of 20 per size-class) and the specimens have to be collected in the period just before or very close to the spawning peak of the species. An example of a "percentage maturity table" is reported below.

An example of a percentage maturity table.

Length class	**Total number of specimens**	**Number of mature specimens**	**Maturity percentages (ratio)**
10	128	0	0.00
20	132	2	0.02
30	116	5	0.04
40	144	7	0.05
50	110	12	0.11
60	122	20	0.16
70	141	45	0.32
80	133	60	0.45
90	104	75	0.72
100	102	90	0.88
110	110	92	0.84
120	121	115	0.95
130	99	98	0.99
140	114	114	1.00
150	100	100	1.00

Normally, a standard maturity scale includes the following stages: *immature*, *developing, maturing, mature, spent, recovering*. .*Mature*, *spent* and *recovering* are stages corresponding to adults, so they can be included in the *mature* category. The stages *immature* and *developing* are included in the "not mature" category as a rule. The maturing stage is intermediate, but the passage from *maturing* to *mature* is a very fast process as a rule. Thus we can include the *maturing* individuals in the *mature* category. In this case, the length at maturity could be slightly underestimated.

Then, if the percentage maturity values per size-class are estimated, these values can be used for fitting the logistic equation: $P_{mat} = 100/[1+\exp^{(a-b*L_{mat})}]$
where P_{mat} = percentage maturity; L_{mat} = body length; *a* is a constant; *b* is a coefficient.

The logistic model allows calculation of the:

- maturity $length_{50\%}$ = (a)/ (b)
- maturity range $L_{25\%}$–$L_{75\%}$:

$$L_{25\%} = (a-1.09861)/b$$
$$L_{75\%} = (a+1.09861)/b$$

The logistic model is a generalized model; however, other ad hoc models are also available which allow definition of the maturity ratio (proportion of mature specimens in a given size-class), as in the following example:

$$P_{r.mat} = 1/[1+ \exp^{-b*(L_{mat}-L_{m50})}]$$

where $P_{r.mat}$ = maturity maturity ratio L_{mat} = length corresponding to the maturity ratio; L_{m50} = length at the 50% maturity ratio; b is a coefficient (King, 1995). In this case, the value of L_{m50} may be taken directly as a model parameter.

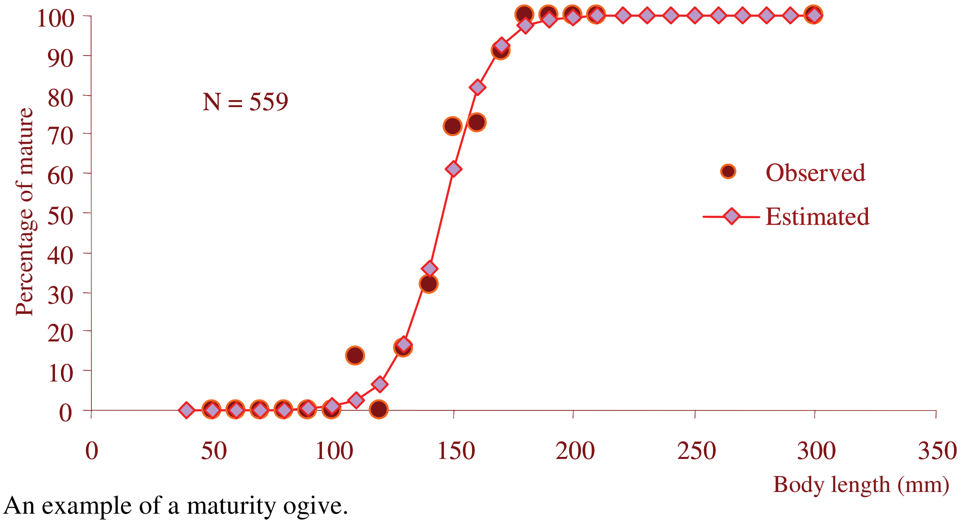


Fig. 36. An example of a maturity ogive.

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