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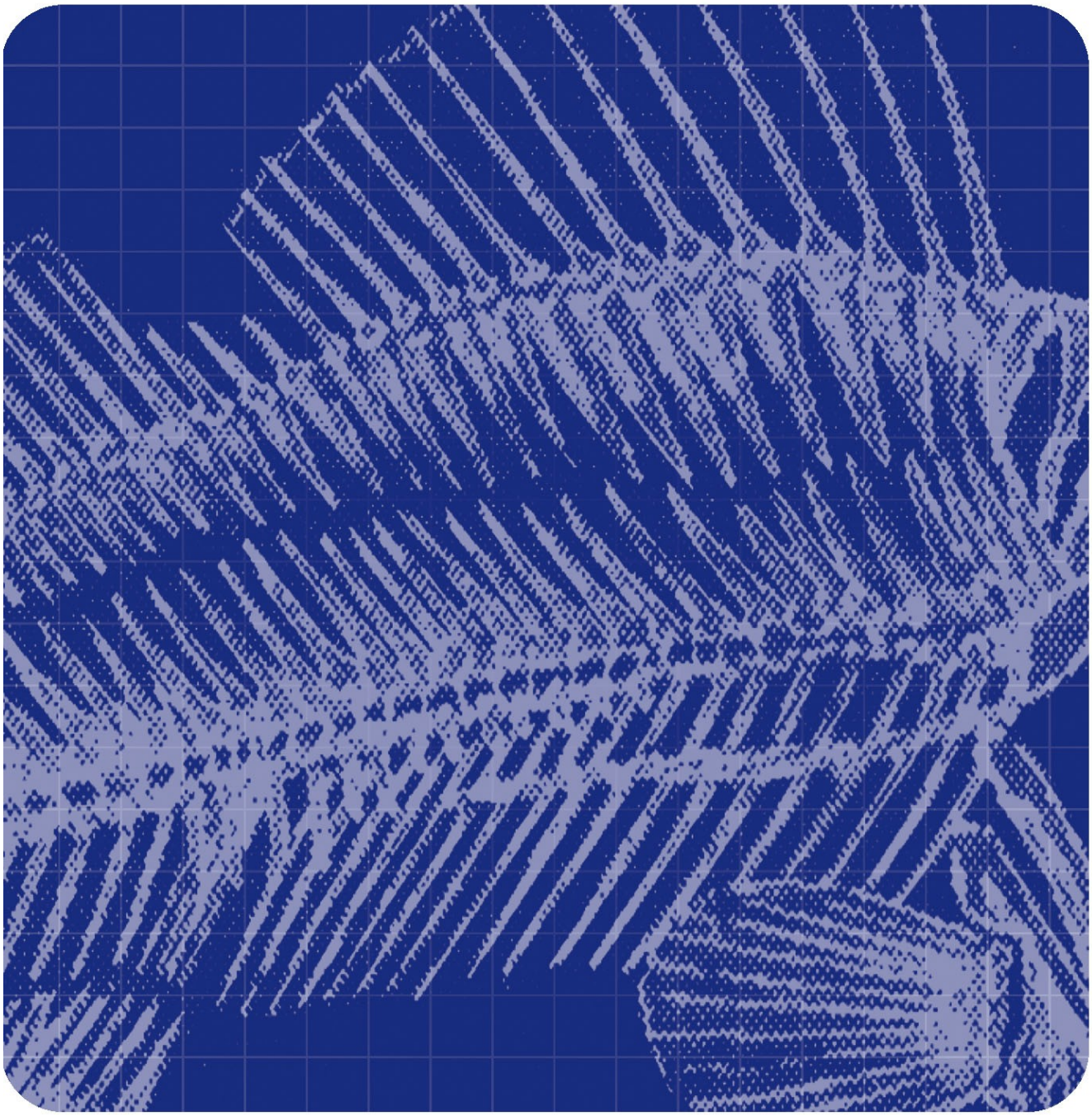
Maturity stages of shrimp *Pandalus borealis* Krøyer 1838

Method for classification and description of characteristics

Hege Øverbø Hansen and Michaela Aschan



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REPORT

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Maturity stages of shrimp (*Pandalus borealis* Krøyer 1838)

Method for classification and description of characteristics

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Summary:

Pandalus borealis is a protandric hermaphrodite that shows a great variation in both age at sex change and in the proportion of males that become females. This plasticity is believed to be a phenotypic response to maximize individual reproductive success. Since 1992, we have classified all shrimp taken for length measurements into maturity stages in order to understand more of the population structure of shrimp in the Barents Sea and Svalbard area . The development of sex characters and transition from male to female shrimp was characterized by seven stages using the morphology of the endopod of the first pleopod, sternal spines and head roe. After the juvenile stage, shrimp mature first as males (Stage 2). Thereafter they become intersex or transitionals (Stage 3) before they develop into females with head roe (Stage 4). When the females mate, the roe is spawned under the abdomen and kept there by the pleopods (Stage 5), where it stays until the larvae hatch (Stage 6). Some females then enter a resting period (Stage 7), while others start on a new cycle with head roe (Stage 8).

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1 DESCRIPTION OF MATURITY STAGES FOR *PANDALUS BOREALIS* KRØYER 1838

1.1 Study area and sampling methods

Since 1992, Fiskeriforskning has conducted annual research surveys for shrimp, *Pandalus borealis*, in the Barents Sea and Svalbard area. The Barents Sea survey is usually conducted in spring (April-May) while the Svalbard survey is conducted in late summer (August-September). The first year a commercial trawler was used. Since 1993 the Norwegian research vessel "R/T Jan Mayen" has been used for both survey areas.

A Campelen 1800 bottom trawl was towed for 20 min at a speed of 3 knots, covering a distance over the ground of approximately 1.0 naut. mile. A detailed description of survey methodology is given in Aschan and Sunnanå (MS 1997). To ensure the capture of small shrimp, a small meshed bag (0.8 mm) with a $1m^2$ opening was attached to the under belly of the trawl (Aschan, 2000; Nilssen *et al.*, MS 1986).

A subsample of 300 shrimp at each station was examined for maturity stage. The shrimp sample was taken randomly and provides an estimation of the sex- and maturity distribution on each station.

1.2 General reproductive biology of *Pandalus borealis*

Pandalus borealis is a protandric hermaphrodite, as discovered by Berkley (1929). Protandry means that individuals first function as males and then change sex to become females. This reproductive strategy is not always obligate. In some populations shrimp may develop directly into females (primary females) (Butler, 1971). Although young shrimp show male morphological characteristics early in life they may not develop into functional males, but instead the male characteristics degenerate and development succeed into functional females (early maturing females). It seems that both the age of sex change and the proportion of males developing into females can vary not only geographically but also from year to year. (Bergstrøm, 1997, 1992b; Haynes and Wigley, 1969; Butler, 1964b; Allen, 1959; Rasmussen 1953; Hjort and Ruud, 1938). This phenotypic sex determination indicates that environmental demography is probably of great importance in maximizing individuals' reproductive succes (Charnov and Anderson, 1989; Charnov and Bergstrøm, 1987; Charnov *et al*., 1978; Warner, 1975).

P. borealis reproduces annually. Mating and spawning occurs during the autumn. The eggs are fertilized on their way from the oviduct to the pleopods. The female carries the eggs under the abdomen until spring when the eggs hatch. Then, during the summer the female starts to develop head roe and will then spawn again the following autumn. However, some females enter a resting stage and will not spawn again until the next year (Teigsmark, 1983).

1.3 Morphological characteristics of maturity stages

Sex determination of shrimp is generally based on examination of the first two pairs of pleopods (Rasmussen, 1953, Allen, 1959; Shumway *et al*., 1985). A further differention of the females into different maturity stages was done by the method of Horsted and Smidt (1956) (Fig. 1). For convenience in field work we are primarily using the 1. pair of pleopods for determination (Fig. 2A). This method allows us to determine the male stage from the transitional stage without the use of a magnifying lens. The 1. endopod (Fig. 2B) is a rounded, leaf like structure characterized as the male stage with an appendix interna on its inner distal edge. This appendix interna degenerates through the transitional stage and finally disappears at the first time spawning female stage. The shape of the endopod then changes to a lancet like shape in the female.

The sternal spines disappear between Stages 4 and 5. The spines are situated along the ventral midline on the transverse ridge separating the abdominal sternites (Fig. 3). We use the first pair of sternal spines to differentiate between the first or second time spawning female (McCrary, 1971).

Stage 5 is characterized by extruded eggs attached to the abdomen. The eggs are blue in colour. The opacity (and colour) of the eggs gradually decrease until hatching.
The long setae on the pleopods of a female in breeding dress hold the eggs to the abdomen. These setae are visible until after hatching and are a typical character of stage 6.

Shrimp that are not going to spawn the following season will enter a resting stage. These are shrimp with no head roe and no sternal spines. Shrimp that have spawn and hatched eggs last season and then again spawn the following season will have head roe but no sternal spines and are characterized as second time spawners.

Sometimes it is difficult to separate shrimp between first (stage 4) and second time spawners (stage 8). This is because the sternal spines may still be seen as slight protuberances in some second time spawners. In these cases it will be useful to look at the appendix masculina of the second pleopod (Fig. 2B). In stage 8 this appendix will be absent, in stage 4 it may be some degenerated remains left of the appendix masculina. This inspection must be done in a magnifying lens.

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3 FIGURES

All figures are redrawn or modified from Grimsmo, 1993.

Figure 1. Maturity stages and codes for *Pandalus borealis*.

Figure 2A. Location of 1. and 2. pair of pleopods. The endopod on the 1. pleopod and the appendix interna and appendix masculina on 2. pleopod.

Figure 2B. Development of the endopod of the first pleopod and the corresponding appendix masculina and appendix interna of the second pleopod. Black endopod: males. Hatched endopod: transitionals. White endopod: females.

Figure 3. Change in sternal spines of males, transitionals and females.

Figure 4. Flow diagram of stages in sex and maturity determination of *Pandalus borealis*.

Pandalus borealis maturity stages – codes

Maturity stage	Code
Juvenile	---
Male • Sternal spines prominent (Fig. 3) • Male structure of the endopod of the 1. pleopod (Fig. 2B)	2
Intersex (transitionals) • Sternal spines prominent • Intersex/female structure of the endopod of the 1. pleopode (Fig. 2B)	3
Female (first time spawning) • Sternal spines prominent • Head roe clearly visible • Female structure of the endopod of the 1. pleopode (Fig. 2B)	4
Female • Sternal spines reduced • Extruded eggs under the abdomen • Head roe may be presence	5
Female • Sternal spines reduced • With setae and remains of eggs/hatching eggs • Head roe may be presence	6
Female (resting stage) • Sternal spines reduced or disappeared • No setae or eggs	7
Female (second time spawning) • Sternal spines reduced • Head roe distinct	8

Figure 1

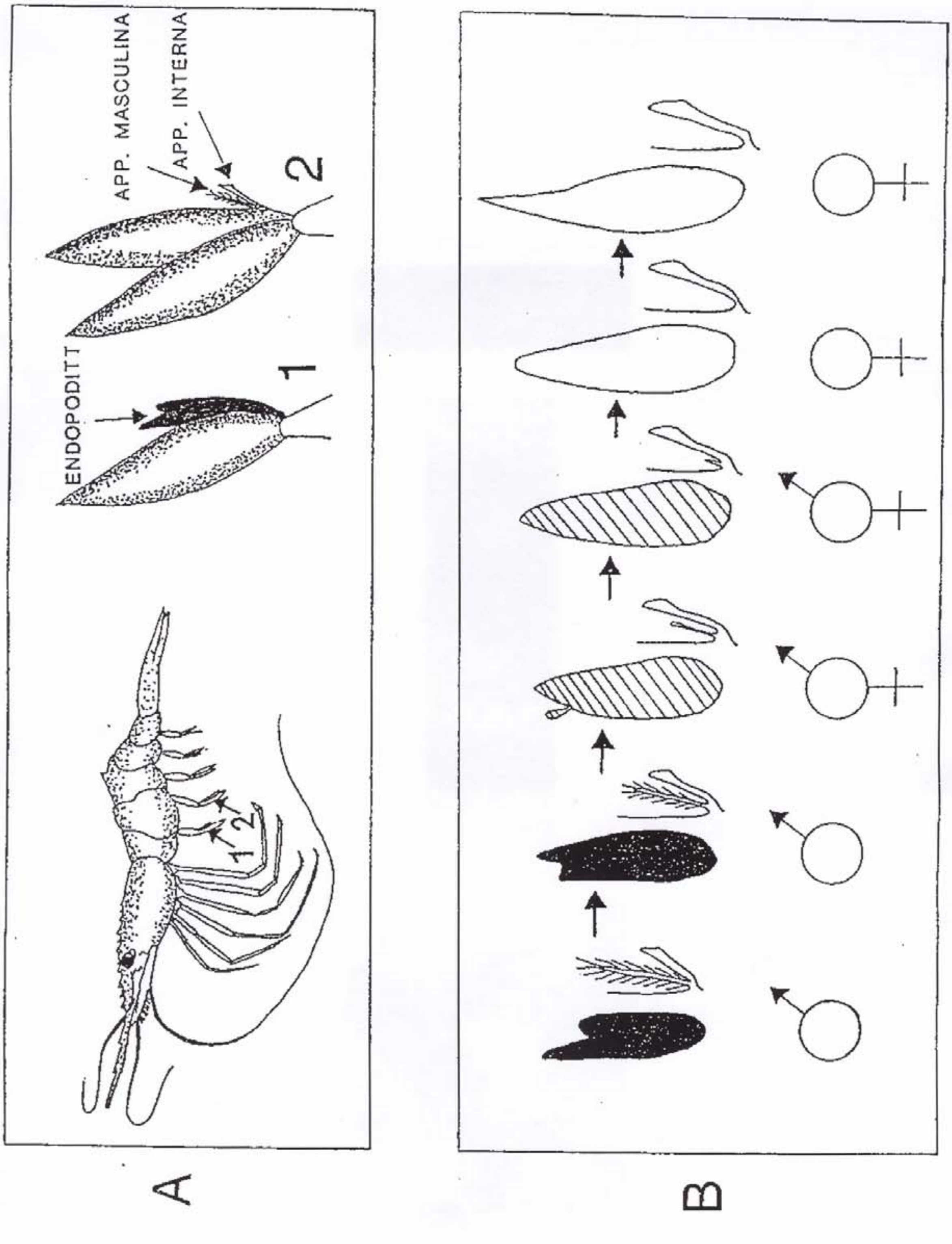

Figure 2

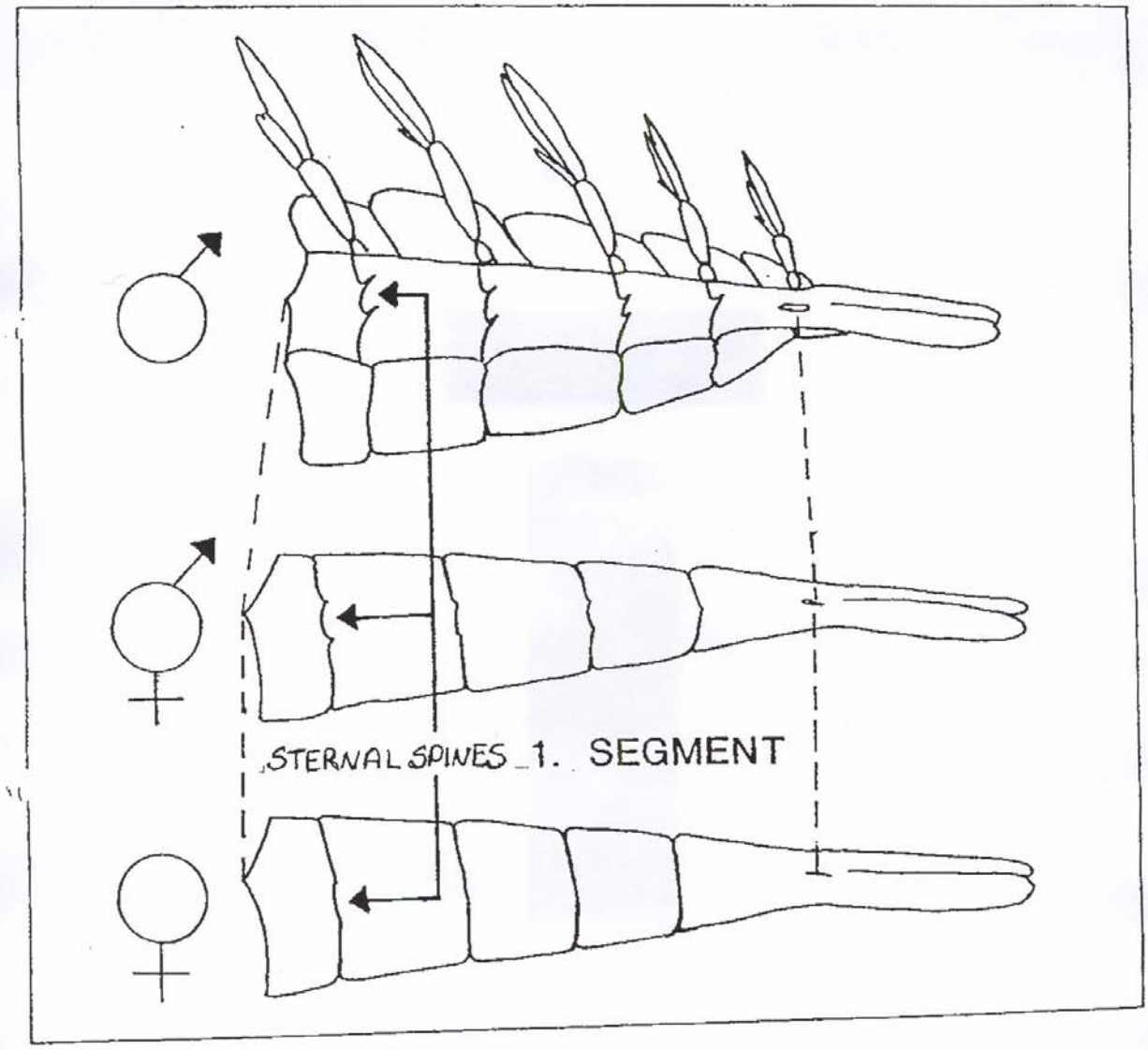

Figure 3

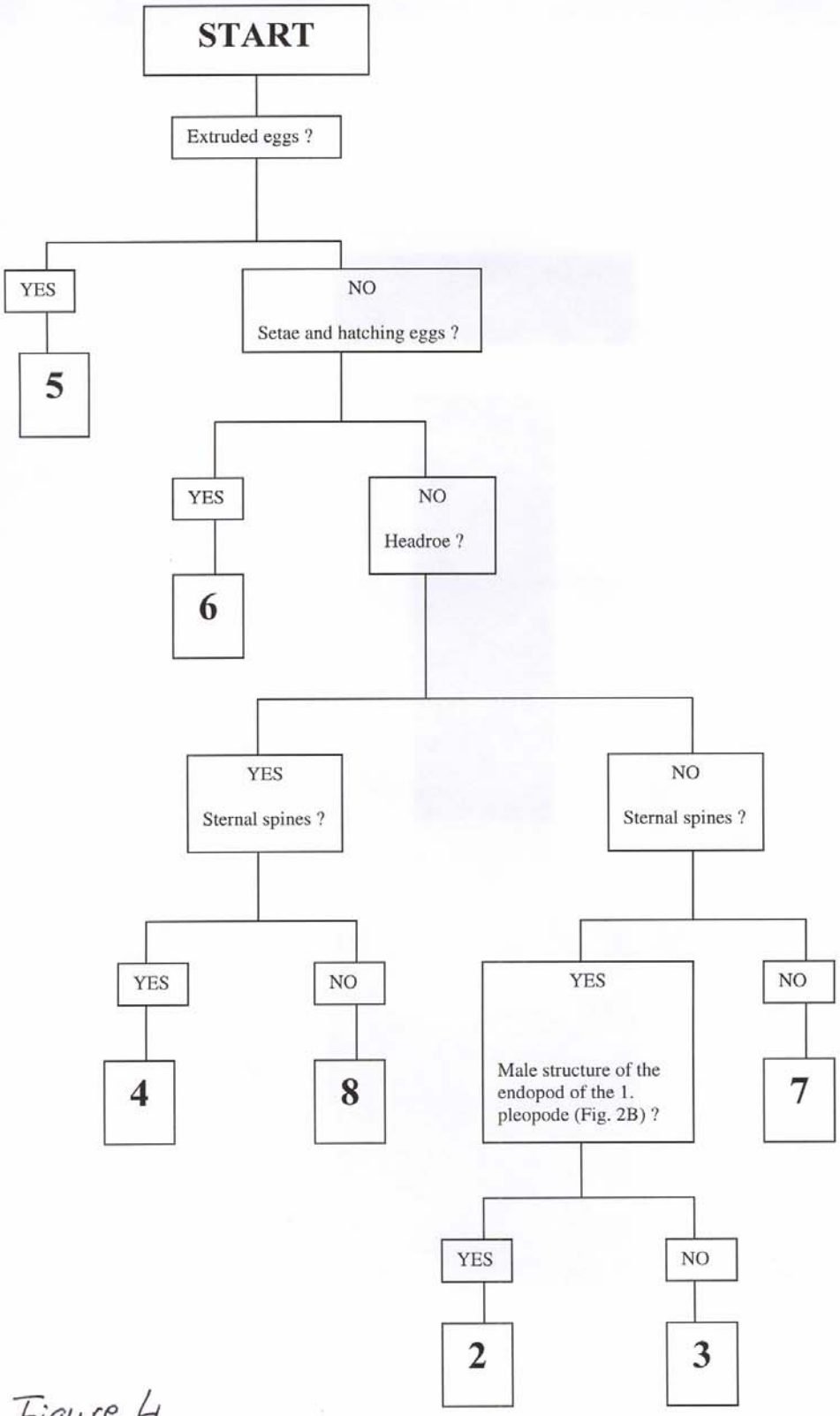
START
Extruded eggs ?
YES
5
NO
Setae and hatching eggs ?
YES
6
NO
Headroe ?
YES
Sternal spines ?
NO
Sternal spines ?
YES
4
NO
8
YES
Male structure of the endopod of the 1. pleopode (Fig. 2B) ?
NO
7
YES
2
NO
3

Figure 4

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