Antarctic Science 8 (2): 185–192 (1996)

Reproduction in three species of fish from the Ross Sea and Mawson Sea

M. VACCHI[1], R. WILLIAMS[2] and M. LA MESA[1]

[1]*ICRAM, Central Institute for Marine Research, Via L. Respighi 5, 00197 Rome, Italy*
[2]*Australian Antarctic Division, Channel Highway, Kingston, Tasmania 7050, Australia*

Abstract: Reproductive characteristics are compared of the nototheniids *Trematomus bernacchii* and *T. hansoni* and the channichthyid *Chionodraco hamatus* caught in summer at Terra Nova Bay (Ross Sea) and caught all the year round in the waters off Casey Station (Mawson Sea). Whilst spawning of *T. bernacchii* took place in October–November off Casey and probably at Terra Nova Bay, the spawning periodo f *T. hansoni* differed between the sites (September–November off Casey, December–February at Terra Nova Bay). The spawning period also differed between sites for *C. hamatus* (August–October off Casey, December–February at Terra Nova Bay). Fecundity was higher and egg size was lower in nototheniid species (*c.* 8000 eggs of 3–4 mm) than in channichthyid (*c.* 4000 eggs of 4–5 mm). Moreover, the fecundity was lower and egg size higher in the specimens from Terra Nova Bay when compared to Casey.

Received 25 May 1995, accepted 15 January 1996

Key words: Antarctic, fish, fecundity, reproduction, spawning period

Introduction

Early observations on the reproductive biology of Antarctic fish were carried out around Iles Kerguelen, South Georgia and the South Orkney Islands (reviews in Everson 1984, Kock 1985, Duhamel 1987, North & White 1987, Kock & Kellermann 1991). Only more recently has information on reproduction of the High Antarctic fish become available mainly for species from the Weddell Sea (Ekau 1991, Duhamel *et al.* 1993) with some data on species in the Ross Sea (Dearborn 1965, Pankhurst 1990), near Terre Adélie (Hureau 1970) and in the Davis and Mawson Seas (Butskaya & Faleeva 1987, Shandikov & Faleeva 1992).

All of these studies pointed out some common features: prolonged gametogenesis, oocyte maturation is a biennial process, (although spawning probably occurs annually), low fecundity and relatively large yolky eggs. Moreover, in nototheniids a general trend of decreasing fecundity and increasing egg size was found towards higher latitudes (Kock & Kellermann 1991). Existing information on spawning time of the Antarctic fish indicate that the species living in the Seasonal Pack-ice Zone or around the islands north of it are mostly autumn and winter spawners, while in the High Antarctic Zone a higher proportion of fish are spring and particularly summer spawners (Kock & Kellermann 1991).

The present study was carried out on the nototheniids *Trematomus bernacchii* Boulenger, 1902 and *Trematomus hansoni* Boulenger, 1902 and on the channichthyid *Chionodraco hamatus* (Lönnberg, 1905), which are the most common species in the coastal fish communities of Terra Nova Bay, Ross Sea (Vacchi *et al.* 1991, 1992). These benthic species are circumantarctic and are common mainly in the High Antarctic Zone; they live in a wide depth range, from near surface to *c.* 600 m (Gon & Heemstra 1990).

In this paper we describe some aspects of their reproductive biology (annual gonad cycle, fecundity, egg size, spawning season) in the areas of Terra Nova Bay (Ross Sea) and near Casey Station (Mawson Sea) and compare the results to detect difference between these two High Antarctic sites located at different latitudes and longitudes.

Material and methods

Samples were collected during the austral summer 1987–88 and 1990–91 (3rd and 6th Italian Antarctic Expeditions) at Terra Nova Bay and throughout the year of 1988 in the waters off Casey Research Station. The sampling at Terra Nova Bay (74°42´S, 164°06´E) was conducted by nets, lines and traps. Overall, 61 hauls from 14–265 m depth were carried out in January–February 1988, and 90 hauls from 16–680 mdepth were carried out in December 1990–February 1991 (Vacchi *et al.* 1991, 1992). In the waters off Casey (66°17´S, 110°32´E), fishes were collected by angling in several localities within a 5 km radius of the Station, and in each locality at least at monthly intervals. Depth range in which the three species were caught was about 3–200 m. *T. bernacchii*, *T. hansoni* and *C. hamatus* were caught in both areas in large numbers.

Total length (TL) measured to the nearest mm below. Total weight (W) was determined to the nearest gram below. Each specimen was gutted and its gonads weighed and assessed on a five point scale (Everson 1977, Anon. 1989). Gonado-somatic index (GSI) was calculated as percentage of gonadal to total weight (Hureau 1970).

Fecundity and egg size were calculated in ripe females (maturity stage 4) and, in some specimens from Casey, from developing females (maturity stage 3) as well. To estimate fecundity, a subsample of each ovary was weighed to the nearest 0.01 g and the number of eggs counted under a dissecting microscope; this value was then extrapolated to the entire ovary (absolute or potential fecundity). Relative fecundity, i.e. the number of oocytes produced per gram of total weight, was also determined.

Ten eggs (50 eggs in the specimens from Casey) were selected from each gonad, measured under a dissecting microscope to the nearest 0.1 mm diameter and the mean value calculated. The egg size pattern in the ovaries of ripe females of *T. hansoni* and *C. hamatus* from Terra Nova Bay was characterized by two distinct groups of oocytes: one batch of small oocytes up to 1 mm, representing probably the following year's spawn, and many large yolky oocytes (mean diameter between 3.1–5 mm according to the species) forming the current season's spawn. In the results, we refer to the latter oocyte group.

The relationship between fecundity and fish size were determined from (Kartas & Quignard 1984):

$$F = a \times TL^b$$
$$F = a \times W^b$$

where a and b are constants, F is the total fecundity, TL is the total length and W is the total mass. The values of a and b are derived from the least-squares fit on the log transformed data of dependent (F) and independent (TL and W) variables.

Length at sexual maturity and length at first spawning were not determined because of the low number of juvenile specimens.

Results

Length frequency distribution

The maximum size of females was larger than that of males in all the three species caught in Terra Nova Bay. The size range (TL) of females and males was 140–330 and 140–260 mm in *T. bernacchii*, 190–350 and 190–270 mm in *T. hansoni*, 320–440 and 300–390 mm in *C. hamatus*, respectively. The same sexual dimorphism was found in the specimens caught off Casey. At this site the size range (TL) of females and males was respectively 131–288 and 109–273 mm in *T. bernacchii*, 175–358 and 159–308 mm in *T. hansoni*, 352–504 and 352–469 mm in *C. hamatus*.

Gonado-somatic index (GSI) and maturity stages (MS)

The annual pattern of GSI for *T. bernacchii* at Casey Station showed an increase from August to October-November, ranging between 5.7–13.1% in females (Fig. 1a) and 1.1–2.8%

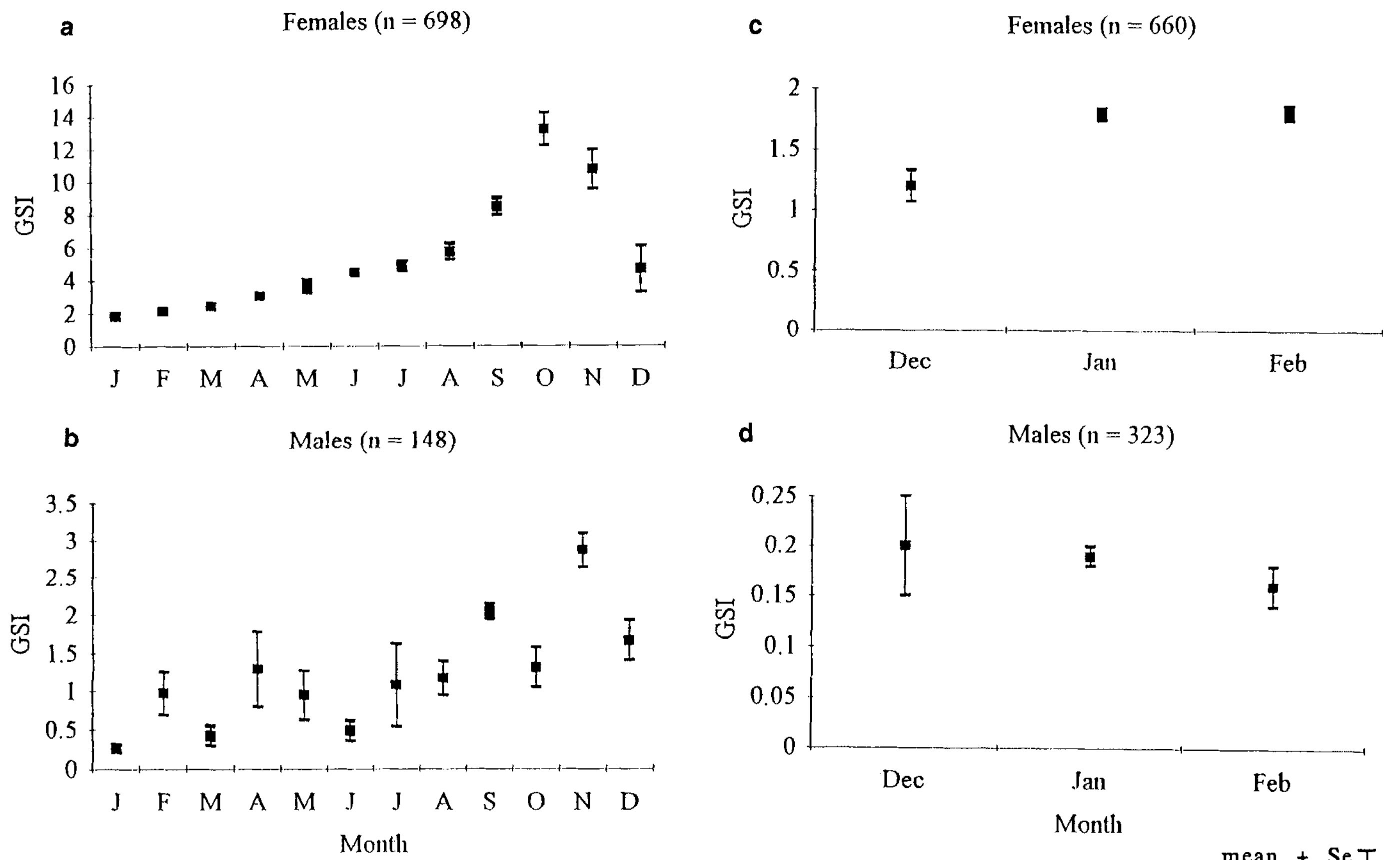

Fig 1. Annual and seasonal pattern of gonado-somatic index (GSI) of *Trematomus bernacchii* from Casey (**a.,b.**) and Terra Nova (**c.,d.**), respectively.

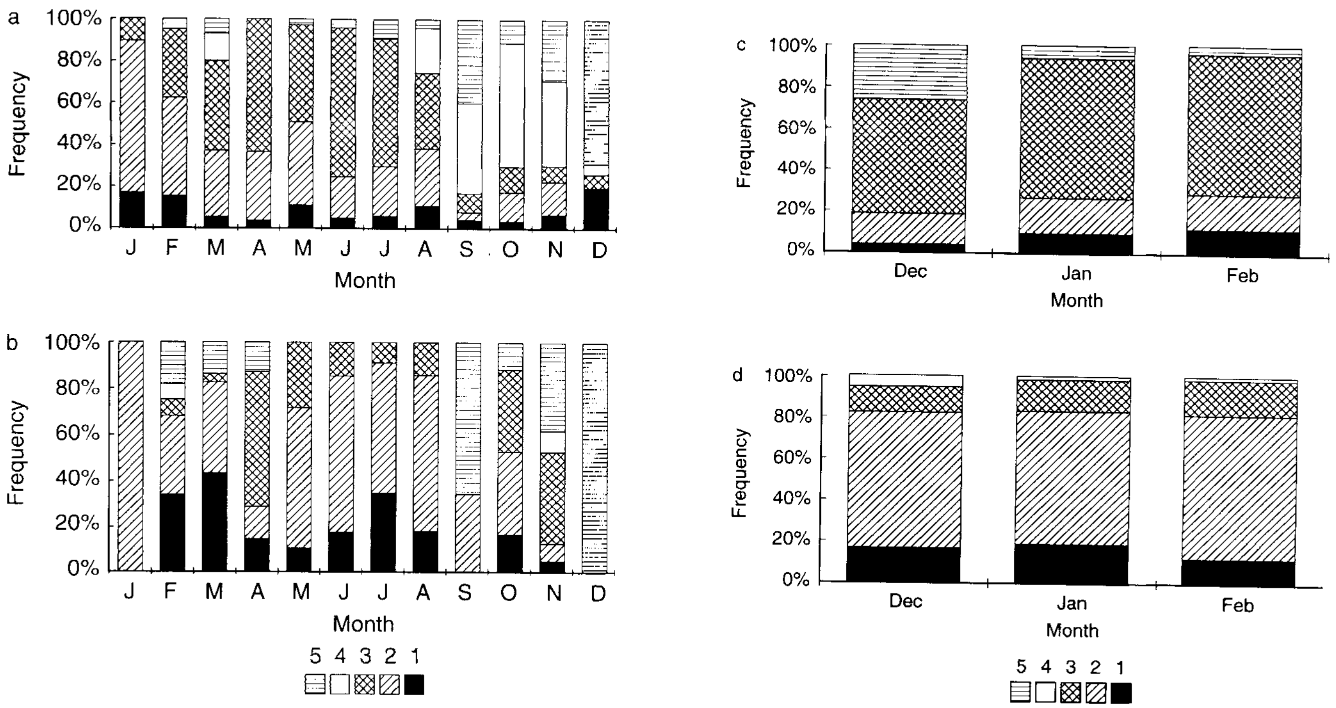

Fig 2. Annual and seasonal pattern of maturity stages frequency of *Trematomus bernacchii* from Casey (**a.** Females *n* = 698, **b.** males *n* = 148) and Terra Nova (**c.** Females *n* = 660, **d.** males *n* = 323), respectively.

in males (Fig. 1b). In this period, there were a high percentage of gravid females (stage 4), but the highest percentage of spent females was found in December (Fig. 2a). Ripe males were mostly collected in November, whilst all the specimens caught in December were spent (Fig. 2b).

T. bernacchii from Terra Nova Bay showed a decrease in percentage of spent females and an increase in early stage 3 (developing stage) from December to February (Fig. 2c). Almost all of the males were in the early gonad development stages (Fig. 2d).GSI was low in all the three months, namely 1.2–1.8% in females (Fig. 1c) and 0.2% in males (Fig. 1d).

GSI of *T. hansoni* from Casey increased from July to September and subsequently decreased; the range for females and males was 2.4–12.5% (Fig. 3a) and 0.1–0.4% (Fig. 3b), respectively. A similar trend was found in the percentage of gravid females (in September, all the females were in maturity stage 4) (Fig. 4a). Strangely, no ripe males were found during the entire sampling period and only one specimen in maturity stage 3 was collected in October (Fig. 4b).

Data on *T. hansoni* from Terra Nova Bay suggested that, in the period December–February this species was in spawning condition: GSI in females ranged from 9.9–11.8% (Fig. 3c) and in males from 0.15–0.23% (Fig 3d). Simultaneously, there was a high percentage of gravid females (45–68%) (Fig. 4c). Again no ripe males were found (Fig. 4d).

The small amount of data on *C. hamatus* for the period June–December at Casey showed an increase of GSI in females from August (7.0%) to October (22.9%) followed by a sharp decrease in November–December (Fig. 5a); a similar trend was also observed in males between June–October (Fig. 5b). Gravid females were found in August, September and October (Fig. 6a), whereas the only ripe male was caught in September (Fig. 6b).

Most specimens of *C. hamatus* caught in Terra Nova Bay during December–February were in spawning condition with a GSI range of 7.0–14.4% in females (Fig. 5c) and 1.5–1.8% in males (Fig. 5d). As well the percentage of stage 4 decreased progressively from December to February in both sexes (Fig. 6c, d).

Fecundity and egg size

Data on *T. bernacchii* from Casey showed an increase in total fecundity and egg size from April to October–November. Total fecundity ranged from 1012 to 4570 eggs and mean egg diameter from 1.4 to 3.8 mm (Fig 7a). Because of a lack of gravid females, it was not possible to determine the fecundity at Terra Nova Bay.

Mean egg diameter of *T. hansoni* from Casey increased from 1 mm (April) to 2.9 mm (November), while total fecundity showed an irregular pattern (range 3358–8636 eggs) (Fig. 7b). Egg size and total fecundity of *T. hansoni* from Terra Nova Bay were 3.1–3.6 mm and 5149–6527 eggs, respectively, both increasing from December–February

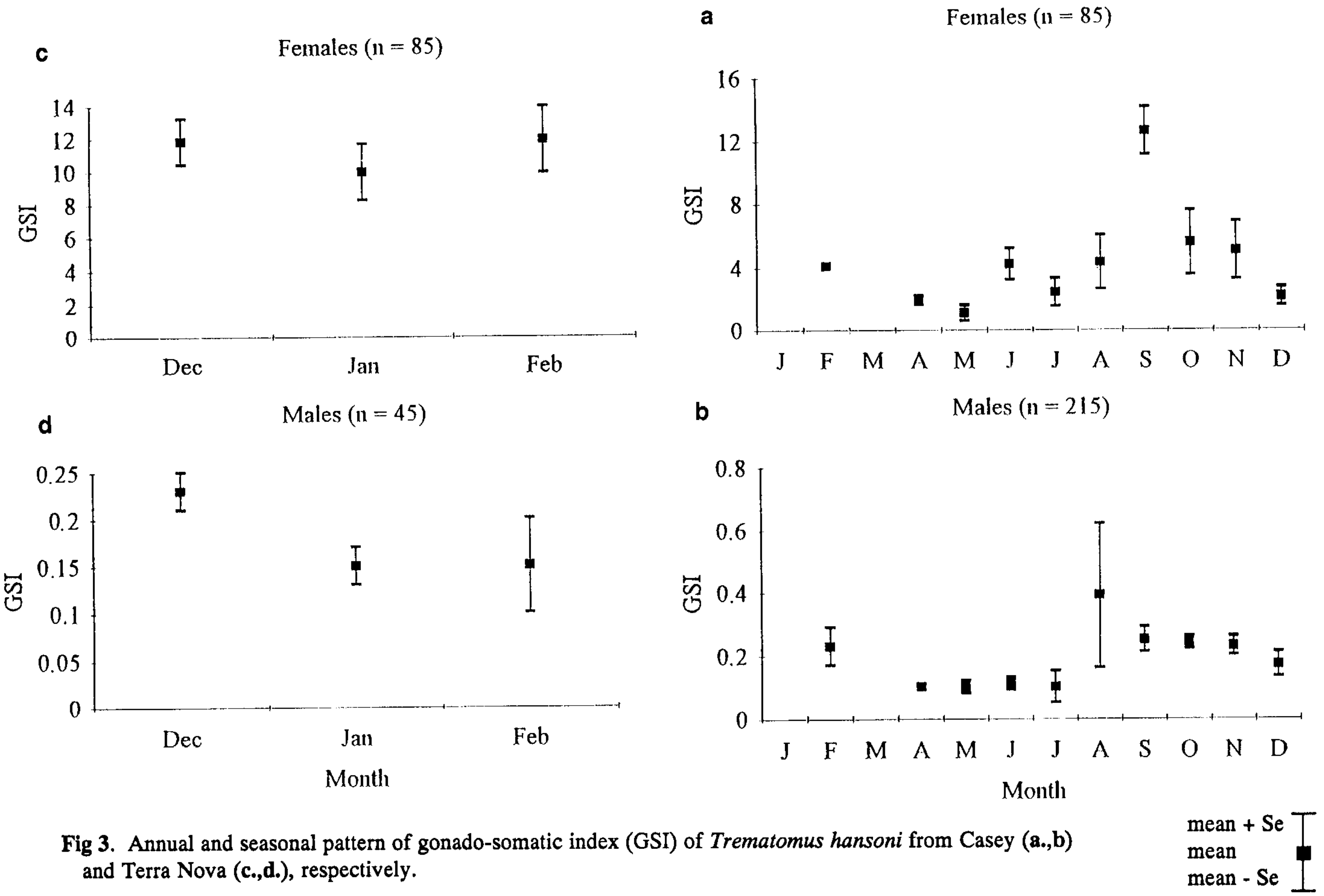

Fig 3. Annual and seasonal pattern of gonado-somatic index (GSI) of *Trematomus hansoni* from Casey (**a.,b**) and Terra Nova (**c.,d.**), respectively.

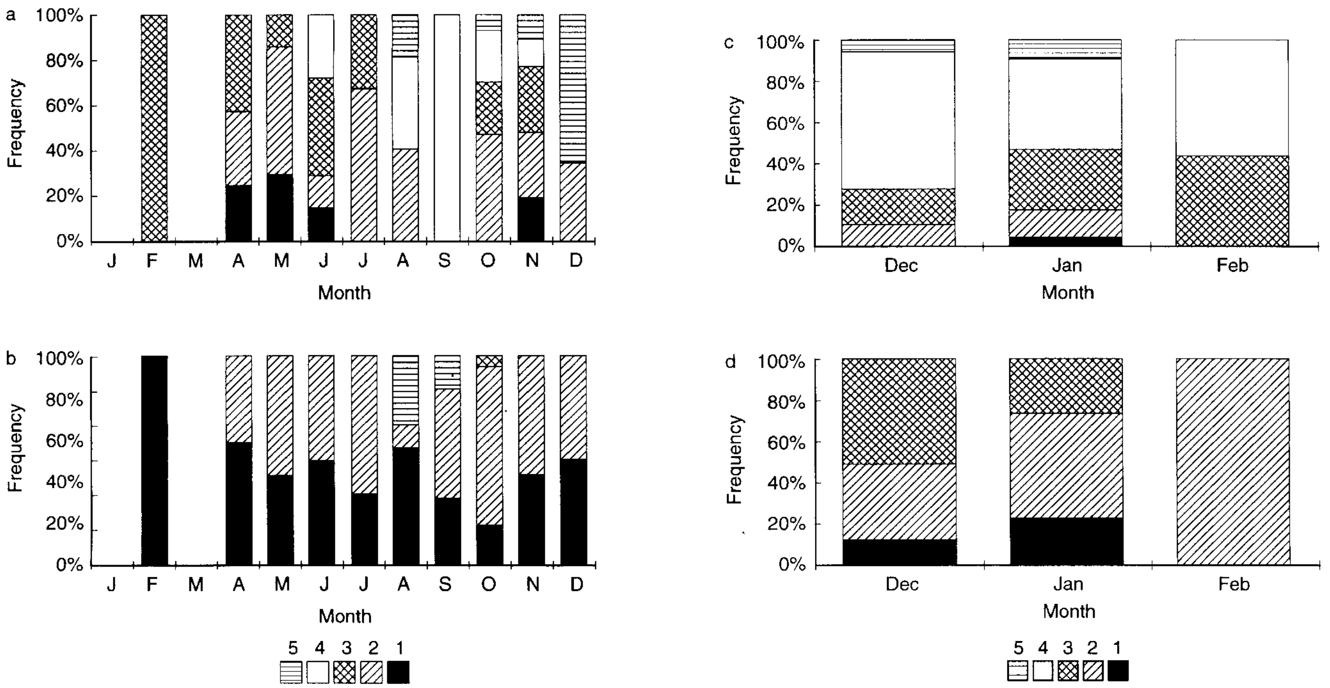

Fig 4. Annual and seasonal pattern of maturity stages frequency of *Trematomus hansoni* from Casey (**a.** Females *n* = 85, **b.** Males *n* = 221) and Terra Nova (**c.** Females *n* = 85, **d.** Males *n* = 45) respectively.

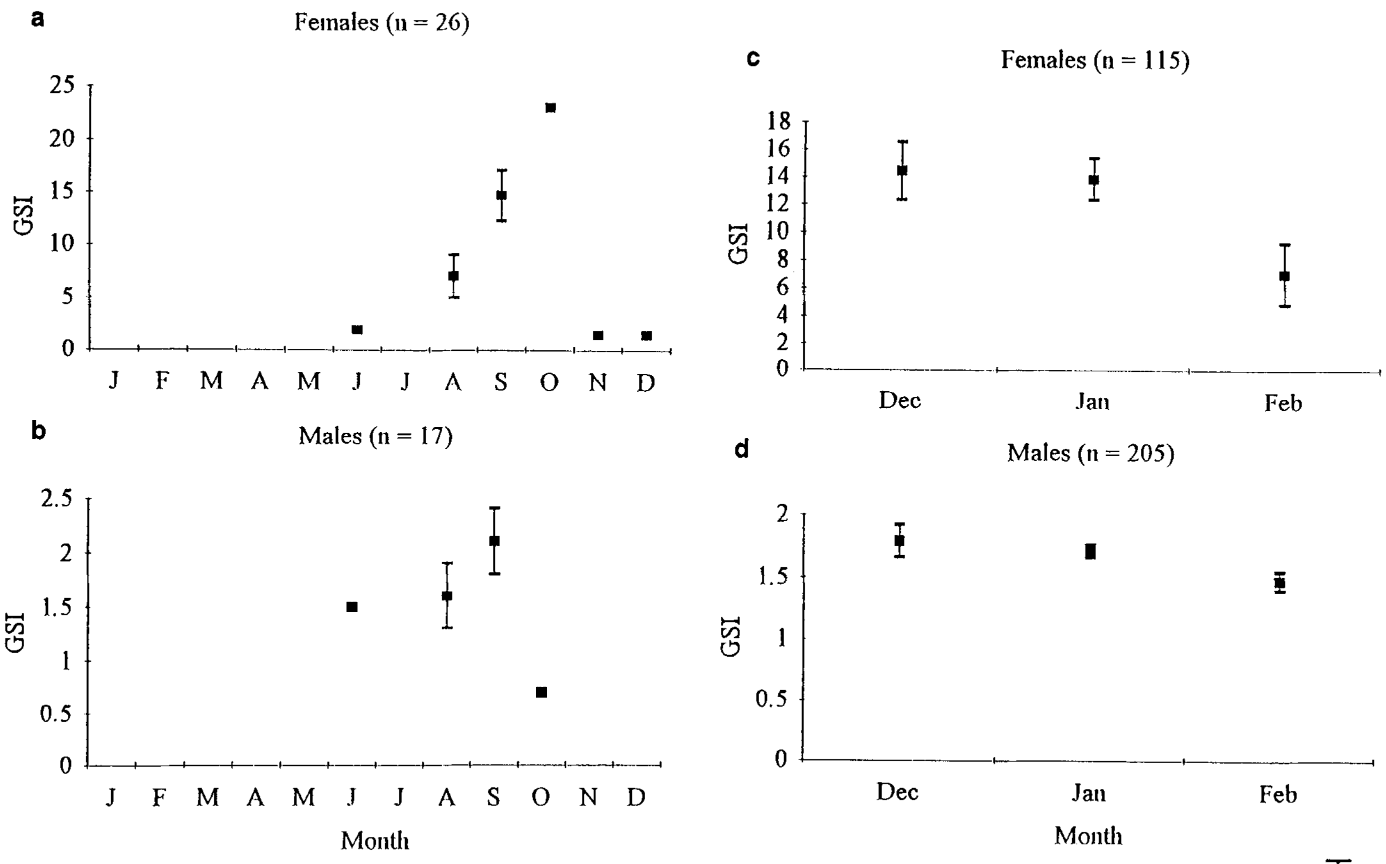

Fig 5. Annual and seasonal pattern of gonado-somatic index (GSI) of *Chionodraco hamatus* from Casey (a.,b.) and Terra Nova (c.,d.), respectively.

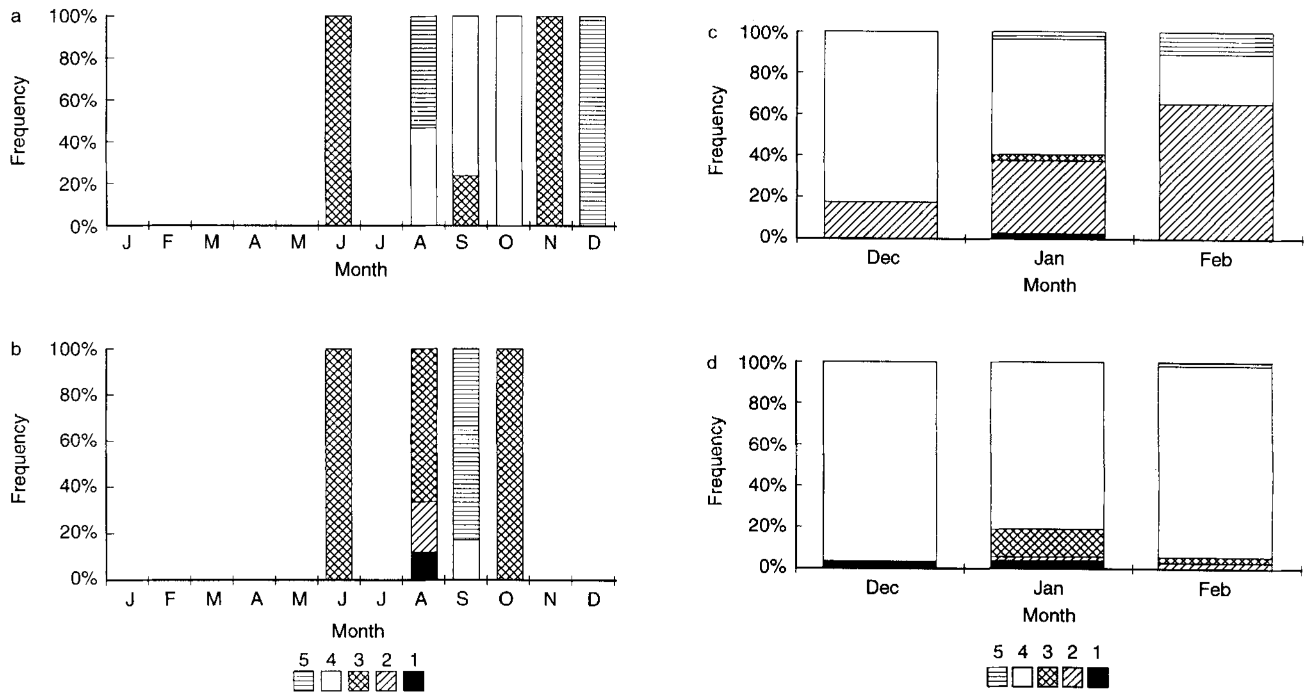

Fig 6. Annual and seasonal pattern of maturity stages frequency of *Chionodraco hamatus* from Casey (**a.** Females n = 26, **b.** Males n = 17) and Terra Nova (**c.** Females n = 115, **d.** Males n = 205) respectively.

https://doi.org/10.1017/S0954102096000259 Published online by Cambridge University Press

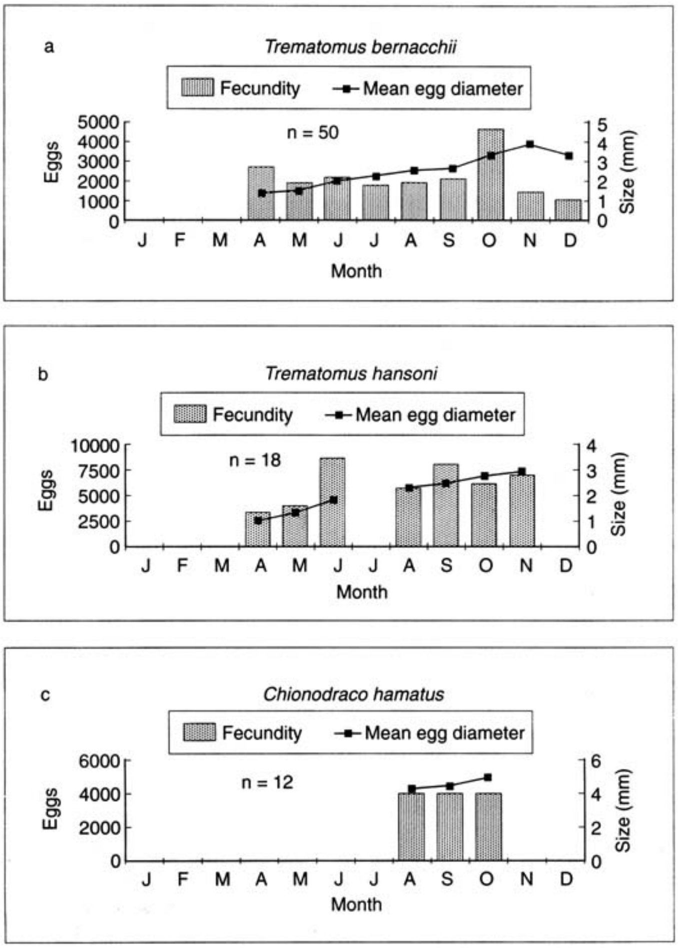

Fig. 7. Annual pattern of total fecundity and egg size from Casey. **a.** *Trematomus bernacchii.* **b.** *Trematomus hansoni.* **c.** *Chionodraco hamatus.*

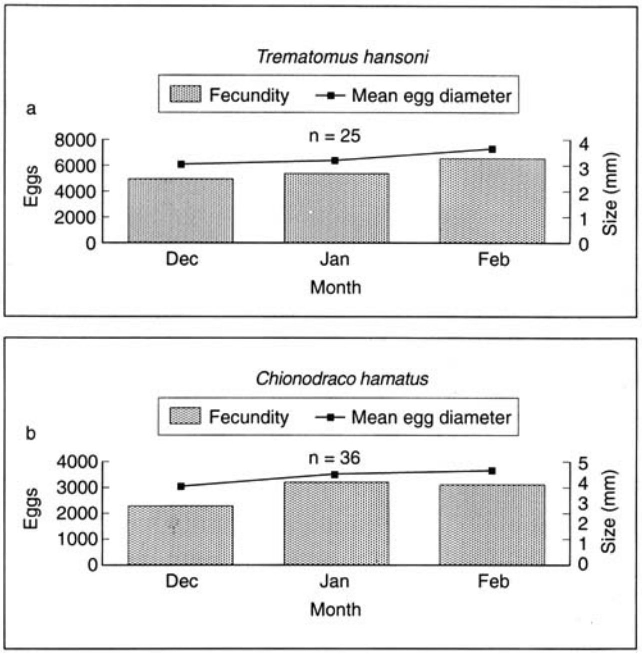

Fig. 8. Seasonal pattern of total fecundity and egg size from Terra Nova. **a.** *Trematomus hansoni*. **b.** *Chionodraco hamatus*.

(Fig 8a). Relative fecundity of this species ranged between 9.8–16.5 eggs per gram total weight.

Egg size of the channichthyid *C. hamatus* was higher than for either of the two nototheniids, whilst fecundity was lower. The range of mean egg diameter and fecundity of *C. hamatus* was respectively 4–4.6 mm and 2360–3317 eggs (2.9–7.9 being the range of relative fecundity) from specimens caught in Terra Nova Bay (Fig. 8b). Individuals at Casey exhibited about the same value of egg size (4.4–5 mm), but their fecundity was higher (4105–4158 eggs) (Fig. 7c).

The relationship between total fecundity and fish size was determined for *T. hansoni* and *C. hamatus* in Terra Nova Bay:

Trematomus hansoni

$F = 11.714 \times W1.016$ $(n = 25;\ r = 0.917)$

$F = 0.0000409 \times L3.276$ $(n = 25;\ r = 0.815)$

Chionodraco hamatus

$F = 61.615 \times W0.632$ $(n = 33;\ r = 0.763)$

$F = 0.017 \times L2.033$ $(n = 33;\ r = 0.694)$

Discussion

Reproductive biology of *T. bernacchii*, *T. hansoni* and *C. hamatus* has been poorly studied so far. Early studies in the Ross Sea (Dearborn 1965) and off Terre Adélie (Hureau 1970) have been supplemented by those off South Georgia (Sil'yanova 1981, 1982, Burchett *et al.* 1983), in the Davis and Mawson Seas (Butskaya & Faleeva 1987, Shandikov & Faleeva 1992) and in the Weddell Sea (Ekau 1991, Duhamel *et al.* 1993).

In the Ross Sea Dearborn (1965) reported that spawning of *T. bernacchii* could occur between August and January, but uaually between mid-December and mid-January. However, Hureau (1970) found that spawning in *T. bernacchii* off Terre Adélie was October–November when the GSI of females was 15.3–18.5%, the egg diameter was *c.* 3.5 mm and fecundity ranged from 1500–2500 eggs. The low fecundity of *T. bernacchii* could be a successful strategy because it is one of the few species in which some parental care has been observed. In the shallow waters off the Antarctic Peninsula, this species deposits its eggs in sponges and the female undertakes egg guarding until hatching (Moreno 1980).

Our results on *T. bernacchii* clearly show that spawning occurs in October–November, at least off Casey, and fully agree with data from the Davis Sea (Butskaya & Faleeva 1987)and Terre Adélie. With *T. bernacchii* in resting-early developing stage between December–February at Terra Nova Bay, the spawning at this site could have taken place in spring, consistent with the other localities.

T. hansoni caught off Terre Adélie spawned in January–

https://doi.org/10.1017/S0954102096000259 Published online by Cambridge University Press

February, (GSI 19% and egg size 2.5–2.7 mm (Hureau 1970); but for the same period in the Weddell Sea, *T. hansoni* had a low GSI (1.6–2.1%) (Ekau 1991) and seemed to be in the early stage of maturation (Duhamel *et al.* 1993). Considerable differences in the spawning period of this species also occur between fishes from the South Georgia, where they are late summer–early autumn spawners (February–March) (Sil'yanova 1981, 1982, Burchett *et al.* 1983), and those from the Davis Sea, where they are a spring spawners (October–November) (Butskaya & Faleeva 1987). Moreover, the finding of an extended larval hatching period of *T. hansoni* from March through to July at South Georgia, (Kellermann 1989), is further evidence for an extended spawning season in this species (Kock 1992).

We also found that the spawning period of *T. hansoni* differed in the two areas investigated. This species spawned in spring (September–November) off Casey Station, while at Terra Nova Bay spawning occurs in summer (December–February). Moreover, egg size was higher and fecundity was lower in specimens from Terra Nova Bay compared to those from Casey; in agreement with the general trend towards producing fewer but larger eggs towards higher latitudes (Kock 1992). Similar latitudinal variations are also found in Southern Ocean shrimps (*Chorismus antarcticum* and *Notocrangon antarcticus*) from South Georgia and the Weddell Sea: individuals in the higher latitude populations grow to a larger size, mature at a larger size and produce larger eggs when compared with lower latitude populations (Gorny *et al.* 1992). A similar latitudinal cline has been shown for the isopod *Ceratoserolis trilobitoides*, possibly associated with a need to provide a greater amount of nutrient for a newly hatched larva at higher latitudes (Clarke & Gore 1992).

Spawning of *C. hamatus* in the Weddell Sea and in the Davis Sea takes place in late summer–early autumn in both areas (Duhamel *et al.* 1993, Shandikov & Faleeva 1992), except for the specimens examined by Ekau (1991), which spawned in spring (October–November). Egg size varied from 3.4–4.0 mm in the Weddell Sea and 4.4–4.9 in the Davis Sea, while fecundity was estimated at 2700–4600 eggs in both sites. Our limited data on *C. hamatus*, seem to indicate some difference in the spawning period of this species: off Casey it spawned from August to October, whilst at Terra Nova Bay from December to February.

Finally, our results on the reproductive patterns of the three species agree well with the existing information on spawning periods of High Antarctic Zone species, which show a higher proportion of spring and particularly summer spawning species (Kock 1992). On the other hand, the majority of species and populations in the Seasonal Pack-ice Zone and around the islands north of it are autumn and winter spawners; for example, *T. hansoni* sampled in the waters off South Georgia spawns in autumn (Sil'yanova 1981, 1982).

At least for *T. hansoni* and *C. hamatus* the study areas show a shift of the spawning period, which is later at Terra Nova Bay than off Casey. Nevertheless, a comparison of the observed spawning period among the populations of the three species in all sites do not show a well defined latitudinal trend. This is probably due to the several variables, independent of latitude, involved in determining the spawning season of a species; for example, Hureau (1970) found slight variations in the spawning period of *T. hansoni* sampled off Terre Adélie in two consecutive years (1961–1962), and attributed this to variations in the onset of the austral summer.

Acknowledgements

We thank Dr Erwin Erb for the fish from Casey, and Andrew McEldowney for the fecundity and egg diameter measurements on the Casey fish; we also are indebted to Dr Silvio Greco for sampling the fish at Terra Nova Bay. This work was supported by PNRA (Italian National Project of Antarctic Researches) and by the Australian Antarctic Division.

References

Anon. 1989. Report of the Working Group on Fish Stock Assessment. *In Report of the Eighth Meeting of the Scientific Committee of CCAMLR, Hobart, Australia, 6–10 November 1989*, Annex 6, 183-295.

Burchett, M.S., Sayers, P.J., North A.W. & White, M.G. 1983. Some biological aspects of the nearshore fish populations at South Georgia. *British Antarctic Survey Bulletin*, No. 59, 63-74.

Butskaya, N.A. & Faleeva, T.I. 1987. Seasonal changes in the gonads and fecundity of Antarctic fishes *Trematomus bernacchii, Trematomus hansoni* and *Pagothenia borchgrevinki*. *Journal of Ichthyology*, **27**, 27-36.

Clarke, A. & Gore, D.J. 1992. Egg size and composition in *Ceratoserolis* (Crustacea: Isopoda) from the Weddell Sea. *Polar Biology*, **12**, 129-134

Dearborn, J.H. 1965. Reproduction in the nototheniid fish *Trematomus bernacchii* Boulenger at McMurdo Sound, Antarctica. *Copeia*, **3**, 302-308.

Duhamel, G. 1987. Reproduction des Nototheniidae et Channichthyidae des Iles Kerguelen. *CNFRA*, **57**, 91-107.

Duhamel, G., Kock, K.H., Balguerias, E. & Hureau, J.C. 1993. Reproduction in fish of the Weddell Sea. *Polar Biology*, **13**, 193-200.

Ekau, W. 1991. Reproduction in High Antarctic fish. *Meeresforschung*, **33**, 159-167.

Everson, I. 1977. The living resources of the Southern Ocean. *Food and Agricultural Organisation*, **GLO/SO/77/1**, 156 pp.

Everson, I. 1984. Fish biology. *In* Laws, R.M., *ed. Antarctic ecology*, vol. 2. London: Academic Press, 491-532.

Gon, O. & Heemstra, P.C. 1990. *Fishes of the Southern Ocean*. Grahamstown: J.L.B Institute of Ichthyology, 462 pp.

Gorny, M., Arntz, W.E., Clarke, A. & Gore, D.J. 1992. Reproductive biology of caridean decapods from the Weddell Sea. *Polar Biology*, **12**, 111-120.

Hureau, J.C. 1970. Biologie comparée de quelques poissons antarctiques (Nototheniidae). *Bulletin de l'Institut Océanographique Monaco*, **68**, 1-244.

Kartas, F. & Quignard, J.P. 1984. *La fécondité des poissons Téléostéens*. Collection de Biologie des Milieux Marins 5. Paris: Masson, 121 pp.

Kellermann, A. 1989. Identification key and catalogue of larval Antarctic fishes. *BIOMASS Scientific Series*, No 10, 136 pp.

Kock, K.H. 1985. Marine habitats-Antarctic Fish. *In* Bonner, W.N. & Walton, D.W.H., *eds. Key environments, Antarctica*. Oxford: Pergamon Press, 173-192.

Kock, K.H. 1992. *Antarctic fish and fisheries*. Cambridge: Cambridge University Press, 359 pp.

Kock, K.H. & Kellermann, A. 1991. Review. Reproduction in Antarctic notothenioid fish. *Antarctic Science*, **3**, 125-150.

Moreno, C.A. 1980. Observations of food and reproduction in *Trematomus bernacchii* (Pisces: Nototheniidae) from the Palmer Archipelago. *Copeia*, **1**, 171-173.

North, A.W. & White, M.G. 1987. Reproductive strategies of Antarctic fish. *In* Kullander, S.O. & Fernholm, B., *eds. Proceedings of the V Congress of the European Ichthylogical Society 1985*. Stockholm, 381-390.

Pankhurst, N.W. 1990. Growth and reproduction of the Antarctic nototheniid fish *Pagothenia borchgrevinki*. *Polar Biology*, **10**, 387-391.

Shandikov, G.A. & Faleeva, T.I. 1992. Features of gametogenesis and sexual cycles of six notothenioid fishes from East Antarctica. *Polar Biology*, **11**, 615-621.

Sil'yanova, Z.S. 1981. Oogenesis and maturity stages of fishes of the family Nototheniidae. *Journal of Ichthyology*, **21**, 81-89.

Sil'yanova, Z.S. 1982. Relative fecundity of some species of fish of the family Nototheniidae. *Journal of Ichthyology*, **22**, 151-154.

Vacchi, M., Greco, S. & La Mesa, M. 1991. Ichthyological survey by fixed gears in Terra Nova Bay (Antarctica). Fish list and first results. *Memorie di Biologia Marina ed Oceanografia*, **19**, 197-202.

Vacchi, M., La Mesa, M. & Tarulli, E. 1992. Investigation by fixed gears on ichthyofauna of Terra Nova Bay (Ross Sea, Antarctica). *In IX Congresso AIOL*, S. Margherita Ligure, 20-23 Novembre 1990, 659-664.