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Wiesław GĄSIOR, Andrzej KOMPOWSKI

Fish biology

BIOLOGICAL AND FISHERY-RELATED OBSERVATIONS ON JACK MACKEREL, *TRACHURUS DECLIVIS* (JENYNS, 1841) STOCK DURING SPAWNING OFF SOUTH-EAST AUSTRALIA

OBSERWACJE BIOLOGICZNO-RYBACKIE NAD STADEM *TRACHURUS DECLIVIS* (JENYNS, 1841) W OKRESIE ROZRODU U WYBRZEŻY PD.-WSCH. AUSTRALII

Institute of Ichthyology,
Szczecin

Modal individual length in a spawning population of *Trachurus declivis* observed was 31 cm. Age groups III and V were found to dominate in the stock. The following parameters of the von Bertalanffy growth equation were estimated: $L_\infty = 47.18$ cm; $K = 0.166$; $t_0 = -1.966$ yr. Total mortality (F + M) was 0.343, 0.397, or 0.453 depending on the estimation method adopted and length at first capture assumed. The stock contained more males than females.

INTRODUCTION

Jack mackerel, *Trachurus declivis* (Jenyns, 1841), is a mass-occurring species on the southern Australia's shelf. Both the biology and resources of the species are poorly known owing, on the one hand, to a negligible importance of the species for Australian fisheries at present and, on the other, to a poor availability of fishing grounds for foreign fleets due to considerable distances and legal restrictions.

Of the existing studies on the species worth mentioning are preliminary observations by Soviet authors (Makarov and Paškin, 1968; Šuntov, 1969) and detailed studies on age and growth by Webb and Grant (1979). According to the latter authors, the resources of Tr. declivis in the Australian waters are substantial.

Two Polish trawlers, the „DELFIN" and „BONITO" carried out several reconnaissance-fishing cruises off Australia within the period of July 1978 – April 1979, biological information being also recorded. The present paper summarises the results of biological and fishery-related studies on the Australian jack mackerel, *Tr. declivis*, from a fishing ground most promising of all those penetrated by the "DELFIN" and located off south-east Australia. The results presented are, hopefully, a contribution to the scientific basis of a future exploitation of the stock, the practical experience gained being useful in economic enterprises.

MATERIALS AND METHODS

The materials for the present work were collected during a reconnaissance-fishing cruise of the "DELFIN" (a B-418 trawler) on the Australian shelf. In the vicinity of the Flinders Archipelago (off the coasts of Victoria) (Fig. 1; the central location: 148°40′E; 38°15′S) a dense spawning concentration of the jack mackerel was detected. Within the period of November 19 – December 1, 1978 45 hauls were taken from the stock by

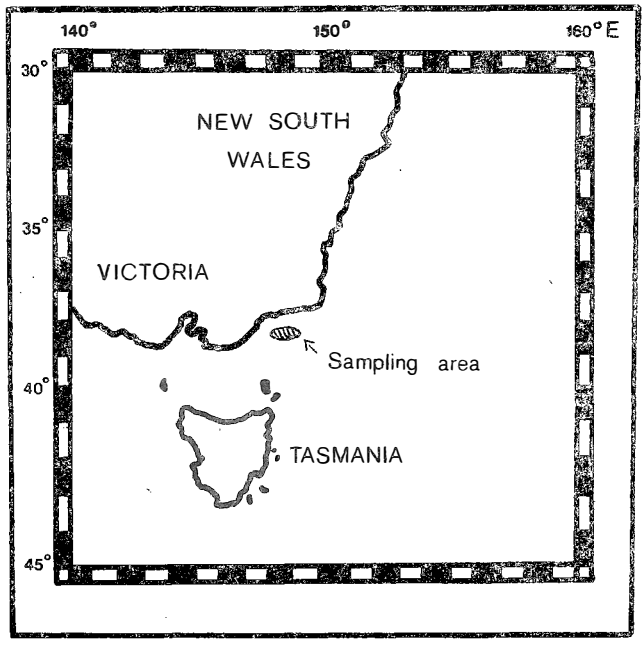

Fig. 1. Location of sampling sites

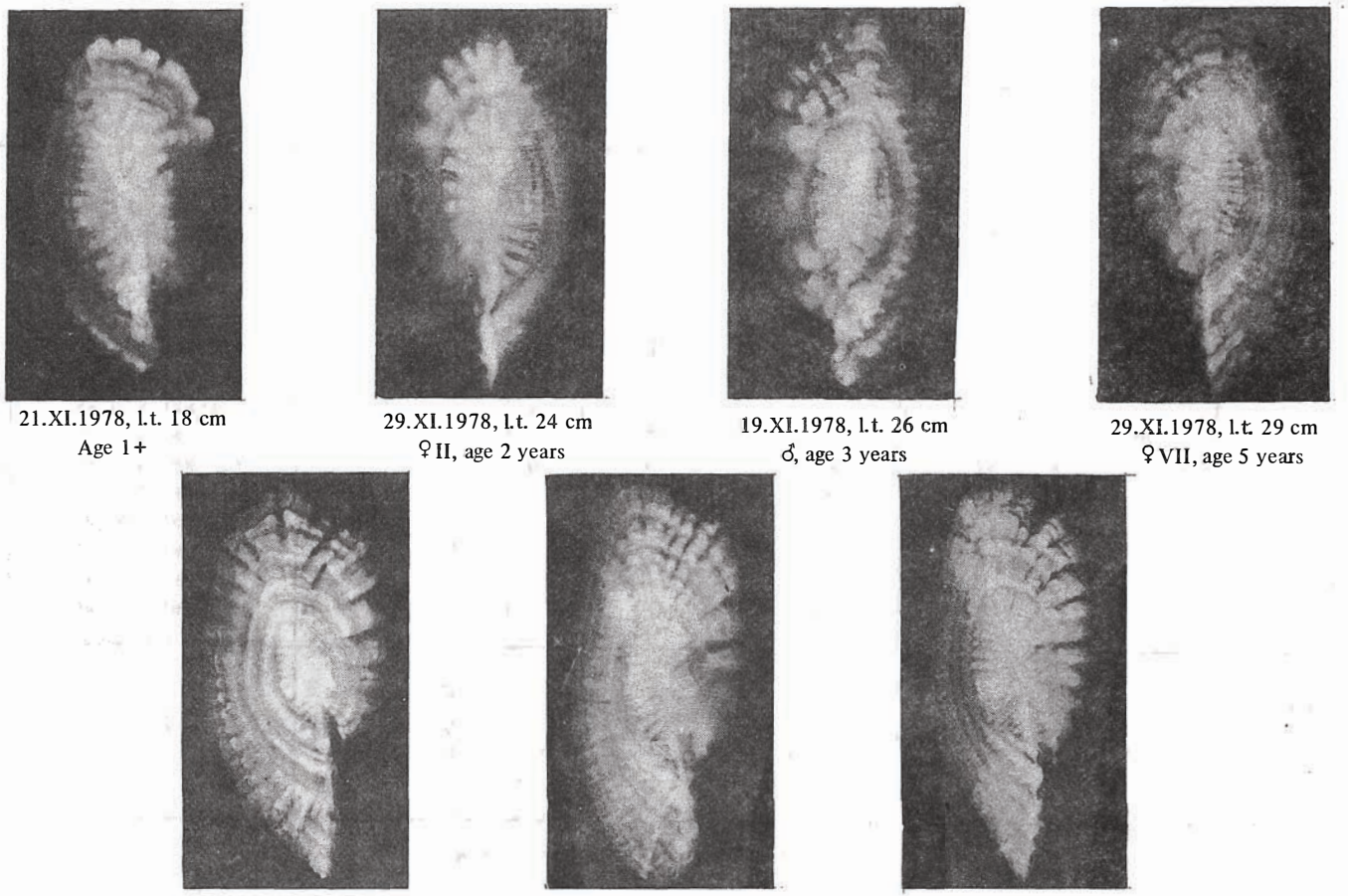

Fig. 2. Jack mackerel (*Trachurus declivis*) otoliths. Photo: Andrzej Kompowski

Table 1

Materials collected and procedures applied

Lp.	Haul location	Date	Mean trawling depth (m)	Procedures (no. of indiv.)				
				Length measurement	Weight measurement	Otoliths	Sex determination	Gonad maturity determination
1.	38°11′S; 148°49′E	19.XI	110	793	765	93	–	–
2.	38°12′S; 148°47′E	19.XI	110	274	–	–	–	–
3.	38°14′S; 148°40′E	20.XI	110	210	195	–	–	–
4.	38°16′S; 148°37′E	20.XI	110	1413	1412	43	–	
5.	38°12′S; 148°49′E	21.XI	110	11	10	11	–	–
6.	38°15′S; 148°37′E	22.XI	110	628	628	54	306	–
7.	38°15′S; 148°36′E	23.XI	110	208	–	–	208	–
8.	38°14′S; 148°36′E	24.XI	105	239	–	23	–	–
9.	38°16′S; 148°32′E	25.XI	110	478	91	29	478	–
10.	38°21′S; 148°25′E	26.XI	90	207	–	–	207	–
11.	38°12′S; 148°43′E	26.XI	108	318	317	78	318	318
12.	38°19′S; 148°28′E	27.XI	100	520	2	13	–	–
13.	38°10′S; 148°43′E	28.XI	105	22	22	22	–	–
14.	38°11′S; 148°46′E	29.XI	110	139	120	79	134	–
15.	38°17′S; 148°31′E	30.XI	115	313	70	–	291	–
16.	38°16′S; 148°40′E	1.XII	105	278	77	62	274	274
			Total (indiv.)	6051	3709	507	2216	592

means of a 20 mm codend minimum mesh size size trawl (26 m vertical opening, 48 m horizontal opening). 16 random samples were taken. The total length of each of 6051 fish individuals was measured to the nearest cm; 3709 specimens were weighed (total weight) to the nearest g, larger fishes (heavier than 500 g) being weighed to the nearest 5 g; 2216 individuals were sexed; gonad maturity was determined in 592 fishes according to the 8-score Maier scale. Ovaries of 10 fishes were weighed to the nearest g. Age was determined on otoliths taken from 507 individuals. The otoliths were burned in order to improve their legibility. They were subsequently transferred to a vessel with a black bottom; the external (concave) otolith surface was examined under a stereomicroscope in incident light. In this way the age of most fishes was read up to their fifth-sixth year of life inclusive (Fig. 2). Otoliths yielded by older fishes frequently had their peripheral parts illegible, in which case an otolith was transversely broken, the age being read from the broken surface (cf. Christensen, 1964; Macer, 1977; Geldenhuys, 1973; Kompowski and Wysokiński, 1976; Webb and Grant, 1979; Kompowski, 1981). Water temperature in the layer affected by the trawl was measured by means of an "ELAC" sensor.

The materials collected and procedures applied are summarised in Table 1.

DESCRIPTION OF THE FISHING GROUND

On November 19 a dense concentration of fishes was recorded off South Victoria in the vicinity of the Flinders Archipelago by hydrolocation devices. A preliminary haul proved it to be a spawning concentration of jack mackerel. During 27 fishing day the "DELFIN" and "BONITO" caught about 2300 t altogether, the potential catch being much higher since the key factor for a daily catch was the processing efficiency of the trawlers. For the "DELFIN", the mean daily catch and mean catch per unit effort were 85.7 t and 10.99 t, respectively (Table 2).

The concentration occurred over a relatively small area. It should be mentioned that the fishing ground discussed is located within an oil field close to oil rigs. In this context

Table 2

Fishing effort and catches of MT's "DELFIN" and "BONITO" off S. Victoria

	MT "DELFIN"	MT "BONITO"
Period of fishing	Nov. 19 – Dec. 1, 1978	Nov. 20 – Dec. 3, 1978
Days fishing	13	14
No. of hauls	46	57
Trawling time	101 h 20 min.	141 h 20 min.
Total catch	1114 t	1226 t
Mean daily catch	85.69 t	87.57 t
Mean catch per hour	10.99 t	8.68 t

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it is worth remembering that the history of Polish deep sea fisheries has often recorded large concentrations of fishes in the vicinity of oil fields.

Fishing operations were carried out within the depth range of 85–125 m, the highest yields being obtained within 100–115 m. The sandy-muddy bottom presented no obstacle for trawling. Surface water temperatures were found to range within 15–16°C, while at the trawling depth, 15–18 m above the bottom on the average, the temperature range was 12.5–13.7°C. The highest temperature difference between the surface and trawling layer was 3.3°C, the depth differential being 95 m.

The catches consisted mainly of jack mackerel making up about 95%. The remaining 5% consisted, i.a., of *Thyrsistes atun, Rexea solandri,* rays, sharks, *Scomber australasicus, Pterygotrigla polyommata,* and *Paratrigla papilio.*

LENGTHS OF FISHES OCCURRING IN CATCHES

Figs. 3 and 4 show the length distribution of fishes found in catches. The fish length was found to range within 17–51 cm. The most common length range was 26–40 cm, the 31 cm length class containing the highest number of individuals. The smallest fishes in which sex could still be distinguished measured 25–26 cm. If the sporadically occurring small fishes (17–22 cm) are disregarded, it can be assumed that the lower length limit recorded in catches was 25–26 cm. As the 25–26 cm long individuals occurred for the first time in the spawning concentration subject to trawling, their lenght can be assumed the length at first capture (l_c) in the population exploited.

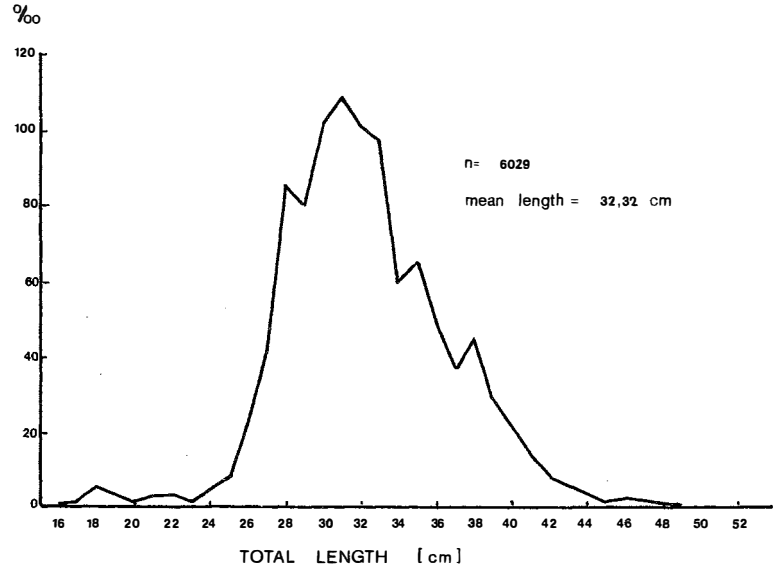

Fig. 3. Length distribution of *Tr. declivis* caught within Nov. 19 – Dec. 1, 1978 in shelf waters off Victoria

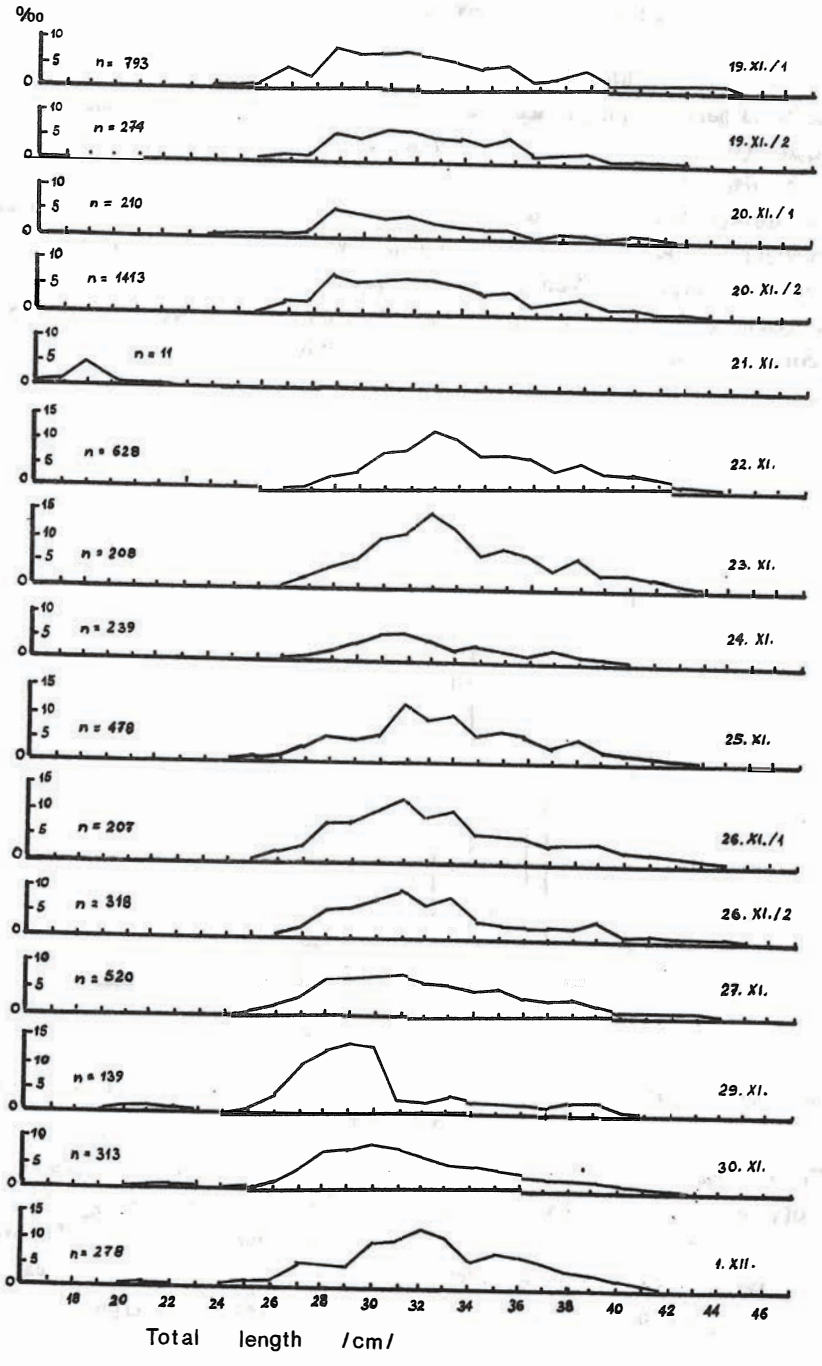

Fig. 4. Length distribution in *Tr. declivis* catches from shelf waters off Victoria by haul

AGE COMPOSITION OF THE STOCK EXPLOITED

Examination of otoliths showed a hyaline zone to occur on otolith margins, a narrow opaque band being frequently seen behind it on otoliths of younger fishes (age groups I, II, and III) (Fig. 2). During the period of study the spawning was in progress. According to Webb (after Webb and Grant, 1979) spawning in the area of study proceeds from October through February. Thus the hyaline zone on *Tr. declivis* otoliths is formed in the pre-spawning period of an intensive gonad development. This is in agreement with previous observations of Webb and Grant (1979), results of studies on other *Trachurus* species (Geldenhuys, 1979; Kompowski and Wysokiński, 1976; Kompowski, 1981) being corroborated as well. Owing to the fact that the hyaline zone on otolith margins was already formed in virtually all the fishes, the day of November 1 was assumed to be the date of birth, two months earlier than January 1 suggested by Webb and Grant (1979).

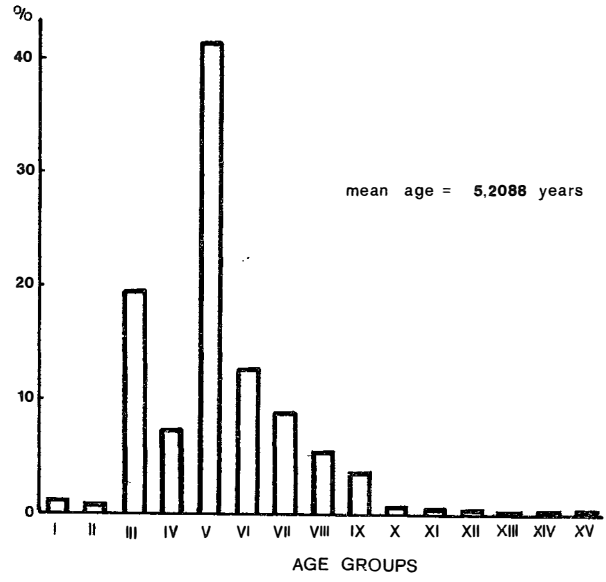

Fig. 5. Age distribution of *Tr. declivis* caught within Nov. 19 – Dec. 1, 1978 in shelf waters off S. Victoria

The age distribution in catches is presented in Fig. 5. Two age groups making up about 60% of the fishes are clearly dominant: group III (19.5%) and group V (41.5%). The remaining groups were much less abundant (not exceeding 12.5%, group VI). Fishes older than 10 years were rare, although a few individuals 18, 19, 20 and even 22-years-old were encountered. The age distribution observed can be regarded as typical of a "resting" stock.

GROWTH RATE

Table 3 contains mean lengths of every age group. A relatively large (18.97 cm) mean length in the first group and small differences between this and consecutive means striking. The first age group mean length is most probably an overestimate, resulting perhaps from a "natural selectivity": smaller fishes staying in shallower coastal waters tend to migrate with age to deeper layers. Thus the fishing ground studied, far away from the coast, was inhabited by only those group I fishes that had passed a certain length threshold. The "natural selectivity" phenomenon is commonly known in the genus *Trachurus* (cf. i.a., Dardignac, 1963; Barraca, 1964; Lipskaya and Vyskrebiencev, 1969; Sahrhage, 1970).

Table 3

Mean lengths in age groups as converted to mass measurement and von Bertalanffy theoretical lengths for *Tr. declivis* caught off S. Victoria
l.t. (cm)

	Age group									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Mean length	18.97	23.50	28.32	29.11	31.87	33.58	36.82	38.84	39.50	41.28
n	30	10	120	27	136	42	42	34	28	7
Theoretical length	18.58	23.02	26.77	29.94	32.61	34.88	36.79	38.40	39.76	40.92

Based on the data from Table 3, the following von Bertalanffy equation parameters were estimated: $L_\infty = 47.1842$ cm; $K = 0.1687$: $t_0 = -1.9662$ yr. The theoretical lengths calculated by means of the equation are presented in Table 3.

Growth rate of *Tr. declivis* off south-east Australia was studied earlier by Webb and Grant (1979) who collected their materials from an area much more extensive than that surveyed in the present study; their jack mackerel were caught, with various gear, from shallow coastal waters. Those authors used otolith back readings to determine growth rate, a method eliminating both the "natural" and gear selectivities. Their results are hardly comparable with ours as they measured the fish caudal lenght (*l. caud.*), no *l. caud.*–l.t. relationship for *Tr. declivis* being found in the literature available. The von Bertalanffy equation parameters determined by Webb and Grant are as follows: $L_\infty = 46.3$ cm; $K = 0.23$; $t_0 = -0.10$ yr. The growth parameters seem to apply to the entire *Tr. declivis* population off south-east Australia, our parameters being applicable to the spawning population exploited during the period of study.

The weight-length relationship for *Tr. declivis* under study was found by the least squares method as

$$W = 0.009963\ L^{2.9754}$$

Webb and Grant (1979) found the following relationship:

$$W = 0.95 \cdot 10^{-5}\ L^{3.04098}$$

("L" in this formula corresponds to the caudal length). They noted a significant difference between the relationships for mature and immature individuals.

MORTALITY

Considerable differences in abundance of various year classes (Fig. 5) made it impossible to utilise the age composition in a mortality assessment. The methods given by Beverton and Holt (1956) were used instead:

$$(F+M) = \frac{K(l_\infty - \bar{l})}{\bar{l} - l_c} \qquad (1)$$

where: $(F+M)$ = total mortality,
K = von Bertalanffy katabolism coefficient,
$\bar{l}$ = mean length of fish caught,
L_∞ = asymptotic length,
l_c = length at first capture.

When the previously calculated values of K, L_∞, and $\bar{l}$ are considered and l_c is assumed to be 26 cm, (F + M) = 0.3967. On the other hand, if l_c is 25 cm, (F + M) = 0.3425. The other method of Beverton and Holt involves a mean stock age as in the formula below:

$$(F+M) = \frac{1}{\bar{t} - t_c} \qquad (2)$$

where: $\bar{t}$ = mean age of exploited stock,
t_c = age at first capture.

Calculating, from the age composition shown in Fig. 5, the mean age $\bar{t}$= 5.2088 yr and assuming t_c = 3 yr as the age at the first capture (i.e., the age of the first abundant age group in the population exploited), the mortality (F + M) = 0.4527, a value higher than those resulting from the application of the previous methods.

The *Tr. declivis* stock discussed is hardly exploited by the fishery. Thus it can be assumed that the total mortality consists almost exclusively of the natural one. It should be reminded here that the values of l_c and t_c are adopted rather arbitrarily, whereby the mortality assessment given above should be considered preliminary and calling for a check by means of other methods.

SPAWNING

The jack mackerel concentration under study was a spawning one. On November 22, 1978 numerous shoals "swarming" just beneath the surface were attracting the attention of onlookers on board. On some days there were several shoals to be seen, while on other days the shoals were not visible or could be observed for a short time only. The shoals were usually active and visible near the surface at noon during sunny days. They did not occur after dusk. The shoals as seen from above the surface are shown on photographs (Figs. 6 and 7). Apart from the surface shoals, bottom concentrations were registered by echo-soundings.

A characteristic feature of the fishing ground was a large number of medusae present there. Small individuals of jack mackerel were being found in the gastro-vascular cavities of the medusae, which, however, does not necessarily prove the medusae to feed on the jack mackerel. The phenomenon of juvenile horse mackerel and other fish seeking shelter under the umbrellas of medusae, which bears some features of either symbiosis or parasitism, is commonly known and has been treated in detal by Thiel (1970).

The maturity analysis made on the jack mackerel in the fishing ground concerned shows some fishes to be immature in spite of the spawning being in progress. The spawning stock structure in terms of sex ratio and gonad maturity as observed on

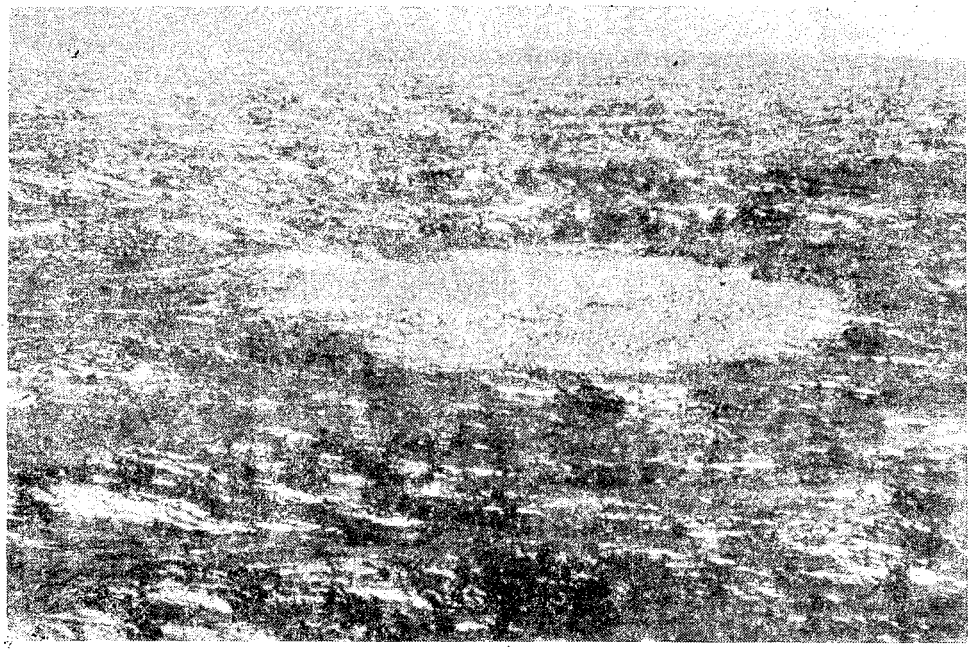

Fig. 6. A jack mackerel spawning shoal. Nov. 24, 1978; 14.00 h; 3°B state of sea; 16°C surface water temperature. Photo: Wiesław Gąsior

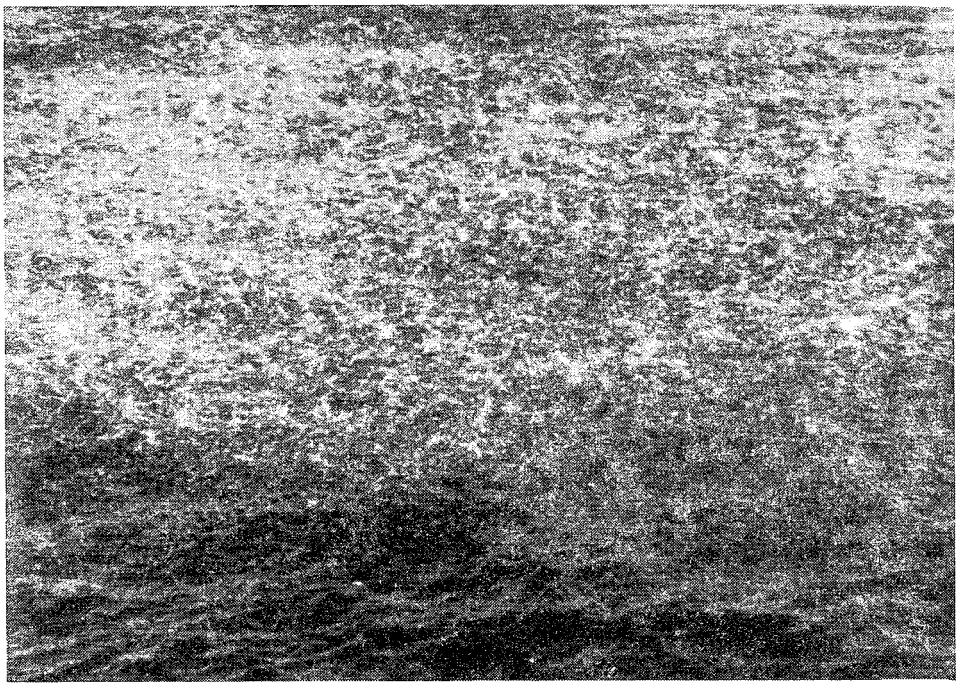

Fig. 7. A close-up of the spawning shoal. Photo: Wiesław Gąsior

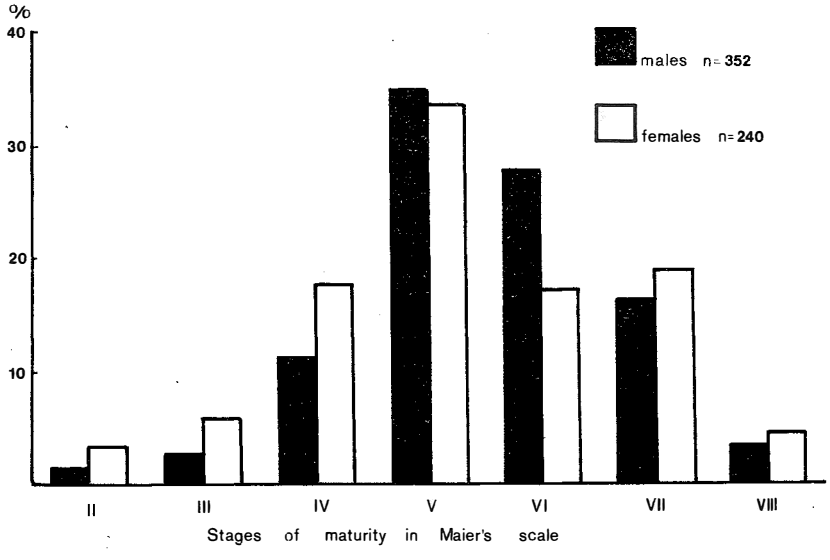

Fig. 8. Gonad maturity distribution in *Tr. declivis*

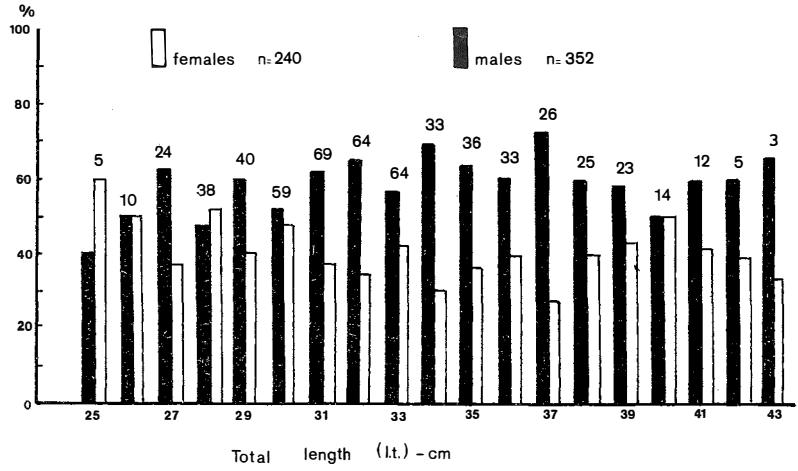

Fig. 9. Sex ratio in *Tr. declivis* catches relative to fish length

November 26 and December 1, 1978 is presented in Figs. 8 and 9. The simultaneous occurrence of individuals of various maturity stages confirms the known fact of the Trachurus spawning being extended in time. According to Webb and Grant (1979) *Tr. declivis* in the area spawns from October through February.

The stock analysed shows the numerical domination of males (62.27%) over females (37.73%) (Fig. 9; Table 4). As seen from Fig. 9, no definite changes in the sex ratio that would accompany length growth were observed with growth. In the genus *Trachurus,* sex ratio is usually close to unity (Alejev, 1957; Da Franca and Paes-Da Franca, 1958; Overko, 1964; 1969, 1971; MacGregor, 1966; Polonskij and Tormosova, 1969; Macer,

Table 4

Sex ratio in catches of *Tr. declivis*

Date	Males		Females		Total	
	no. of. ind.	%	no. of ind.	%	no. of ind.	%
Nov. 22, 1978	198	64.71	108	35.29	306	100.00
Nov. 23, 1978	135	64.90	73	35.10	208	100.00
Nov. 25, 1978	300	62.76	178	37.24	478	100.00
Nov. 26, 1978/1	124	59.90	83	40.10	207	100.00
Nov. 26, 1978/2	188	59.12	130	40.88	318	100.00
Nov. 29, 1978	82	61.19	52	38.81	184	100.00
Nov. 30, 1978	189	64.94	102	35.05	187	100.00
Dec. 1, 1978	164	59.85	110	40.15	192	100.00
Total	1380	62.27	836	37.73	2216	100.00

Table 5

Female *Tr. declivis* gonad weight as related to body weight

Fish length (cm)	Gonad maturity stage	Total body weight (%)	Gonad weight (g)	Gonad weight as % of body weight
37	VI–VII	540	65	12.03
37	VI	525	70	13.33
39	VI	600	65	10.83
39	VI	670	70	10.45
40	VI	690	120	17.39
40	VII	645	60	9.30
42	VII	710	55	7.75
45	VI	900	145	16.11
48	VI	1250	215	17.20
49	VI	1070	130	12.15

1974; Jackowski and Wrzesiński, 1980). It is only Planas and Vives (1953) who observed a sex ratio in favour of males in the common horse mackerel of the Valencia Bay in the Mediterranean, the domination of males being particularly clear during spawning. Polonskij and Tormosova (1969) refer to Alejev's observations on spawing of *Tr. mediterraneus* in the Black Sea: a spawning concentration was found to be stratified, males gathering in the upper part and females in the lower one. All our hauls were demersal. Should the *Tr. declivis* spawning concentrations be structured similarly to those of *Tr. mediterraneus*, the catches would have to be dominated by females rather than by males. The explanation of the problem requires further studies.

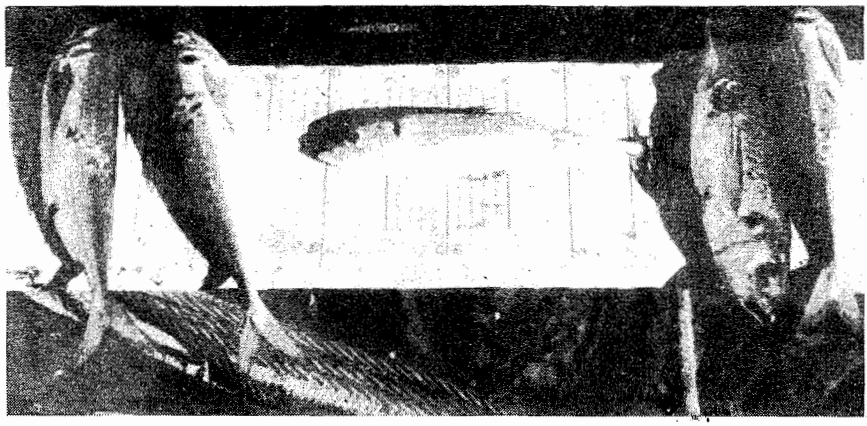

Fig. 10. Ulceration observed in a jack mackerel from the area of study. Photo: Wiesław Gąsior

A part of the spawning population was found to be feeding intensively, the activity proceeding concurrently with spawning. Although the stomach filling was uneven, those individuals having their gonads at the maturity stage 6 showed full stomachs, their content including small euphausid crustaceans. A striking feature of the fishing ground under study is its ample food supply as shown by the abundance of the *Euphausiacea* not only in the jack mackerel stomachs. but also in the water with which water tanks for storage of fish were filled.

Random weighines of female gonads (Table 5) show the egg mass in large females at the maturity stage 6 to make up always more than 10% and to range within 10.8–17.2% of the body weight.

It is worth adding that some jack mackerel individuals showed external ulceration as seen in Fig. 10. No naked eye-detectable parasites were found in the flesh.

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W. Gąsior, A. Kompowski

OBSERWACJE BIOLOGICZNO-RYBACKIE NAD STADEM *TRACHURUS DECLIVIS* (JENYNS, 1841) W OKRESIE ROZRODU U WYBRZEŻY PD.-WSCH. AUSTRALII

STRESZCZENIE

W rejonie zbliżonym do wybrzeży Pd. Victorii (rys. 1) wykryto pod koniec listopada 1978 gęste skupisko tarłowe. *Tr. declivis*. Połowy przeprowadzone w okresie od 19 XI do 3 XII na głębokości 85 do 125 m przy pomocy włoka – składały się w 95% z ostroboka. Wydajności dobowe były ograniczone technicznymi możliwościami przetwórczymi statków i wynosiły ok. 85 t (tab. 2). W połowach dominowały ryby od 26 do 40 cm z wartością modalną 31 cm. Z analizy otolitów

wynika, że dominującymi grupami wieku były III (19,5%) i V (41,5%), a populacja stanowi przykład stada ugorującego (rys. 5). Na podstawie średnich długości grup wieku (tab. 3) ustalono następujące parametry równania wzrostowego von Bertalanffy: L_∞ = 47.18 cm; K = 0.1687 i t_0 = −1.9662 roku. Zależność między masą a długością jest następująca: $W = 0.009963\ L^{2.9754}$. Śmiertelność całkowita oszacowana z zastosowaniem wzoru (1) wyniosła: (F + M) = 0.3967 przy założeniu, że długość pierwszej łowności wynosi 26 cm i 0.3425 przy założeniu, że długość pierwszej łowności wynosi 25 cm. Przy zastosowaniu wzoru (2) otrzymano wartość śmiertelności całkowitej: 0.4527. Przy dobrym nasłonecznieniu obserwowano ławice tarłowe ostroboka na powierzchni (rys. 6 i 7). W połowach występowały ostroboki w różnych stadiach dojrzałości – przeważały osobniki z gonadami w V i VI stopniu dojrzałości skali Maiera (rys. 8). Niezależnie od długości badanych ryb, w stadzie przeważały liczbowo samce (62.27%) nad samicami (rys. 9, tab. 4).

Гонсиор В., Комповски А.

РЫБОХОЗЯЙСТВЕННЫЕ НАБЛЮДЕНИЯ ЗА ПОПУЛЯЦИЕЙ TRACHURUS DECLIVIS (JENYNS, 1841) В ПЕРИОД РАЗМНОЖЕНИЯ У БЕРЕГОВ ЮГО-ВОСТ. АВСТРАЛИИ

Р е з ю м е

Вблизи Южной Виктории (рис.1) обнаружено в конце ноября 1978 года плотное нерестующие скоплениеTr.declivis . Лов производили тралами в период с 19 X1 до 3XII на глубине 85 до 125 м. Улов в 95% состоял из ставриды. Суточный вылов ограничивался техническими возможностями переработки рыбы на судах и составлял около 85 т. (таб.2). В уловах преобладали рыбы длиной 26 до 40 см с модальной длиной 31 см. Из анализа отолитов вытекает, что доминирующими возрастными группами были III (19,5%) и (41,5%), а популяция является примером неэксплуатированного скопления. На основании средних длин возрастных групп (таб.3) определили следующие параметры уравнения роста по Берталанффи: L_∞= 47,18 cm; K = 0,1687, t_o= -1,9662. . Зависимость между массой и длиной имеет вид: $W = 0{,}009963\ L^{2{,}9754}$ Общая смертность определена с помощью уравнения(1) составила (F+M)=0,3967 принимая во внимание что длина пополнения составила 26 см и 0,325 при длине пополнения 25 см. Применяя формулу (2) получили значение общей смертности 0,4527. При хорошем освещении наблюдали нерестовые косяки ставриды у поверхности (рис.6 и 7). В уловах наблюдали ставриды различных стадий зрелости- преобладали особи с гонадами V и VI стадии зрелости по Мейеру (рис.8). Независимо от длины исследуемых рыб, в популяции преобладали самцы (62,27%) (рис.9 таб.4):

Перевод: Dr Józef Domagała

Authors' addresses:
Dr W. Gąsior
Zrzeszenie Gospodarki Rybnej
ul. Odrowąża 1, 71-420 Szczecin

Dr hab. A. Kompowski
Instytut Oceanografii i Ochrony Morza
Zakład Biologicznych Zasobów Morza
ul. Kazimierza Królewicza 4
71-550 Szczecin
Polska (Poland)

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