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Haematological characteristics of albacore, *Thunnus alalunga* (Bonnaterre), and skipjack, *Katsuwonus pelamis* (Linnaeus)

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Observations on haematological characteristics of albacore, *Thunnus alalunga*, and skipjack *Katsuwonus pelamis*, tunas, were made on blood samples collected from specimens immediately after they were caught and from an immobilized, restrained albacore sampled serially over a 24 h period. Results indicated eight types of blood cells in the peripheral circulation of both species. Lymphocytes were the most common leucocyte followed, in decreasing order, by neutrophils, eosinophils and monocytes in fish sampled immediately after being landed. Variations in differential and total white blood cell counts were observed in the immobilized, restrained albacore. High packed cell volumes and haemoglobin concentrations, typical for fast swimming fishes, were found in both species. Red blood cell counts were similar to those of other teleosts, and reticulocytes expressed as a percentage of mature erythrocytes were 6·1% and 5·2% for albacore and skipjack, respectively.

I. INTRODUCTION

Haemograms were made on blood samples from albacore, *Thunnus alalunga* (Bonnaterre), and skipjack, *Katsuwonus pelamis* (Linnaeus) tunas. Studies of erythrocytes included red cell counts, haemoglobins, packed cell volumes and reticulocyte counts. Leucocyte characterizations included white blood cell counts and differential cell counts. Cell measurements and morphological descriptions were also made.

There are only limited published reports regarding the blood characterizations of albacore and skipjack tunas. These reports deal primarily with haemoglobin values (Klawe, Barrett & Klawe, 1963; Barrett & Williams, 1965), packed cell volumes (Saito, 1954, 1959; Magnuson, 1969), and types and migration of haemoglobins (Sharp, 1969, 1973, 1975). Published information concerning leucocytes in tunas include a description of bluefin tuna, *Thunnus thynnus*, white cell morphology (Gutierrez, 1967) and cell count (Becker *et al.*, 1958), and tables containing differential counts for skipjack, little tuna, *Euthynnus alleterattus*, and yellowfin tuna, *Thunnus albacares* (Saunders, 1966; Saito, 1954). This paper will report haematological results observed as part of an investigation of albacore and skipjack tuna physiology and biochemistry.

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II. METHODS

Fish for blood sampling were caught by trolling or rod-and-reel during August 1977 and September 1978. Trolling was carried on at a speed of 5·5 knots and rod-and-reel fishing when the ship was stopped. Immediately upon a jig strike the ship was put out of gear and the fish reeled to it using a hydraulic gurdie. A dip net was used to bring on board fish caught using both fishing methods. The time required to land jig caught fish was usually about 1 min and to land rod-and-reel caught fish was 5–15 min.

Blood samples were collected by cardiac puncture with a 1 ml syringe using an 18 or 20 gauge needle immediately after the fish were brought on board. In some cases sea water was flushed over the gills of the fish during blood collection. Blood samples were also collected over a 24 h period from an albacore which was immobilized with Gallamine triethiodide (Flaxedil) to obtain information on haemogram profiles for use in studies to transport live albacore to holding facilities on shore. The fish was restrained and the gills were artificially irrigated with sea water beginning immediately after it was landed. A 0·4 ml dose of Flaxedil (20 mg per ml) was injected intravascularly promptly after the fish was brought on board and four additional 0·2 ml dosages were administered at various intervals during the sampling period. Blood samples were drawn through an indwelling catheter–stopcock system positioned in the upper, left subcutaneous vein. The initial blood sample was drawn approximately 13 min after the fish struck the lure. Subsequent sampling intervals and results are shown in Table III.

Blood samples from all fish were placed in pediatric EDTA tubes and mixed to prevent clot formation. In 1977 the analyses were performed aboard ship as soon as possible after collection, except reticulocyte and differential counts which were made on shore. In 1978 the samples were stored in EDTA tubes and held on ice for 9 to 18 h prior to being analyzed on shore.

In 1977 red cell counts were made according to the methods outlined by Hesser (1960) with fresh stains prepared daily. In 1978 a 1% Brilliant Cresyl Blue (BCB) solution diluted 1:1 with 0·85% saline was used instead of the solutions recommended by Hesser. Blood and diluent were mixed in red cell pipettes according to standard techniques. An improved Neubauer haemocytometer was used in making cell counts and the values were calculated using formulae given by Wintrobe (1974). White cell counts were made using methods outlined by Hesser (1960).

The cyanmethaemoglobin method was used to measure haemoglobins. Drabkins solution (Wintrobe, 1974) was prepared in 1977 and Becton-Dickinson haemoglobin unopettes were used in 1978. Standard curves were prepared from Hycel haemoglobin standard and percent transmittances of standards and samples were measured on a Coleman, Jr. or Beckman model DB spectrophotometer. Haemoglobin measurements were made on fresh albacore blood; however, haemoglobin measurements of skipjack blood were made on samples which had been frozen at −50° F for several weeks. Some precipitation occurred in the skipjack samples and they were centrifuged for 5 min at 5000 **g** to remove the precipitate prior to being read on the spectrophotometer. No precipitate was observed in the albacore blood-unopette solutions, which were colorimetrically stable over a 6 h period at ambient temperatures. Packed cell volume measurements were made in duplicate on blood samples collected in microhaematocrit tubes which were sealed with 'Critoseal' and centrifuged on a Clay Adams 'Autocrit' at 12 000 **g** for 5 min. Measurements were made on all cell types except reticulocytes, with an ocular micrometer. A minimum of 100 red cells and thrombocytes and 15 to 30 white cells were measured.

Differential blood counts were made on a minimum of two slides per fish sampled on the 1977 cruise. Blood smears were held for approximately 4 months prior to being stained and there was some loss of differential staining activity. The following steps described by Gallachio (1975) were used to enhance the staining quality of the smears. Smears were flooded with a 1% benzidine solution in absolute alcohol and allowed to react for 2 min. They were then lightly flooded with Superoxol (1 ml 30% H_2O_2 to 3 ml 70% ethanol), allowed to react for 2 min, flooded again with Superoxol, and allowed to react for another 2 min. The smears were then rinsed with tap water, air dried and stained with Wright's Giemsa (Harleco 'Diff-Quick'). Using this modification the cytoplasm of the red cells

stained brown, providing a marked contrast between the brown cytoplasm of the nucleated red cells and the basophilic cytoplasm of the white cells and thrombocytes. A comparison of smears stained only with Wright's stain and those stained with the modified procedure showed that the modification did not interfere with the staining characteristics of the eosinophil granules or with the estimation of the age of red cells, as the younger red cells stained a lighter brown. One hundred white cells per slide were counted and classified. Thrombocyte counts were estimated by multiplying the mean thrombocyte count per field for 20 consecutive fields (1000 X) times 15 000. This method is currently used in human clinical laboratories as a means of cross-checking direct haemocytometer and automated thrombocyte counts. The number of reticulocytes per 1000 mature red cells was counted on smears from samples collected in 1977. The smears were made after allowing equal volumes of 1% BCB and blood to react for 10 min; reticulocyte identification was based on descriptions according to Dawson (1933). Photomicrographs were made of representative cell types using a tungsten light source without filters and Kodak Ektachrome EH 135-36 film at a magnification of 1000 X.

III. RESULTS AND DISCUSSION

CELLULAR OBSERVATIONS

The literature dealing with fish haematology is often confusing because of the lack of uniformity in morphological criteria and terminology applied to blood cell identification. This contributed to difficulties encountered in this study, especially in the identification of white cells. Ellis (1977) discusses these problems in detail.

Eight types of blood cells were recognized in albacore and skipjack tunas: reticulocytes, mature erythrocytes, thrombocytes, neutrophils, lymphocytes, monocytes, eosinophils and an eosinophil-like cell. Information on mean size and distinguishing features of the blood cells are summarized in Table I. The morphology of the skipjack cells was nearly the same as for albacore except: (1) the red cells were smaller, $8{\cdot}0 \times 6{\cdot}4\ \mu m$; and (2) the lymphocytes and thrombocytes were larger, $6{\cdot}3 \times 5{\cdot}5$ and $6{\cdot}7 \times 4{\cdot}0\ \mu m$, respectively. The morphology of the albacore and skipjack blood cells closely resembled those of bluefin tuna as described by Gutierrez (1967).

Leucocytes

The lymphocytes in albacore and skipjack were similar in appearance to those reported in other teleosts, although a range of sizes was observed rather than 'small' and 'large' as has been reported for some other species (Saunders, 1966; Gutierrez, 1967; Ellis, 1977). Monocytes were present in low numbers in both albacore and skipjack. They were the largest cell in the peripheral circulation of both species and typically contained one or more vacuoles in the cytoplasm. A variety of nuclear configurations have been reported for neutrophils from teleosts (Saunders, 1966; Conroy, 1972; Ellis, 1977). The most prevalent form observed in our studies was an eccentric, monolobed nucleus; however, occasionally a bilobed nucleus was noted. The cytoplasm had a 'ground-glass' appearance, created by the presence of many fine, faintly grey-pink granules. Basophils were not observed in either albacore or skipjack, which is in agreement with earlier observations on skipjack (Saito, 1954; Saunders, 1966), little tuna (Saunders, 1966), and yellowfin tuna (Saito, 1954). This observation also agrees with Becker *et al.* (1958) who did not observe basophils in bluefin; however, it does not agree with Gutierrez (1967), who reported basophils to be the smallest and most scarce

TABLE I. Size range and distinguishing features of the blood cells of the albacore tuna

Cell type	Number of cells measured	Nucleus	Cytoplasm and cell outline	Mean size of cells (μm)
Reticulocytes	—	Oval; slightly larger and more rounded than in mature red cells; chromatin less pyknotic than in mature red cells; basophilic	Circular; more polychromatophilic than mature red cells; in benzidene-treated smears, cytoplasm much lighter brown than in mature red cells	—
Erythrocytes	100	Elliptical; basophilic, chromatin pyknotic	Elliptical; polychromatophilic with varying degrees of polychromasia; in benzidene-treated smears cytoplasm brown; inclusion bodies present in most cells tending to form ring around nucleus	9·0 × 6·6
Thrombocytes	100	Elliptical; homogeneous; basophilic; takes up major portion of cell; occasionally slightly indented	Spindle-shaped; cytoplasm appears as a blue-grey, thin rim; punctate, clear areas sometimes observed in cytoplasm at top of nucleus or bilaterally next to nucleus in centre of cell	4·7 × 3·0
Neutrophils	20	Irregularly elliptical, eccentric; appears red-purple; chromatin lattice-like appearance and slightly clumped	Irregularly elliptical; appears blue-grey; cytoplasm occasionally contained fine, sand-like particles imparting a ground glass appearance	8·6 × 7·9
Lymphocytes	30	Irregularly elliptical; homogeneous; appears red-purple; takes up major portion of cell	Irregularly elliptical; cytoplasm in narrow rim around cell; strongly basophilic; occasional azurophilic granules observed	5·7 × 5·2
Eosinophils	20	Oval; eccentric; chromatin slightly clumped and appears red-purple	Oval to elliptical; cytoplasm filled with discrete, rod-shaped eosinophilic granules	8·9 × 5·0
Eosinophil-like	10	Oval; eccentric; homogeneous; basophilic	Oval to elliptical; cytoplasm faintly eosinophilic, but no discrete granules apparent	6·6 × 5·0
Monocytes	15	Oval; eccentric, chromatin clumped and appears red-purple	Oval; appears grey-blue; rough and bumpy in appearance, frequently containing one or more vacuoles	10·5 × 9·5

of the granulocytes present in bluefin tuna. It is possible that basophils could be present in low numbers in the peripheral circulation of albacore and skipjack, yet not be in the smears which we examined. Eosinophils were present in both the skipjack and albacore and their occurrence has been reported in many other fishes (McKnight, 1966; Saunders, 1966; Gutierrez, 1967; Ellis, 1977, and others). Saunders mentions the presence of 'large' and 'small' eosinophils in the skipjack, but did not give comparative sizes; this phenomenon was not observed in our study.

A cell similar in appearance to, but smaller than, the eosinophil was observed in low numbers in both species. The nucleus was eccentric, homogeneous and basophilic. The cytoplasm appeared eosinophilic, but lacked the granules which typify the eosinophil. The eosinophil-like cell observed in this study somewhat resembled a cell first characterized by Downey (1909) from the kidney tissue of paddle fish (*Polydon spathula*) and later described by Saunders (1966). However, until further studies are performed, its exact classification remains unknown.

Thrombocytes

The thrombocytes of both the albacore and skipjack were typically elliptical cells with thin rims of pale blue cytoplasm, with those of the albacore being smaller and more rounded than those of the skipjack. The cytoplasm occasionally contained vacuoles or peri-nuclear clear areas similar to those reported for bluefin tuna by Gutierrez (1967). Ellis (1977) cites several authors who have reported four thrombocyte maturation stages present in the peripheral circulation of different fish species. This was not observed in this study, although several basophilic 'lone nuclei' forms were noted, which appeared more like erythrocytic precursors (Catton, 1951) than like immature thrombocytes. Thrombocytes were more abundant in albacore than skipjack, averaging 44 380 mm^{-3} and 28 880 mm^{-3}, respectively (Table II).

Erythrocytes

The red cells of the albacore and skipjack were elliptical, elongated and nucleated with perinuclear granules. The granules are believed to be of cytoplasmic origin and associated with the formation of haemoglobin (Dawson, 1933). The reticulocytes, when observed with a supra-vital stain and in contradistinction to the mammalian non-nucleated immature red cells, were more rounded than the mature cells. The reticulum formed a loose, disconnected mesh around the nucleus when observed in supra-vital stained smears. The cytoplasm appeared more polychromatophilic in the reticulocyte than in the mature erythrocyte when observed in Wright's stained smears.

WHITE CELL COUNTS

Direct counts of total white blood cells were attempted, but the results are considered questionable due to cellular clumping, stain precipitation and variable staining. The limited data we collected suggest that total white cell counts were relatively low in both species, ranging from approximately 2000 to 10 000 mm^{-3}. A decreasing trend in the total white cell count was noted over the approximately 24 h period that the immobilized, restrained albacore was sampled (Table III).

TABLE II. Summary of erythrocytic data for albacore and skipjack tunas

	Albacore								Skipjack			
	Group I (1977)				Group II (1978)							
	Sample size	Range	Mean	Std.	Sample size	Range	Mean	Std.	Sample size	Range	Mean	Std.
Length (cm)	17	55–77†	66	7·4	16	80–90*	87	—	15	52–57	55	2·2
Weight (kg)	17	3·3–8·2	5·7	1·8	16	10·1–14·2*	12·9	—	15	2·5–4·5	3·5	0·52
Packed cell volume (%)	23	42–57	49·8	4·48	29	53–63	58·2	2·99	15	42–66	59·3	5·98
Haemoglobin (g/dl)	16	11·0–17·8	15·0	1·50	29	15·0–17·8	16·3	0·63	6	15·8–22·3	18·0	2·38
Mature erythrocytes ($\times 10^6$ mm^{-3})	17	2·65–4·36	3·17	0·48	15	2·31–2·95	2·60	0·22	15	2·5–4·8	4·14	0·64
Reticulocytes (%)†	14	3·33–9·03	6·10	1·62	(no observations)				9	2·39–9·97	5·20	2·38
Thrombocytes ($\times 10^4$ mm^{-3})	5	33–69	44·38	16·29	(no observations)				5	22–26·5	28·88	3·58

*Estimated; †Expressed as percentage of mature erythrocytes.

TABLE III. Summary of haematological data for an immobilized, restrained albacore sampled over approximately 24 h period

Time	Sampling interval	Packed cell volume (%)	Haemoglobin (g/dl)	Red blood cells ($\times 10^6$ mm^{-3})	White blood cells ($\times 10^3$ mm^{-3})	Differentials (%) Neutrophils	Lymphocytes	Monocytes	Eosinophils
07.54	0*	55·5	17·8	3·47	7·8	10	71	5	14
08.44	50″	52·5	16·9	3·90	10·6	4	88	2	6
09.45	1′51″	50·5	16·2	3·66	8·8	8	84		8
10.39	2′45″	51·5	15·3	3·87	7·2	12	72		16
11.49	3′55″	50·0	19·4	3·63	5·4	14	68		18
13.21	5′21″	49·5	17·7	3·82	6·0	4	60	4	32
14.34	6′40″	47·5	16·5	3·45	5·1	8	62		30
17.34	9′40″	46·0	13·3	3·37	4·0	16	68		16
20.35	12′31″	41·0	14·9	3·10	4·4	4	76		20
05.55	22′01″	59·0	19·5	4·25	2·7	24	50		26
07.05	23′11″	58·5	20·2	3·96	2·0	6	74	4	16

*Initial sample taken approximately 13 minutes after fish struck lure, fish caught on rod and reel and landed in approximately one minute.

TABLE IV. Differential counts for albacore and skipjack sampled in 1977

Cell type	Albacore		Skipjack	
	Mean*	Range	Mean*	Range
Neutrophils	24	0–80	33	10–98
Lymphocytes	51	0–92	46	2–92
Eosinophils	13	0–28	11	0–24
Eosinophil-like	6	0–12	4	0–10
Monocytes	6	0–20	6	0–12

*Mean values weighted so sum equals 100.

DIFFERENTIAL BLOOD CELL COUNTS

In albacore and skipjack sampled immediately after being brought on board, lymphocytes were the most common leucocyte in the peripheral circulation, followed in decreasing order by neutrophils, eosinophils and monocytes (Table IV). In the albacore sampled over time, lymphocytes were also the most prevalent white cell in the peripheral circulation; however, eosinophils were more abundant than neutrophils and tended to increase with time, while the total white cell count appeared to decrease (Table III).

A selected review of recent literature reveals that some authors include thrombocytes in differential white cell counts (Boyar, 1962; Saunders, 1966; Gardner & Yevich, 1969; Sherbourne, 1973; McCarthy, Stevenson & Roberts, 1973, 1975) while others do not (Becker *et al.*, 1958; Watson *et al.*, 1963; Colgrove, 1966; Pitombeira & Martins, 1970; Blaxhall, 1972; Conroy, 1972). We have followed the convention used in mammalian studies and did not include thrombocytes in the differential white cell counts. While a direct comparison with published differential counts is difficult, our differential counts are generally consistent with those reported in the literature. The high lymphocyte counts we found in albacore and skipjack agree with results reported for bluefin tuna (Becker *et al.*, 1958), little tuna (Saunders, 1966), mackerel (Becker *et al.*, 1958; Pitombeira & Martins, 1970) and other teleosts (Watson *et al.*, 1963; Mulcahy, 1970; McCarthy *et al.*, 1973, 1975, and others). The increase in circulating eosinophils observed over time in the restrained, immobilized albacore is similar to findings made by Gardner & Yevich (1969) who noted increases in eosinophil levels over time in *Fundulus heteroclitus*, which the authors judged were stressed because the fish were held in small aquaria. They also found that specimens held in large aquaria showed little change in the eosinophil level over time.

ERYTHROCYTIC CHARACTERISTICS

A summary of erythrocytic data observed for albacore and skipjack tunas sampled immediately after being brought on deck is presented in Tables II and V, and for the immobilized albacore sampled serially over approximately 24 h in Table III. The erythrocytic results found in this study are in agreement with published data for tunas, which have been summarized in Table V.

Red blood cell counts

We found mean red blood cell counts of $3{\cdot}17 \times 10^6$ mm^{-3} (1977) and $2{\cdot}60 \times 10^6$ mm^{-3} (1978) for albacore and $4{\cdot}14 \times 10^6$ mm^{-3} for skipjack (Table II). The red cell counts of the immobilized albacore sampled serially over approximately 24 h ranged from $3{\cdot}10 \times 10^6$ mm^{-3} to $4{\cdot}25 \times 10^6$ mm^{-3} (Table III). These values are similar to those reported in the literature for tunas (see Table V).

The difference in mean red cell counts for albacore observed in 1977 and 1978 is statistically significant ($P = 0{\cdot}005$). This difference could be related to numerous contributory factors. For example, based on albacore tagging data and fishery data collected during the two years, it appears that the fish sampled in 1978 had immigrated into the area of capture and remained there several weeks longer before capture than had the fish sampled in 1977. There may, therefore, have been differences in migratory status, diet, and nutritional status in the fish sampled in the two years. Also, the fish sampled in 1978 were about twice the mean size of the fish sampled in 1977 (Table II). The effect of size, if any, on albacore red cell counts is not known. Gutierrez (1967, 1970) reported results for bluefin tuna that suggest a relationship between spawning and red cell count. He observed lower red cell counts in pre-spawning individuals than in post-spawning individuals.

Reticulocytes

The mean number of reticulocytes in the peripheral circulation, expressed as a percentage of the mature erythrocytes, was 6·1% in albacore and 5·2% in skipjack. We found no published data on reticulocyte counts for tunas and only a few reports for other teleosts. Dawson (1933) reported the proportion of circulating immature erythrocytes in what he termed 'active' fishes, which included the Atlantic mackerel, *Scomber scombrus*, as approximately 20%, in less 'active' fishes as 3–6%, and in relatively sluggish fishes as few or rare. Dawson's study was conducted on fishes held in aquaria and he notes that in general the group of fish he included as 'active' are characterized by their inability to survive for any extended period in restricted quarters, and that the sensitivity to confinement could be a factor in his results. Catton (1951) reported that reticulocytes formed 1–2% of the erythrocyte population in three freshwater and two marine species of fishes. Watson *et al.* (1963) noted that immature erythrocytes are frequently encountered in the blood of healthy goldfish, *Carassius auratus*, and do not indicate a blood dysfunction.

Haemoglobin values

We found mean haemoglobin values of 15·0 g/dl (1977) and 16·3 g/dl (1978) for albacore and 18·0 g/dl for skipjack (Table II). These values are comparable with those observed in tunas by other investigators (Table V). Haemoglobin values for the immobilized albacore ranged from 13·3 g/dl to 20·2 g/dl with minimum values occurring at the same sampling times, 9·40 hours and 12·31 hours, as the minima in red blood cell counts (Table III).

Packed cell volume

Mean packed cell volume values (PCV) for albacore were 49·8% (1977) and

TABLE V. Summary of published red blood cell counts, haemoglobin concentrations and packed cell volumes observed in tunas and mackerels

Species		Red blood count ($\times 10^6$)			Haemoglobin (g/dl)			Packed cell volume (%)		
Scientific name	Common name	Number	Mean	Range	Number	Mean	Range	Number	Mean	Range
Thunnus alalunga	Albacore									
Present study		17	3·17	2·65–4·36	16	15·0	11·0–17·8	23	49·8	42–57
		15	2·60	2·31–2·95	29	16·30	15·0–17·8	29	58·4	53–63
Barrett and Williams (1965)					11	17·97	15·3–19·3			
Thunnus thynnus	Bluefin tuna									
Gutierrez (1970)		10	2·85	2·1–4·1	10	17·3	15·2–20·5	10	52·8	50–57
		10	2·35	1·9–3·4	10	16·2	14·8–19·2	10	51·1	43–56
Gutierrez (1967)		12	2·15	1·8–2·4	12	15·4	15·0–16·0	12	52·4	50–55
		10	1·95	1·8–2·04	10	14·9	14·5–15·3	10	51·0	46–58
Barrett and Williams (1965)					10	19·8	18·7–21·0			
Becker et al. (1958)		—	2·3	—				—	41·0	—
Thunnus albacares	Yellowfin tuna									
Barrett and Williams (1965)					8	16·8	15·3–19·3			
Klawe et al. (1963)					11	—	15·8–18·9			
Barrett and Conner (1962)					22	14·3	11·5–16·5			
Saito (1959)		18	3·87	—	18	14·4	—	18	51·5	—
Saito (1954)		—	3·64	—	—	14·9	—	—	50·1	—
Thunnus obesus	Bigeye tuna									
Barrett and Williams (1965)					25	15·6	10·3–20·8			
Katsuwonus pelamis	Skipjack tuna									
Present study		15	4·14	2·5–4·8	6	18·0	15·8–22·3	15	59·3	42–66
Magnuson (1969)					21	16·1	—	21	56·2	—
Klawe et al. (1963)					9	—	14·1–20·7			
Barrett and Conner (1962)					21	16·7	15·0–18·5			
Saito (1959)		24	3·92	—	24	14·1	—	24	53·3	—
Saito (1954)		—	3.396	—	—	14·4	—	—	48·3	—

Euthynnus lineatus	Black skipjack									
Klawe et al. (1963)					5	—	16·9–19·9			
Sarda chiliensis	Pacific bonito									
Barrett and Williams (1965)					9	12·9	11·2–15·3			
Klawe et al. (1963)					14	—	8·3–14·8			
Auxis rochei	Frigate mackerel									
Barrett and Williams (1965)					10	19·2	16·5–22·8			
Klawe et al. (1963)					6	—	17·8–21·2			
Scomber scombrus	Atlantic mackerel									
Larsen et al. (1976)					3	12·7	—	3	52·5	—
Scomber japonicus	Pacific mackerel									
Klawe et al. (1963)					10	—	8·0–14·8			
Scomber australasicus	Spotted chub mackerel									
Saito (1959)		27	3·80	—	27	13·8	—	27	50·6	—
Saito (1954)		—	3·51	—	—	13·9	—	—	47	—
Scomberomorus maculatus	Spanish mackerel									
Pitombeira and Martins (1970)		100	3·48	1·5–5·43	100	11·1	6·4–15·0	100	47	34–61
Engel and Davis (1965)		58	4·54	3·15–6·13	58	10·4	7·6–12·2	58	38·8	26·5–48·0
Becker et al. (1958)		—	3·2	—				—	38	—
Scomberomorus regalis	Cero									
Swarts (1969)					1	12	—	1	44	—
Scomberomorus cavalla	King mackerel									
Engel and Davis (1965)		6	3·54	2·66–4·59	6	9·3	7·3–10·3	6	36·3	32–43

58·2% (1978) and for skipjack was 59·3% (Table II). These values are similar to those reported in the literature for tunas (Table V). The PCV values for the immobilized albacore showed a gradual decrease from an initial value of 55·5% to a minimum of 41·0% at the 12·31 hours sampling time. The final two packed cell volumes sampled at 22·01 hours and 23·11 hours, were elevated to 59·0% and 58·5%, respectively (Table III).

Little is known about the ranges and variation of 'normal' haematologic values for the tunas. The results presented in this manuscript are intended to assist research workers in establishing ranges of normal haematologic values for albacore and skipjack tunas. This information is necessary before haematological data can be used to accurately assess physiological status in tunas. Many factors may contribute to variations in haematological parameters of fishes and must be evaluated for the tunas. These factors may be grouped into categories including: (1) those which can cause individual haematological differences *in vivo* in tunas, e.g. age, sex, migration, season, environmental conditions, etc.; (2) those which are due to stress resulting from capture, handling and sampling procedures; and (3) those due to the inaccuracy of analytical methods, identifications, etc.

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