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SYSTEMATICS AND MERISTIC VARIATION IN THE BUTTERFISH (ODAX PULLUS (FORSTER))

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FISHERIES TECHNICAL REPORT

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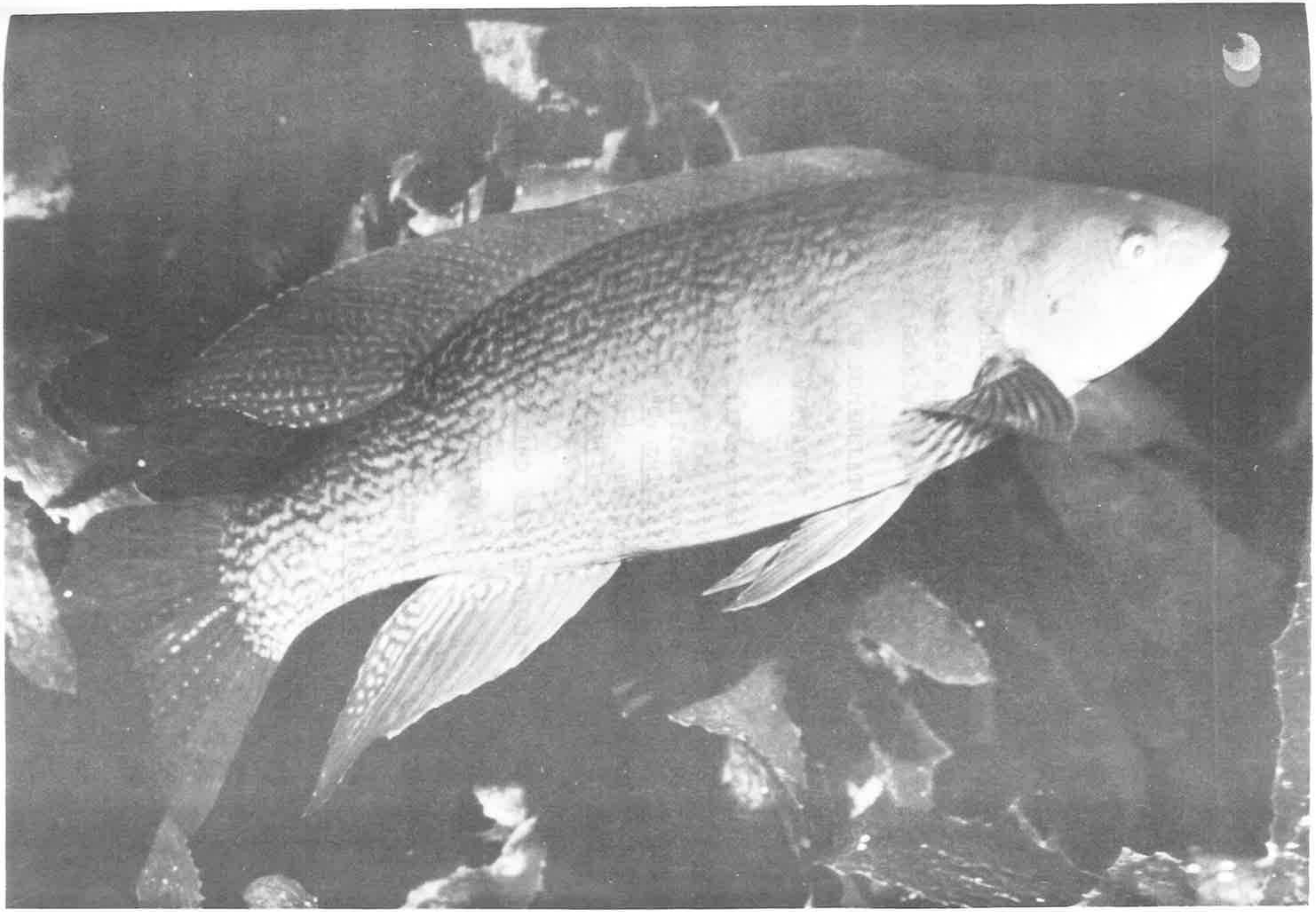
WHANGAREI.



Male butterfish, with nuptial markings, on display. Ecklonia forest at 10 m depth, Poor Knights Islands. Photo : L.D.R. Rolleimarine.

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ABSTRACT

An historical review of the systematic literature of *Coridodax pullus* Forster *in* Bloch and Schneider, 1801 and *Odax vittatus* Solander *in* Richardson, 1843 is given, and these nominal species are synonymised. *Odax pullus*, the New Zealand butterfish, is described and its form, colour, and behavioural changes with growth are discussed. Variation in the number of fin rays, scale rows and vertebrae is shown to have significant negative correlation with sea surface temperature.

INTRODUCTION

Odax pullus (Forster, 1801), the butterfish, greenbone, or marari is the sole New Zealand representative of the Odacidae, a small and unimportant Australasian family of labroid teleosts. It occurs throughout New Zealand in shallow, inshore waters wherever rocks and brown algae are abundant. Odacids appear to be a temperate water derivative of the much more diverse tropical and subtropical labroid group represented by the families Labridae and Scaridae. They resemble other labroids in body and fin form, in the anatomy of the pharyngeal teeth and in the scarid beak but have greater numbers of repeated body parts such as vertebrae, fin rays, and scale rows, than the other two families.

Taxonomy of the labroid fishes is complicated by inadequate original descriptions of closely allied species and because of the failure of early workers to base their diagnoses on sufficient numbers of each species, including juveniles and adults of both sexes. Recent work by Schultz (1958), Randall (1963), Randall & Randall (1963), Randall & Böhlke (1965), Choat (1965, 1968) and Tortonese (1967) has elucidated some problems of colour phase occurrence and species validity. Underwater observational work by Randall (1963) and Randall & Randall (1963) has proven quite conclusively that some differently named scarid and labrid fish were different sex and colour phases of a single species.

Underwater observation and examination of speared specimens of O. vittatus and C. pullus suggested that these two nominal species are in fact different age, colour and maturity phases of the same fish. Many commercial fishermen and skindivers have for years held the same view. Subsequent examination of meristic characters, proportional dimensions, and anatomic features established that the two supposed species are conspecific. Differences in fins, cheek scales, and snout angle can now all be shown to be a result of change with growth and the attainment of sexual maturity. O. vittatus is the juvenile form and colour phase of C. pullus and the valid name for the butterfish is Odax pullus - this is discussed below.

Examination of butterfish samples from different areas throughout New Zealand showed that a significant amount of meristic variation occurs amongst the local populations sampled, and that meristic characters are similar wherever the surface sea water temperatures are similar.

The present paper is the first of two derived from my MSc (zoology thesis, University of Wellington, 1969), dealing with aspects of the biology of the butterfish. The second (Ritchie, 1975 in prep.) discusses the reproductive biology of the butterfish including: seasonal gonad changes, deposition fat changes, the early life history, the rearing of larvae, and other aspects of the biology including the length/weight relationship, age and growth, feeding and parasites.

MATERIALS AND METHODS

(a) Sampling Methods and Localities

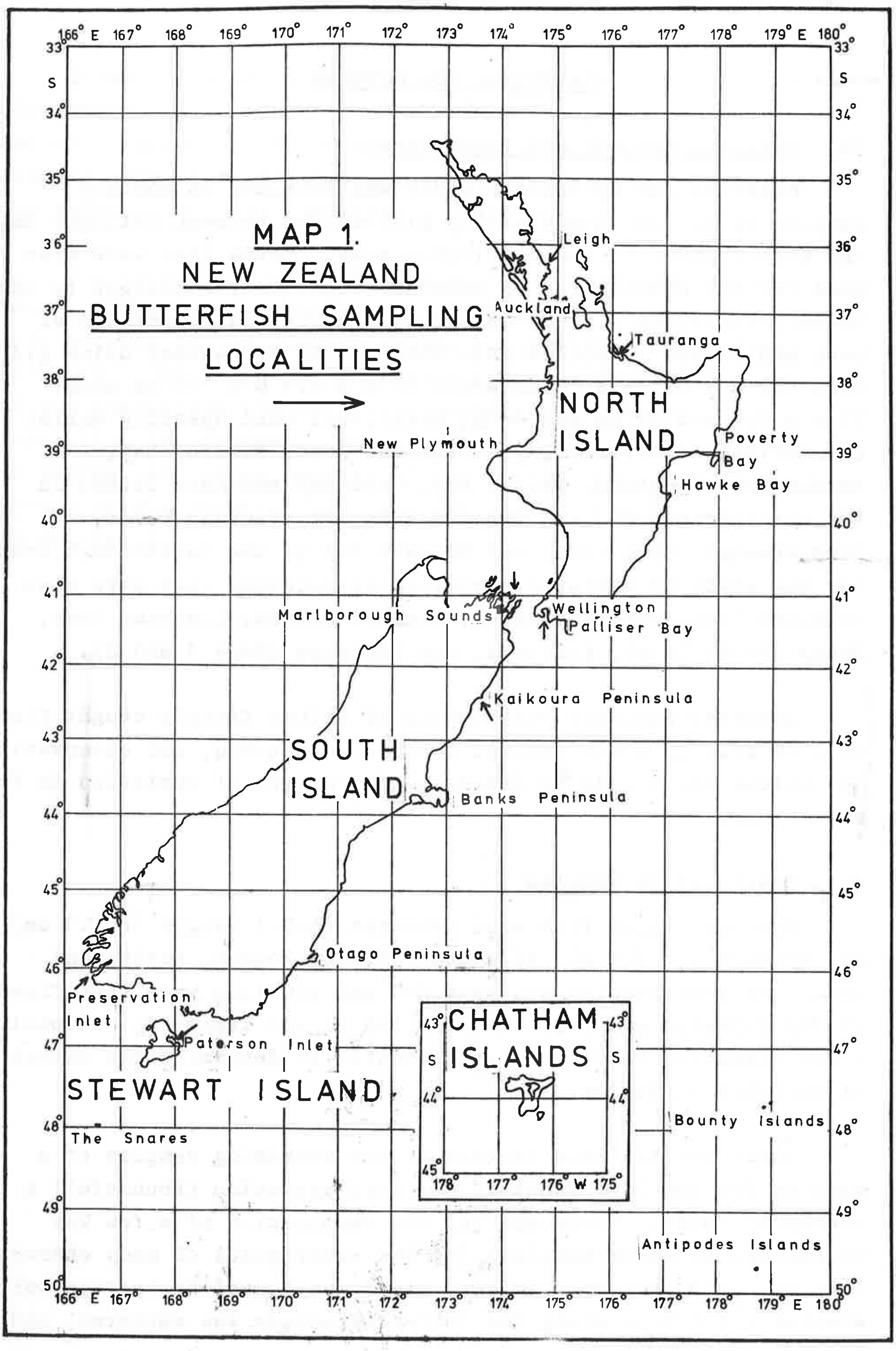
Material for systematic study was obtained as monthly samples of 20 fish commercially gill-netted between Palliser Bay and Karori Light in the Wellington area. These fish were also used for the elucidation of seasonal reproductive changes in the butterfish (Ritchie, 1975 in prep.). Additional specimens of both adults and juveniles were obtained by the author using gill nets (37 m x 2.5 m x 40 mm mesh; 37 m x 2.5 m x 100 mm mesh; 73 m x 7.3 m x 25 mm and 40 mm mesh), and hand spearing whilst skindiving at Palliser Bay, Turakirae Head, Fitzroy Bay, Breaker Bay, Seatoun, Island Bay, Ohau Bay and Mana Island in the Wellington area, and Cape Jackson, Dieffenbach Point, Tory Channel, Ship Cove, and Ngararu Bay in the Marlborough Sounds. For the study of meristic variation gill-netted fish were also obtained from Patterson Inlet, Stewart Island; Luncheon Cove, Dusky Sound; Leigh, Kaikoura, and Tauranga (Maps 1 and 2).

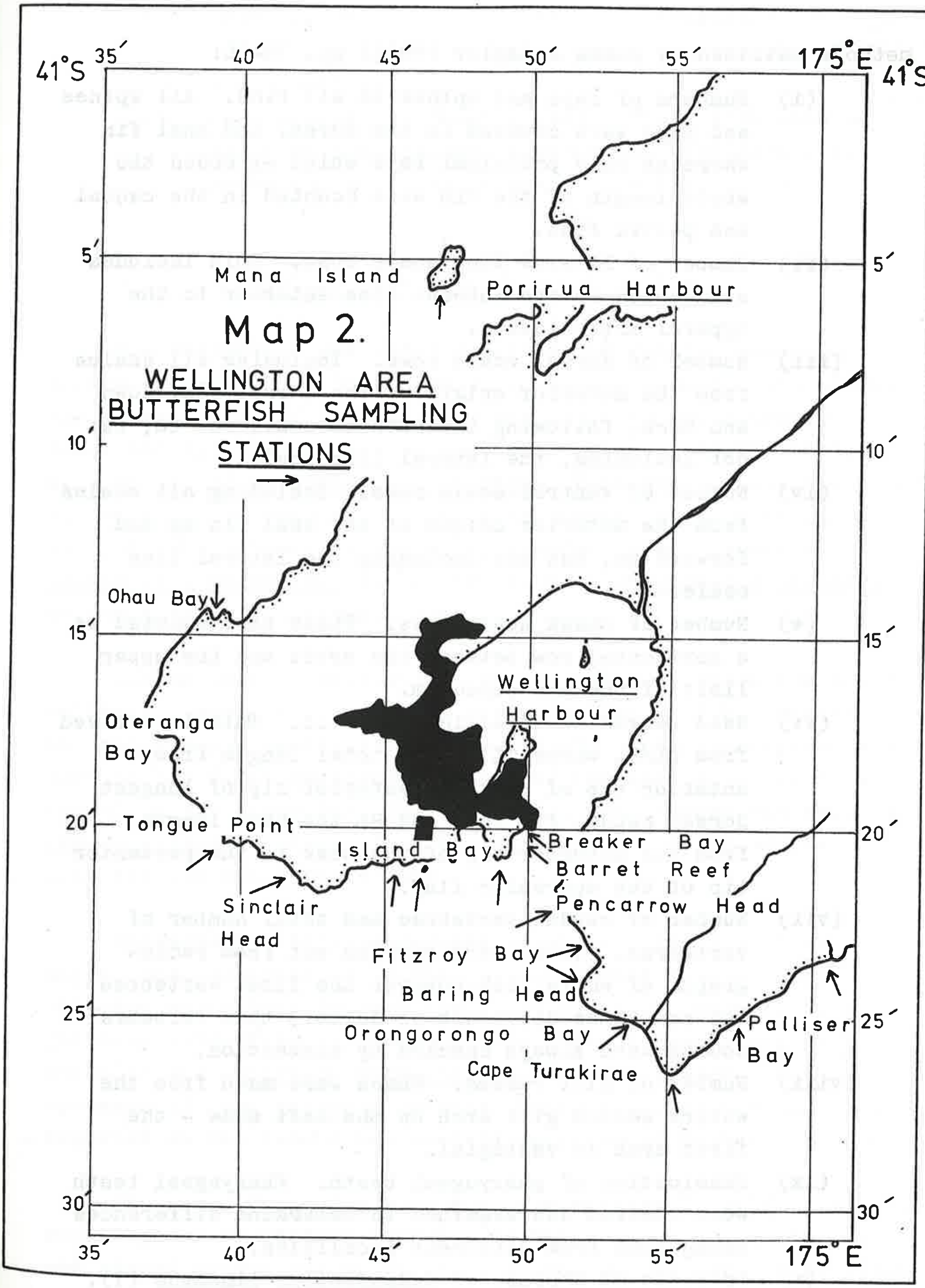
Whenever possible photographs of either freshly caught fish or live fish in their natural habitat were taken, and observations and colour notes made to determine the extent of variation in form and colour.

(b) Treatment of Samples

Freshly caught fish were measured (total length to 0.1 cm) and weighed (to 1.0 g), alimentary tract, gonads, scales and parasites were removed and retained and the fish were then fixed in 10% formalin and later transferred to 40% iso-propyl alcohol. These preserved fish were later studied to determine the extent of meristic variation.

There are two main techniques for examining samples of a species for the occurrence of meristic variation (Rounsefell & Everhart, 1953). These are (a) the examination of a few key characters in large samples; (b) the examination of many characters in small samples. As only small samples of butterfish were available for this study the latter technique was employed, and the following meristic counts and measurements were made using


MAP 1.
NEW ZEALAND
BUTTERFISH SAMPLING
LOCALITIES
NORTH ISLAND
SOUTH ISLAND
STEWART ISLAND
Leigh
Auckland
Tauranga
New Plymouth
Poverty Bay
Hawke Bay
Marlborough Sounds
Wellington
Palliser Bay
Kaikoura Peninsula
Banks Peninsula
Otago Peninsula
Preservation Inlet
Paterson Inlet
The Snares
Bounty Islands
Antipodes Islands
CHATHAM ISLANDS
166° E 167° 168° 169° 170° 171° 172° 173° 174° 175° 176° 177° 178° 179° E 180°
33° S 34° 35° 36° 37° 38° 39° 40° 41° 42° 43° 44° 45° 46° 47° 48° 49° 50°
43° S 44° 45°
178° 177° 176° W 175°


Map 2.
WELLINGTON AREA
BUTTERFISH SAMPLING
STATIONS
41°S
175°E
35′
40′
45′
50′
55′
5′
10′
15′
20′
25′
30′
Mana Island
Porirua Harbour
Ohau Bay
Oteranga
Bay
Tongue Point
Sinclair
Head
Island Bay
Wellington
Harbour
Breaker Bay
Barret Reef
Pencarrow Head
Fitzroy Bay
Baring Head
Orongorongo Bay
Cape Turakirae
Palliser
Bay

methods outlined by Hubbs & Lagler (1958) pp. 19-26:

(i) Numbers of rays and spines in all fins. All spines and rays were counted in the dorsal and anal fin where as only principal rays which extended the whole length of the fin were counted in the caudal and pelvic fins.

(ii) Number of lateral line scale rows. This includes all scales on the lateral line anterior to the hypural articulation.

(iii) Number of dorsal scale rows. Including all scales from the anterior origin of the dorsal fin, down and back, following the natural scale row to, but not including, the lateral line scale.

(iv) Number of ventral scale rows. Including all scales from the anterior origin of the anal fin up and forward to, but not including the lateral line scale.

(v) Number of cheek scale rows. These were counted as a horizontal row between the orbit and the upper limit of the preoperculum.

(vi) Head length to total length ratio. This is derived from TL/HL where TL is the total length from anterior tip of beak to posterior tip of longest dorsal caudal fin ray, and HL the head length from the anterior tip of the beak to the posterior tip of the opercular flap.

(vii) Number of caudal vertebrae and total number of vertebrae. These were carried out from radiographs of whole fish however the first vertebrae was sometimes difficult to delimit thus vertebral counts were always checked by dissection.

(viii) Number of gill rakers. These were made from the entire second gill arch on the left side - the first arch is vestigial.

(ix) Examination of pharyngeal teeth. Pharyngeal teeth were removed and examined to determine differences among fish from different localities.

(x) Presence of absence of Codonophilus lineatus (?). This parasitic isopod commonly infests the throat region of female butterfish.

(xi) Body proportions expressed as a percentage of total length. These were used to compare juvenile and adult butterfish.

(xii) Measurements of snout angles. These were used to describe form changes with growth (for method of measuring snout angle see - Fig. 1, F).

HISTORICAL REVIEW OF NOMENCLATURE

The butterfish was first collected on Cook's "Endeavour" voyage 1768-1772, at "Mattaruhow" (a misspelling of Mataruahow, the present site of Napier), New Zealand, and subsequently described by Solander in his manuscript "Pisces Australiae", p. 1 and p. 39 as Coregonus vittatus. Parkinson's (pl. 44, No.2) illustration of this fish (an easily recognisable painting of the juvenile butterfish - L.D.R.) apparently was labelled Callyodon coregonoides on the front, and Coregonoides vittatus on the reverse (Whitehead, 1968).

During Cook's "Resolution" voyage the butterfish was again collected, sketched, and named Sparus pullus by J.R. Forster in his manuscript "Descriptiones Animalium". This description was used in the first published account of the species by Schneider (in Bloch and Schneider, 1801, p. 288), who changed the name to Scarus pullus Forster. This is therefore the first available name for the adult butterfish.

Richardson (1843) reproduced Solander's (at that time) unpublished description of the juvenile butterfish as Odax vittatus which thus becomes the first available name for the juvenile butterfish. The manuscript names Coregonoides vittatus Solander and Callyodon coregonoides Parkinson, were treated as synonyms of Odax vittatus Solander which subsequently has been regarded as the second New Zealand kelpfish or butterfish species.

The genus Coridodax with a single species C. pullus (Forster) was proposed by Günther (1862). In the synonymy of C. pullus was placed Scarus pullus Forster, Scarus pullus Forster in Bloch and Schneider, and Odax pullus Forster in Cuvier and Valenciennes. Günther (1862) added (p. 243): "Type of the species, fifteen inches long; ... from Forster's Collection." Odax vittatus Solander was also recognised by Günther as a separate species and most subsequent accounts of the New Zealand butterfish have recognised the two species, Coridodax pullus and Odax vittatus.

If the view that C. pullus and O. vittatus are synonymous is accepted, then the specific name pullus has priority. Generic assignment of this species has been subject to prolonged confusion and clarification is not easy. The genera Callyodon, Coregonus, Scarus, and Sparus can be dismissed as they all belong to families quite different from the butterfishes. Coregonoides (see Whitley, 1968, p. 65) has no status from Richardson's (1843) account because it appeared there as a synonym. Odax was first used in a footnote in Lacépède (1802) - based on a Commerson manuscript - for a species of the family Scaridae. This usage was recognised by Norman (1966. p. 356) as synonymous with Scarus Forskål. Direction 32 and title No. 39 in the Official Index of Rejected and Invalid Works in Zoological Nomenclature (1958, p. 8) suppressed Commerson names given as footnotes in Lacépède, hence Odax Commerson in Lacépède is not available.

The next usage of Odax is in Cuvier (1829) where only one species Scarus pullus is listed under "Les Odax" (p. 266) and thus Odax is not used in binomial form. However in the index to this work (p. xii) Odax is listed. It can be argued that this usage of Odax as an index listing satisfies Article II (c) ii of the International Code. Thus Odax pullus becomes the type species for the genus by original monotypy despite Cuvier and Valencienne's (1842) subsequent nomination of Odax semifasciatus as the type species.

Clarification of the authorship of Odax may require an appeal to the International Commission. If this resulted in the rejection of Odax, then Günther's (1862) Coridodax would be the next available name. The relationship of Coridodax to Neoodax Castelnau (1875) which has been used by several authors for Australian species has yet to be determined, but in any case if *Odax* were invalidated *Coridodax* would have priority over *Neoodax*.

In summary, *Odax pullus* must at present be assigned to the New Zealand butterfish despite the lack of an incontrovertible decision as to the status of the generic name *Odax*.

A COMPARISON OF "ODAX VITTATUS" AND "CORIDODAX PULLUS"

The parallel use of two names for the New Zealand butterfish arose because the juvenile was collected and described by Solander on Cook's first voyage to New Zealand and the adult was collected and described by Forster on Cook's second voyage. The juvenile fish was finally standardised in the literature by Richardson (1843) as "*Odax vittatus*" and the adult was standardised by Günther (1862) as "*Coridodax pullus*". Subsequent workers have perpetuated this error by merely quoting these authorities without recourse to the fish itself. In the following section I present evidence to show that the two above names refer to the same fish - *Odax pullus*.

(a) Supposed Generic Differences Between Odax and Coridodax

Comparison of the generic diagnoses given by Günther (1862) for *Odax* and *Coridodax* shows that these genera were separated only by the following characters:

Odax	*Coridodax*
Cheeks and opercles scaly.	Head naked, a few scales behind the orbit.
Snout conical.	Snout of moderate extent.

In my material I find that both juvenile (= "*O. vittatus*") and adult (= "*C. pullus*") butterfish have scales high on the operculum, but while 0 - 5 (usually 3) scale rows are present behind the orbit on the preoperculum of the juvenile, these become wholly or partly buried under the epidermis in the adult. However only rarely is it possible to find an adult fish, which on close examination, has no trace of cheek scales.

For the same reason more predorsal fin scale rows are usually visible in the juvenile than in the adult. Similarly, snout shape and angle can be shown to be a function of size and age (see Table 3 below).

(b) Supposed Specific Differences Between "*O. vittatus*" and "*C. pullus*"

Similarly, a comparison of the specific diagnoses given by Günther (1862) for these two species shows that they were separated only by the following characters:

O. vittatus	*C. pullus*
Entirely brown, with a silvery band commencing from the lower jaw and running through the base of the pectoral to the lower part of the caudal. Sometimes there are a series of small violet spots along the back and side: old individuals have the silvery band interrupted and composed of spots.	Uniform blackish-brown.

The differences in colouration between adults and juveniles are well marked and are shown (below) to have behavioural significance. Juvenile butterfish have a golden brown colouration with a variously interrupted lateral silvery stripe (up to approximately 35 cm TL). As they grow they become darker until large fish become almost black dorsally with generally pale shades of brown, green, and yellow ventrally and with dark olive green fin rays. Further colour notes are given in the description (below).

(c) Notes on Other Generic and Specific Characters of "*O. vittatus*" and "*C. pullus*"

Günther (1862) describes the pharyngeal teeth of *Odax* as follows: "The dentigerous plate of the lower pharyngeal triangular, much broader than long." In the *Coridodax* diagnosis, Günther writes: "Pharygeal apparatus?" - because the type species, *C. pullus*, from Forster's Collection, had had the pharyngeals removed (Günther, 1862 p. 243). During this study pharyngeals teeth were collected from "O. vittatus" and "C. pullus" from several localities. Superficial examination of these teeth revealed no consistent differences either between adults and juveniles or among the samples from different areas.

Another specific character described by Günther (1862) for "O. vittatus" is the undulating nature of the dorsal fin, viz: "The dorsal fin undulates, varying in its height: its first four rays are equal to each other, after which the fin gradually lowers to the thirteenth or fourteenth spine and then rises again, so that the posterior quarter of the fin is higher than the first rays."

My observations of live free swimming juvenile butterfish suggest that the undulating fin is a behavioural characteristic of relaxed or feeding individuals. When alarmed, juveniles will extend the dorsal and anal fin fully thus losing the dorsal fin undulation. Preserved specimens up to 35 cm TL also always exhibit the undulating dorsal fin. Fig. 1 B is drawn from a photograph of a slow swimming captive juvenile (33 cm TL). It is approximately the same size as the fish figured by Parkinson (per Whitehead, 1968), and exhibits the undulating dorsal fin described by Richardson (1843) - below, and quoted by Günther (1862).

In young juveniles all dorsal fin rays are approximately the same length but the posterior soft rays of dorsal and anal fins elongate with age and may almost reach to the tip of the caudal fin in large males (Fig. 1 E). Also, adult fish tend to lose the undulating fin characteristics of juveniles. As the dorsal fin elongates with growth the entire fin seems to be normally held in a semi-erect position. When the adult is alarmed the entire dorsal fin (and anal fin) is erected just as in the juvenile. Males often carry the dorsal and anal fins erect throughout much of the spawning season - probably to display the prominent nuptial colours on them.

With increasing size and age the soft rayed portions of the dorsal and anal fin become increasingly pigmented with the general body colouration and similarly all soft fin rays become increasingly dichotomized (Fig. 2 A & B).

Richardson (1843) and Günther (1862) pointed out that fin ray counts were similar in both fish (see description). Indeed, Richardson came close to the realisation that "O. vittatus" and "C. pullus" - (from Forster's sketch of Odax pullus) were the same fish and had further specimens been available to him he would almost certainly have synonymised the nominal species. Concerning "O. vittatus", Richardson (1843) wrote as follows:

"George Forster's sketch of Odax pullus (202. Banks. Libr.), discovered in Queen Charlotte's Sound, New Zealand, seem, from a query appended to it, "an Callyodon coregonoides?" to have been considered by some annotator to be a representation of Solander's fish. The general proportions of the fish and the numbers of the fin-rays correspond, but the figure does not indicate the characteristic lateral stripe of vittatus, nor does the dorsal exactly correspond in shape, being even for two-thirds of its length, and then rising agreeably with the phrase in J.R. Forster's notes as quoted by Schneider (Scarus pullus, p. 288), "pinna dorsi longitudinalis, primum aequalis dein adscendens." ... "

Changes in fin shape and body proportion which occur with age and growth are illustrated in Fig. 1 A - E; and fin ray dichotomy changes are illustrated in Fig. 2 A & B. Also, comparisons of meristic data, body proportions, and the total length/snout angle correlation for "Odax vittatus" (the juvenile butterfish) and "Coridodax pullus" (the adult butterfish) are given in Tables 1 - 3 below.

TABLE 1 - Comparison of means ($\bar{X}$), and standard deviations (S) of meristic counts, and % infestation by *Codonophilus lineatus* (?) in "*O. vittatus*" and "*C. pullus*".
Fish from the Wellington area, Marlborough Sounds and Dusky Sound.

	"*Odax vittatus*"		"*Cordidodax pullus*"	
	$\bar{X}$	S	$\bar{X}$	S
Sample number	27		34	
Mean size of fish	29.3 cm TL		44.7 cm TL	
Scales in L. lat.	77.4	3.76	77.8	3.68
Girth scale rows				
(a) Dorsal fin - L. lat.	12.8	0.68	13.1	1.15
(b) Anal fin - L. lat.	20.8	1.38	21.5	1.48
Cheek scale rows	3.2	0.62	3.0	1.09
HL/TL	4.88	0.24	5.07	0.29
No. caudal vertebrae	20.2	0.68	20.0	0.80
Total No. of vertebrae	47.1	0.92	47.0	0.78
Gill rakers on 2nd arch	15.4	0.90	15.0	0.64
Spines in dorsal fin	20.7	0.96	20.9	0.68
Total No. fin rays and spines	80.6	0.97	81.2	0.88
% infest. *Codonophilus lineatus* (?)	33.3		35.3	

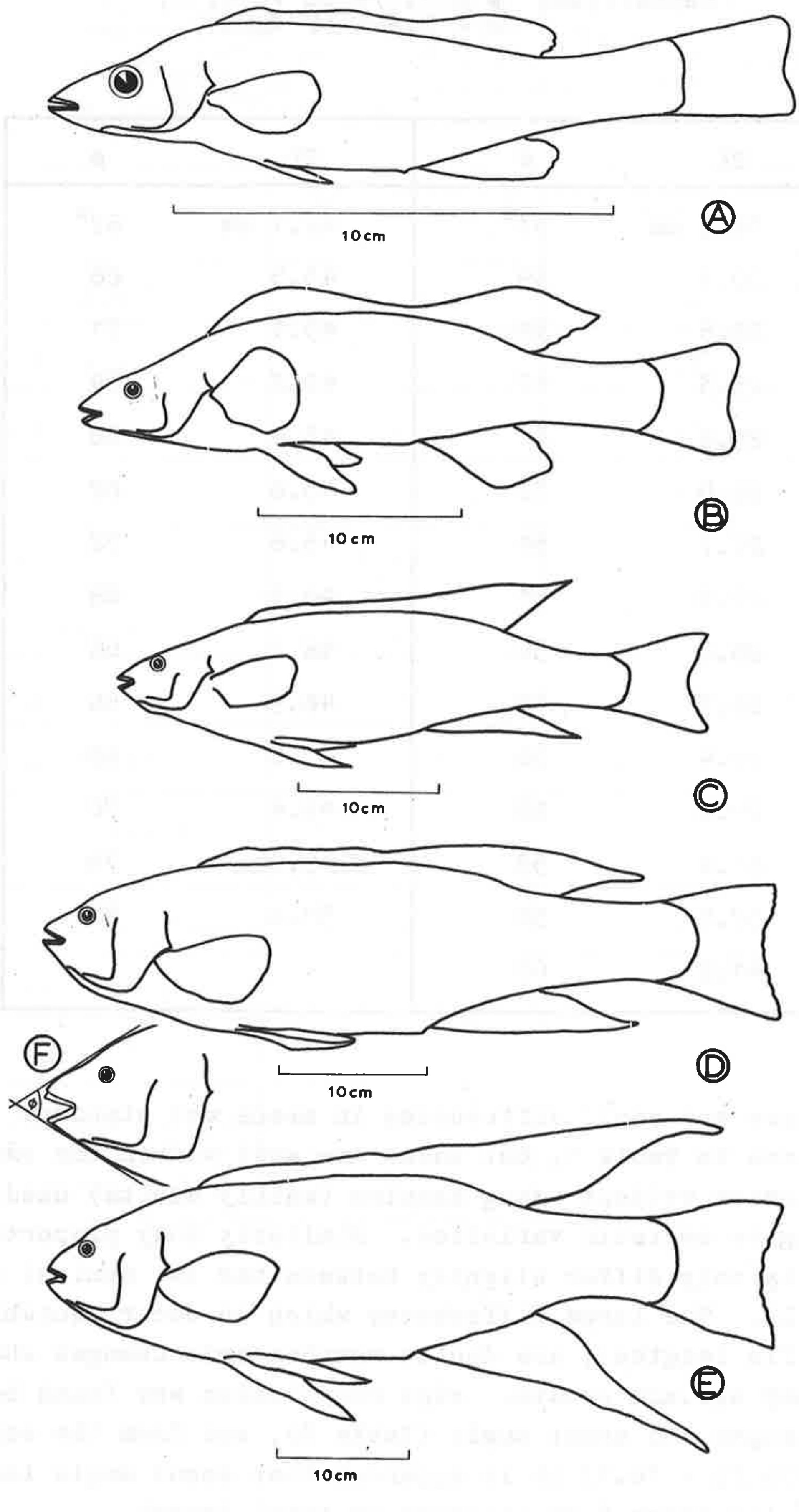
TABLE 2 - Comparison of mean values of body proportions (expressed as % of TL), from 3 male "C. pullus" - (47.0, 46.2 and 43.5 cm TL); and 2 "O. vittatus" - (27.9 and 26.0 cm TL). Wellington area fish.

	Odax vittatus %	Coridodax pullus %
Standard length	80	82
Body depth (max.)	19	23
Head length	20	20
Head width	11	12
Head depth	14	17
Predorsal length	23	22
Snout length	8	7
Postorbital length	10	11
Orbital-preopercular length	6	7
Depressed dorsal length	50	65
Pectoral fin length	15	15
Pelvic fin length	15	20
Caudal peduncle length	20	19
Caudal peduncle depth	9	11

TABLE 3 - TL and snout angle (ø) from 29 Wellington area butterfish; $ø = 1.179\ TL + 16.13$; $r = 0.964\ (P < .001)$

TL	ø	TL	ø
16.9 cm	33°	42.1 cm	67°
20.3	39	43.5	68
22.5	38	45.1	71
25.3	47	45.2	74
25.6	41	45.4	66
26.0	52	45.6	67
27.7	54	45.6	72
27.9	51	46.1	69
28.0	52	46.2	66
28.7	49	46.9	66
29.4	56	47.0	69
29.8	52	48.4	70
31.4	53	49.0	79
32.6	56	51.6	81
41.2	67		

There are small differences in means and standard deviations in Table 1, but these are well within the range of variation evident among samples (mainly adults) used to investigate meristic variation. Similarly body proportions generally only differ slightly between the two nominal species (Table 2). The large differences which do occur (notably in median fin lengths), are due to morphometric changes which accompany age and growth. High correlation was found between total length and snout angle (Table 3), and from the equation $ø = 1.179\ TL + 16.13$ it is apparent that snout angle increases some 6° for every 5 cm increase in total length.



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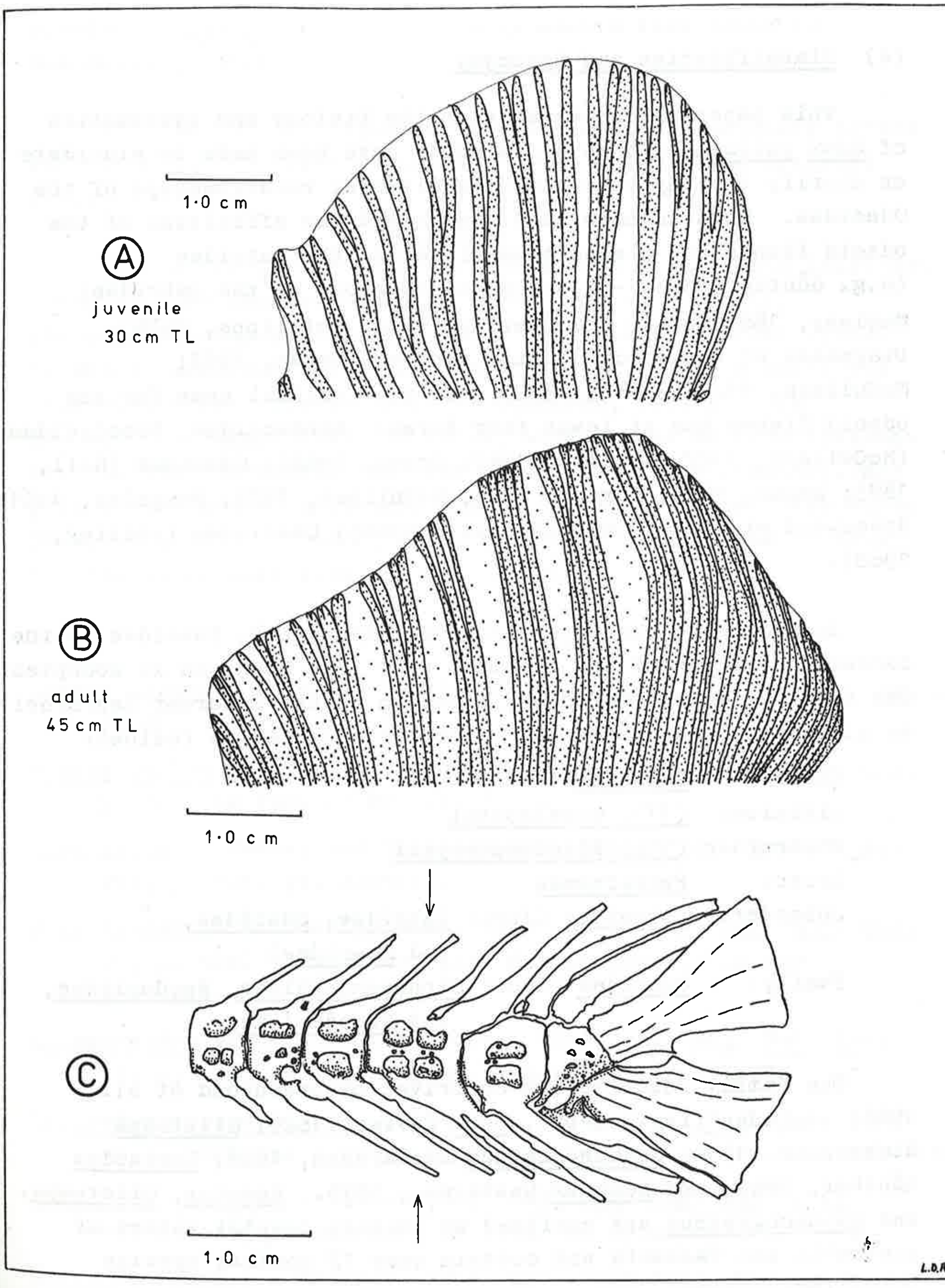

1·0 cm
A
juvenile
30 cm TL
B
adult
45 cm TL
1·0 cm
C
1·0 cm
L.D.R.

CLASSIFICATION, SYNONYMY, AND DESCRIPTION

(a) Classification and Synonymy

This paper is concerned with the biology and systematics of Odax pullus and thus no attempts have been made to elucidate or clarify the phyletic and nomenclatural relationships of the Odacidae. Most authors have recognised the affinities of the odacid fishes and placed them either in the Labridae (e.g. Günther, 1862 - Odacina, sixth group of the Labridae; Macleay, 1881) or in the Scaridae (e.g. Phillipps, 1926). Diagnoses of the odacid family are few (Regan, 1913; McCulloch, 1922; Scott, 1962), and the familial name for the odacid fishes has at least four forms: Neodaciidae, Neoodacidae (McCulloch, 1922; Whitley, 1947; Scott, 1962); Odacidae (Gill, 1893; Regan, 1913; Jordan, 1923; McCulloch, 1929; Roughley, 1951; Greenwood et al., 1966; McAllister 1968); Odaciidae (Whitley, 1968).

According to the International Code (1961), Odacidae is the correct formation of the familial name from Odax and is accepted. The familial and higher classification of the Suborder Labroidei as given by Greenwood et al. (1966) is accepted as follows:

Class:	Teleosti
Division:	(111) Euteleostei
Superorder:	(5th) Acanthopterygii
Order:	Perciformes
Suborder:	Labroidei (incl: Labridae, Odacidae, and Scaridae)
Family:	Odacidae (incl: Siphonognathidae, Neodaciidae, and Neoodacidae)

The family Odacidae (as contrived by Greenwood et al., 1966) includes five genera: Odax Cuvier, 1829; Olisthops Richardson, 1850; Siphonognathus Richardson, 1858; Coridodax Günther, 1862; and Neoodax Castelnau, 1875. Neoodax, Olisthops, and Siphonognathus are confined to inshore coastal waters of Australia and Tasmania and contain some 12 nominal species (McCulloch, 1929).

Odax (= Coridodax) is a monotypic genus containing one species O. pullus which is the only odacid fish found in New Zealand waters.

Regan's (1913) diagnosis of the Odacidae adequately caters for O. pullus and is accepted and given here in its original form:

Odacidae

"Mouth non-protractile, but jaws formed as in the Labridae; teeth in jaws coalescent, forming a sharp edged plate; pharyngeal teeth granular, forming a pavement. Dorsal spines flexible, numerous (16 to 24); each pelvic fin of a spine and four soft rays. Scales small or moderate; lateral line continuous. Skull flattish above, with a more or less distinct interorbital depression for the reception of the praemaxillary pedicels; a short occipital, but no parietal crests. Vertebrae 36 to 53 (19-31 + 17-22); all the ribs on parapophyses. From the coasts of Australia and New Zealand."

Odax pullus (Forster)

Scarus pullus Forster in Bloch and Schneider, 1801, Syst. Ichth., p. 288. (Type locality: Pacific Coast of New Zealand.)

Sparus pullus Forster in Bloch and Schneider, 1801, Syst, Ichth., p. 288, ex Forster MS, IV. 17.

Odax pullus : Cuvier and Valenciennes, 1842, Hist. Nat. Poiss. xvi, p. 304. pl. cccviii.

Odax vittatus Solander in Richardson, 1843, Ann. Mag. Nat. Hist. xi, p. 426. (Type locality: Mattaruhow (?) on the New Zealand Coast.)

Coregonoides vittatus : Richardson, 1843, Ann. Mag. Nat. Hist. xi, p. 426, ex Solander MS. (Name in synonymy.)

Callyodon coregonoides : Richardson, 1843, Ann. Mag. Nat. Hist. xi, p. 426, ex Parkinson MS, pl. 44, No. 2. (name in synonymy).

Coregonus vittatus : Richardson, 1843, Ann. Mag. Nat. Hist. xi, p. 426, ex Solander MS (name in synonymy).

Coridodax pullus : Günther, 1862, Cat. Fish Brit. Mus. iv, pp. 69, 243.

Odax vittatus : Arthur, 1884, *Trans. Proc. N.Z. Inst.* 17, p. 169, pl. 14, fig. 7. (Variety)

Coregonoides vittatus : Whitley, 1968, *Aust. Zool.* xv:1, p. 65.

(b) Description

NOTE : Counts of fin rays, scale rows, cheek scales, gill rakers, vertebrae, and TL/HL measurements, are taken from all fish sampled to investigate meristic variation (see below) - figures give the range and the mode (underlined). Other measurements (given as % of TL), refer to the range of 5 fish used in Table 2.

Fins - dorsal XIIX-XXI-XXIII, 11-13-14; anal II-III, 11-12-14; pectoral 1, 14-15-16; pelvic 1, 4; caudal 0, 12:
Lateral line - scale rows 68-77-87; scales above lateral line 11-13-18; scales below lateral line 18-21-24:
Gill rakers - 14-15-19:
Cheek scale rows - 0-3-5:
Vertebrae - total 44-50; caudal vertebrae 18-20-22.
Head - Snout conical, becoming more obtuse with size (see Table 3). Head almost free of scales; up to 5 scale rows on upper limit of preoperculum - these tend to become buried beneath the epidermis in large specimens. Dorsal part of operculum scaly. Odacid notch - an obvious interorbital depression (Regan, 1913) - present. Lips not fleshy and when relaxed cover beak. Beak formed from coalescent teeth in each jaw, notched in midline, sharp; gape small. Pharyngeal teeth granular, forming a pavement; the dorsal pair with triangular cusps having anterior and posterior cutting edges: a single ventral tooth more broad than long. Cusps on all pharyngeal teeth bright, emerald green. Preoperculum junction clearly defined; operculum extends posteriorly as a membranous scale-free flap just above the pectoral fin. Head length 17%-20%-24%; head depth 14%-17%; head width 11%-12%; snout length 7%-8%; postorbital length 10%-11%; orbit-preopercular distance 6%-7%.
Body - Standard length 80%-82% of TL; slightly compressed in

section; depth 19%-23%; caudal peduncle somewhat compressed, length 20%, depth 9%-11%.

Lateral Line - Scales atypical, exposed portion acute with rounded posterior edge. Lateral line continuous from most posterior scale of caudal fin base, along midlateral line, evenly arched over pectoral fin, terminating near dorsal limit of operculum.

Alimentary tract - 105-140% of TL; stomach poorly differentiated; cross sectional area of intestine large; entire alimentary tract always distended with seaweed.

Bones - All bones bright, grass green.

Fins - Spinous rays are true spines (unbranched, unpaired, and lacking segmentation), but remain soft and flexible. Present in all fins, even if only as non-emergent rudiments.

Dorsal fin - Depressed length highly variable (i.e. 50-75%), depending on size and sex of fish: characteristically depressed in the mid-region, and shortest in juveniles. Posterior soft rays becoming increasingly branched and produced posteriorly in adults, reaching their greatest development in large male fish (Fig. 1 A-E). Predorsal scale rows variously emmergent through the skin, usually between 9 - 17 rows.

Anal fin - Soft rays become increasingly branched and lengthened with fish size increase.

Pectoral fin - Length 15%; soft rays also become increasingly branched with age but do not increase in length disproportionately. In small juveniles only the tips of the soft rays are branched and the fin membrane is transparent. In adults larger than 45 cm TL each soft ray commonly has 4 or more branches and the fin membrane is olive green/blue.

Pelvic fin - Length 15-20%, thoracic in location and reaching greatest relative size in large male fish. Fin web thick, and joined in the posterior midline; the fin web junction is overlain by an elongate triangular flap of skin, bearing from 4-10 small elongate scales.

Caudal fin - Sub-truncate, with no distinct notch; tips rounded somewhat in juveniles. Principal rays soft, massive, with several dichotomies in adults, and 3-4 pairs of small procurrent rays along dorsal and ventral edges of the caudal fin base.

<u>Colour</u> - Highly variable with size, age, and sexual condition.
<u>Juvenile</u> - Very small juveniles (10-15 cm TL), uniform red/brown over entire body surface and fin rays, with an interrupted yellow-white stripe 3-5 scale rows wide midlaterally extending forward across the cheek to the beak, broken only by the eye. The iris forms a bright golden ring about the pupil. Soft rayed portion of all fins except pelvics has transparent web. Spinous portions with some pigmentation. As juveniles grow (15-20 cm TL), they become bright golden brown, and the lateral stripe becomes silvery white and discontinuous. The fin webs become increasingly pigmented with the general body colour. In large juveniles (30-37 cm TL), the golden brown colouration is retained but countershading increases - the dorsum becomes darker brown, and the ventral surface becomes a light yellow brown.

<u>Adult</u> - There are 3 more or less distinct colour forms in the adult. Some small females (38-45 cm TL), retain the colouration of the large juveniles. Countershading is apparent, the fin webs are fully pigmented, and the silvery lateral stripe is always broken into rhomboidal patches. These butterfish tend to associate in large numbers in weedy areas of strong tidal currents, and are called "school butterfish" by fishermen in the Cook Strait area.

A second adult colour form is seen in some females smaller than 45 cm TL, and all females over 45 cm TL:- Dorsum very dark, almost black. Ventral surface dark brown with alternating light yellow and light brown bands in a wave pattern. The lateral stripe is replaced by red-brown rhomboidal patches. The fin rays and web are usually dull red/brown.

Colour of males is similar to that of large females. The dorsum is black, usually becoming dark olive green laterally. In the midlateral region a broad (5-8 scale rows wide), unbroken pale stripe runs from the pectoral fin to the caudal fin. This stripe is never as white or silvery as that of juveniles. The ventral surface is pale, almost cream coloured anteriorly and has longitudinal wavy patterns of light brown and yellow. The fins are usually dark blue/green.

(The above colour notes are taken from live Wellington area fish. Further observation in Northland waters indicates that adult colouration can vary considerably beyond these notes. In general colours of northern fish are lighter and include more greens and blues dorsally. Some large males exhibit an overall bright blue colouration.)

Nuptial Colours

During the spawning season (Ritchie, 1975, in prep.), both males and females possess a blue chin strap on the lower jaw, and dots and whorls of blue on the operculum. This is always much brighter in males than females. The males also bear vivid and highly variable dots, streaks, and patches of blue, lime green, and rust red on the soft rayed portions of the fins. The spinous portion of the dorsal fin of males is sometimes streaked with bright crimson. These nuptial colours are extremely beautiful and always fade rapidly after death. All butterfish tend to darken after death, becoming black dorsally, with dull hues of green and blue ventrally and on the fins. The lateral stripe of the males remains obvious. (See frontispiece.)

(c) Proposed Terminology for Growth Stages and Colour Forms

As indicated above there are several colour forms in the butterfish, but essentially it is dimorphic and dichromatic. It is proposed that the juvenile form and colour phase, which extends as one line of adult females, be termed the "vittatus" phase, characterised as follows:

1. Undulating dorsal fin.
2. Soft rays of all fins simple, or with only a single dichotomy.
3. Soft rayed portions of all fins largely unpigmented.
4. General colouration golden/brown, with a silvery white, variously interrupted, midlateral stripe extending from the beak to the caudal fin base.

It is proposed that the adult form and colour phase be termed the "pullus" phase, characterised as follows:

1. Posterior soft rays of dorsal and anal fin and to some extent pelvic fin are elongated posteriorly.

2. Soft rays of all fins are multiple, with two or more dichotomies.
3. The fin web of all fins is pigmented with usually a blue/green ground colour.
4. Dorsally, the colour is dark olive green/black becoming lighter ventrally in a wave pattern of light brown and yellow bands. There are midlateral, rhomboidal, brown or pale patches (female), or a continuous broad pale stripe from the pectoral fin base to the caudal fin base (male). The narrow, silvery/white lateral stripe of the juvenile is always absent.

(d) Notes on Adaptive Value of "vittatus" and "pullus" Phases

The red/brown colouration, transparent fins and the broken lateral stripe of juveniles in the 10-15 cm TL size group, make these extremely difficult to see because they spend most of the time amongst the darker-coloured red/brown "leafy" Phaeophyceae e.g. *Landsburgia quercifolia*, *Marginariella boryana*, *Sargassum sinclairii*, *Carpophyllum maschalocarpum*, and *Cystophora spp*.

The writer has often observed a small juvenile either resting quietly beside a clump of weed, or else wafting gently with weed by means of its almost invisible (because the fin web is transparent) fins. Even while under careful observation the fish would constantly disappear and reappear and an observer could seldom determine whether the fish had actually moved inside the clump of weed or merely merged with the weed background. Small juveniles seldom stray from weed cover by more than about 2 metres.

Larger juveniles (20-35 cm TL), more typical coloured "*vittatus*" phase fish, still retain a high degree of cryptic behaviour and colouration, but are more active and tend to rest in areas where golden brown laminarians (*Macrocystis pyrifera*, *Ecklonia radiata*, and *Lessonia variegata*), and also *Cystophora spp*. predominate. These "*vittatus*" phase fish can often be observed in aggregations close to the weed beds in the lee of large outjutting rocks. They will cross extensive areas of gravel or sand between weedy reefs, but will still rely on their cryptic colouration, and will "go to ground" rather than elude a predator (e.g. a spear fisherman), by swimming.

"Pullus" phase fish have good countershading with a variously hued but light coloured ventral surface and a dark almost black dorsum. These fish tend to be found in open water more commonly than "vittatus" phase fish and will often swim low over weed beds to evade a predator rather than shelter amongst weed. This is especially true of large male fish.

During the early winter period "pullus" phase fish are often inactive except during maximum current on a rising tide. Under these conditions there is often swimming and feeding activity evident amongst a smallish (20-50 individuals) aggregation. Inactive fish usually shelter beneath the algal forest canopy but can sometimes be seen - especially large males - in rock crevices or caverns.

When grazing, all butterfish tend to swim slowly by means of pectoral, dorsal, and anal fin "sculling", but when alarmed they propel themselves with the tail and are capable of great bursts of speed.

MERISTIC VARIATION

(a) Introduction

Meristic variation - variation in numbers of segmentally or repetitively arranged body parts - is a widely known and well documented phenomenon in teleost fish. In some teleost families meristic variation is uncommon, e.g. Scaridae (Schultz, 1958), and Mugilidae (Thomson, 1957; Sarojini, 1957). In others it occurs but is of little use for differentiating between conspecific populations, e.g. in some scombriform species (Blackburn & Gartner, 1954), and in Miichthyes imbricatus (Hanabuchi, 1966). However, in many species, differences in meristic characters are a reliable means of distinguishing between separate populations of the same species, e.g. Sardinops neopilchardus (Steindachner), Blackburn (1951); Arripis trutta (Bloch and Schneider), Malcolm (1959); and Limanda ferruginea (Storer), Scott (1954).

There may be clinal variation throughout the range of a species or in several conspecific populations the ranges of which may or may not overlap. In instances where different spawning populations of a single species also exhibit meristic differences it is often difficult to determine the extent of the genetic basis of the variation. Mayr (1963, p. 146), suggests that the meristic differences per se may have no genetic basis but he continues, that concomitant factors such as ".. choice of the spawning grounds and various physiological properties of these local races may well be genetically determined."

In the butterfish there is no evidence to suggest that the meristically differentiated local populations of fish differ markedly in gross physiological properties such as fat deposition, or in details of the spawning cycle (Ritchie, 1975, in prep.).

(b) Meristic Variation in the Butterfish

Attempts were made to secure butterfish from as many different localities around New Zealand as possible. Table 4 below, gives the locality, latitude, and numbers of males, females and juveniles examined for this study.

TABLE 4 - Locality, latitude, and numbers of males, females, and juveniles examined.

Locality	Latitude S	Males	Females	Juveniles	Total
Leigh	36° 20'	3	15	-	18
Tauranga	37° 40'	1	-	-	1
Marlb. Sounds	41° 15'	3	7	6	16
Wellington	41° 22'	5	12	12	29
Kaikoura	42° 25'	8	22	2	32
Dusky Sound	46° 40'	-	6	1	7
Stewart Island	46° 50'	1	30	-	31
TOTAL		21	92	21	134

Meristic variation in the butterfish was studied using the following characters (detailed above): dorsal fin spines; total (all fins), rays and spines: girth scale rows; cheek scale rows; gill rakers; caudal vertebrae; total vertebrae; and the TL/HL ratio. These data, including range, frequency, mean ($\bar{X}$), and standard deviation of the mean (S) are given in tables 5 to 14 below.

TABLE 5 - Number of dorsal fin spines in butterfish from seven localities; (($\bar{X}$) - mean, S - standard deviation).

Dorsal fin spines	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
XIIX	-	-	-	-	-	-	-
XIX	3	-	1	-	-	-	-
XX	14	1	7	2	2	1	7
XXI	1	-	18	12	16	6	24
XXII	-	-	2	1	12	-	-
XXIII	-	-	-	1	1	-	-
$\bar{X}$	19.89	-	20.75	21.06	21.28	20.86	20.77
S	0.50	-	0.80	0.68	0.90	0.44	0.54

TABLE 6 - Total number of fin rays and spines in butterfish from seven localities; (($\bar{X}$ - mean, S - standard deviation).

Total fin rays and spines	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
78	3	-	-	-	-	-	-
79	4	-	1	-	1	-	3
80	5	-	8	2	4	2	6
81	4	1	13	8	8	2	9
82	-	-	5	5	14	3	11
83	1	-	1	-	4	-	2
84	-	-	-	1	1	-	-
$\bar{X}$	79.56	-	81.21	81.38	81.38	81.29	81.06
S	1.46	-	0.89	0.96	1.09	0.82	1.12

TABLE 7 - Number of dorsal girth scale rows in butterfish from seven localities; (($\bar{X}$)- mean S - standard deviation).

Girth scale rows. Dorsal fin to lateral line.	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
11	-	-	-	-	-	-	-
12	-	-	8	2	4	2	14
13	-	1	16	6	14	4	14
14	-	-	4	1	4	-	-
15	-	-	-	-	-	-	-
16	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-
18	-	-	-	-	-	1	-
$\bar{X}$	-	-	12.86	12.89	13.0	13.43	12.45
S	-	-	0.77	0.62	0.62	1.99	0.57

TABLE 8 - Number of ventral girth scale rows in butterfish from seven localities; (($\bar{X}$) - mean, S - standard deviation).

Girth scale rows. Anal fin to lateral line.	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
18	-	-	-	-	2	-	6
19	-	1	1	-	1	1	9
20	-	-	5	2	8	3	14
21	-	-	7	5	8	2	2
22	-	-	7	6	3	-	-
23	-	-	4	-	-	-	-
24	-	-	4	1	-	-	-
$\bar{X}$	-	-	21.71	21.50	20.41	20.17	19.39
S	-	-	1.47	1.26	1.10	0.75	1.25

TABLE 9 - Number of lateral line scale rows in butterfish from seven localities; (($\bar{X}$) - mean, (S) - standard deviation).

Lateral line scale rows	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
68	1	-	-	-	-	-	-
69	-	-	1	-	-	-	-
70	-	-	1	-	1	-	-
71	1	-	-	-	-	1	-
72	1	1	-	-	-	-	-
73	1	-	1	-	-	-	1
74	3	-	3	1	-	1	2
75	3	-	5	1	2	1	3
76	2	-	3	3	1	-	2
77	3	-	2	1	1	1	5
78	2	-	4	2	4	-	1
79	-	-	1	3	4	2	3
80	1	-	-	2	3	-	8
81	-	-	3	-	3	-	2
82	-	-	1	1	3	1	2
83	-	-	2	2	4	-	-
84	-	-	-	-	1	-	2
85	-	-	1	-	-	-	-
86	-	-	-	-	2	-	-
87	-	-	-	-	3	-	-
$\bar{X}$	75.00	-	77.07	78.44	80.59	76.71	78.45
S	2.85	-	3.81	2.73	3.89	3.81	2.98

TABLE 10 - Number of cheek scale rows in butterfish from seven localities; (($\bar{X}$) - mean, (S) - standard deviation).

Cheek scale rows	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
0	-	-	2	-	1	-	3
1	-	-	-	1	-	-	2
2	-	-	2	-	2	-	4
3	-	-	17	7	12	3	14
4	-	-	7	1	5	3	8
5	-	-	-	-	-	1	-
$\bar{X}$	-	-	2.96	2.89	3.00	3.71	2.71
S	-	-	1.02	0.80	0.94	0.87	1.22

TABLE 11 - Number of gill rakers in butterfish from seven localities; (($\bar{X}$) - mean, (S) - standard deviation).

Gill rakers	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
14	3	-	4	1	1	1	-
15	14	1	22	8	5	3	15
16	1	-	1	-	12	2	13
17	-	-	-	-	1	1	3
18	-	-	-	-	-	-	-
19	-	-	1	-	-	-	-
$\bar{X}$	14.89	-	15.04	14.89	15.68	15.43	15.61
S	0.50	-	0.88	0.37	0.81	0.89	1.03

TABLE 12 - Number of caudal vertebrae in butterfish from seven localities; (($\bar{X}$) - mean, (S) - standard deviation).

Caudal vertebrae	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
18	-	-	2	-	-	-	-
19	7	1	10	-	-	-	1
20	10	-	15	6	19	4	13
21	1	-	2	9	12	3	15
22	-	-	-	1	1	-	2
$\bar{X}$	19.67	-	19.59	20.69	20.44	20.43	20.58
S	0.77	-	0.94	0.76	0.99	0.54	0.90

TABLE 13 - Total number of vertebrae in butterfish from seven localities; (($\bar{X}$) - mean, (S) - standard deviation).

Total Number of vertebrae	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
44	1	-	-	-	-	-	-
45	6	1	1	-	-	-	-
46	11	-	8	-	-	1	4
47	-	-	19	6	1	5	15
48	-	-	1	6	12	1	11
49	-	-	-	4	17	-	1
50	-	-	-	-	2	-	-
$\bar{X}$	45.56	-	46.69	47.88	48.63	47.0	47.29
S	0.62	-	0.89	0.83	0.85	0.56	0.82

TABLE 14 - TL/HL ratio in butterfish from seven localities; (($\bar{X}$) - mean, (S) standard deviation).

Total Length / Head Length	Leigh	Tauranga	Wellington	Marlb. Sounds	Kaikoura	Dusky Sound	Stewart Island
4.20 - 4.29	-	-	-	-	-	1	-
4.30 - 4.39	-	-	-	-	-	-	-
4.40 - 4.49	-	-	-	-	-	-	-
4.50 - 4.59	-	1	1	-	-	-	-
4.60 - 4.69	1	-	3	1	-	-	-
4.70 - 4.79	-	-	3	-	1	-	2
4.80 - 4.89	-	-	2	-	3	1	6
4.90 - 4.99	3	-	7	4	6	1	3
5.00 - 5.09	1	-	2	6	5	1	7
5.10 - 5.19	6	-	4	1	4	2	5
5.20 - 5.29	3	-	2	2	3	-	3
5.30 - 5.39	2	-	2	1	1	-	2
5.40 - 5.49	1	-	-	1	3	1	2
5.50 - 5.59	-	-	2	-	1	-	1
5.60 - 5.69	-	-	1	-	-	-	-
5.70 - 5.79	-	-	-	-	1	-	-
$\bar{X}$	5.181	-	5.030	5.073	5.121	4.965	5.079
S	0.27	-	0.29	0.19	0.23	0.37	0.24

The general trends apparent from the above data are that dorsal fin spines, lateral line scale rows, gill rakers, caudal vertebrae, and total vertebrae either increase in number, more or less, with increasing latitude, or else have least values at Leigh, midrange values at Wellington, Marlborough Sounds, Dusky Sound, and Stewart Island, and maximum values at Kaikoura.

Total fin rays and spines, girth scale rows, cheek scale rows, and the TL/HL ratio appear to vary in a more random fashion.

(c) Statistical Comparisons of the Data

All counts made were double checked but some meristic characters are open to interpretive errors, e.g. the occasional non-emergence of some scales through the epidermis, or of some spines through the surrounding muscle. Thus, for comparative purposes, only the most accurately determined meristic characters were used, i.e. total vertebral counts and lateral line scale row numbers.

The data are to fragmentary and the sex ratio too biased towards females to allow adequate testing for sexual differences in meristic characters. However, "Student's t test" was employed to indicate whether mean total vertebral numbers differed significantly for males (8), and females (22), in the Kaikoura sample (the only sample with enough male fish to make the significance test meaningful). A "t" value of -1.205 indicated that there was no significant difference between the means ($P > 0.1$).

Similarly, "t" tests were applied to mean total vertebral numbers and mean lateral line scale row numbers, from 17 Wellington area fish and 21 Kaikoura fish. A value for "t" of 8.574 for the lateral line scale row means comparison, were both highly significant ($P < 0.01$). Thus, although there is no apparent significant difference in vertebral number between male and female fish from Kaikoura, there are highly significant differences in vertebral numbers and lateral line scale row numbers between the Wellington and Kaikoura samples.

To test whether significant differences in mean values of the total vertebral number occurred amongst the samples from Leigh, Wellington, Marlborough Sounds, Kaikoura, Dusky Sound, and Stewart Island, an "F" test - analysis of variance - was carried out using the six mean values. The data were tabulated as follows:

TABLE 15 - Vertebral numbers data for butterfish from six localities; (N - sample number, X - vertebral number of one fish).

Locality	N	EX	EX^2	$\bar{X}$
Leigh	18	820	37 362	45.556
Wellington	29	1 354	63 228	46.690
Marlb. Sounds	16	766	36 682	47 875
Kaikoura	32	1 556	75 674	48.625
Dusky Sound	7	329	15 465	47.000
Stewart Island	31	1 466	69 344	47.290

The formula

$$\mathop{E}_{1}^{k_c}\left[\frac{\left(\mathop{E}_{1}^{N_c} X\right)^2}{N_c}\right] - \frac{(EX)^2}{N}$$

was employed to evaluate the variation between the column means; and the formula

$$EX^2 - \mathop{E}_{1}^{k_c}\left[\frac{\left(\mathop{E}_{1}^{N_c} X\right)^2}{N_c}\right]$$

was employed to evaluate the variation within the columns. The estimated variance between the column means, and within the columns produced an "F" value of 55.64. With $n_1 = 5$, and $n_2 = 127$, an "F" value of 3.17 ($P < 0.01$), would be highly significant thus the estimated variance between the column means is very highly significantly larger than the estimated variance within the columns. In summary, the six samples have mean total vertebral numbers which differ markedly from those which could be expected in a randomly distributed (with respect to total vertebral numbers), population. This can reasonably be interpreted as evidence for discrete meristically different populations at the six localities sampled.

(d) The Causes of Meristic Variation

The ability of the phenotype to be modified by the environment has been interpreted in many different ways. Mayr (1963, p. 146) points out that the genotype is not a mould into which characters are cast, but is a "reaction norm" which interacts with the environment to produce the phenotype. Furthermore, the appearance of various phenotypes according to environmental conditions indicates "Developmental flexibility, as usually understood .." (Mayr, 1964, p. 147). However, Thoday (1953) has argued that environmental control of the phenotype actually indicates a lack of epigenotypic plasticity in a higher sense, i.e. the epigenotype is incapable of producing a phenotype which can cope with all environmental conditions. Phenotypic "modifiability" also has a retarding effect on evolution because the response to environment without mutation greatly reduces selection pressure (Mayr, 1963).

Meristic variation in teleosts is usually correlated with several chemical and physical factors, the most important of which is the temperature at which the larvae develop. A negative correlation between vertebral numbers and water temperature is shown or implied by Hubbs (1922 and 1925), Scott (1954), Lawler (1958), Hill (1959), and Pitt (1963); whereas Templeman (1948), Tibbo (1956), and Lindsay (1962), have found this correlation to be positive.

Correlation between number of vertebrae and both summer and winter sea surface temperatures were calculated because the butterfish spawns over an 8 month period - July to February (Ritchie, 1975, in prep.). In the butterfish, good negative correlation exists in both instances (table 16), with $r = 0.906$, $P<0.01$, for winter sea surface temperatures; and $r = 0.712$, $P<0.05$, for summer sea surface temperatures.

TABLE 16 - Locality, latitude south, sea-surface temperatures and salinites (after Garner, 1969), and the mean number of total vertebrae of butterfish from seven localities.

Locality	Latitude S	Winter		Summer		Mean Total Number of Vertebrae
		Temp. °C	Sal. ‰	Temp. °C	Sal. ‰	
Leigh	36° 20'	16.0	35.4	20.0	35.3	45.56
Tauranga	37° 40'	15.0	33.8	20.0	34.7	45.0
Marlborough Sounds	41° 15'	11.5	-	16.0	-	47.88
Wellington	41° 22'	11.5	34.8	16.0	34.8	46.69
Kaikoura	42° 25'	9.5	34.0	16.0	34.5	48.63
Dusky Sound	46° 40'	12.5	34.8	14.5	30.0	47.00
Stewart Island	46° 50'	10.5	34.8	13.0	34.7	47.29

Inspection of the data in table 16 indicates that mean total vertebral numbers correlate more closely with mean water temperature than with latitude.

The high vertebral number for Marlborough Sounds fish is difficult to explain. Possible factors responsible include the relatively enclosed nature of the waters and hence the possibility of greater temperature and salinity fluctuations caused by solar heating, wind cooling, and run-off dilution. Movement between cooler water stocks (Kaikoura area fish), and warmer water stocks (Marlborough Sounds area fish), is also possible.

The unexpectedly low mean vertebral values for Stewart Island and Dusky Sound fish are probably a result of a sub-tropical influence from the east (Garner, 1959, p. 322-324), warming the west coast region of South Island, to a higher level than the east coast, particularly during the winter.

The relationship between temperature and vertebral numbers given in Fig. 3 A & B can only serve as a first approximation. Likely sources of error in the data include:

(a) The use of mean vertebral numbers for grossly unequal samples, i.e. the one fish from Tauranga is near one limit of the regression line (Fig. 3), and thus adds disproportionate weight to the data, giving a bias toward a higher "r" value.

(b) The inadequacy of the temperature data. These data are from Garner (1969) and represent sea-surface temperature in the mid-continental shelf region, and thus do not allow for the probably greater temperature fluctuations in close inshore areas where the butter-fish tend to spawn. Solar heating and wind cooling probably contribute to produce greater temperature fluctuations inshore than in the midshelf region.

(c) The temperatures at which the fish sampled underwent early development is not known, and there were obviously different year classes of fish in each sample. Thus both the temperature data and the sample means for vertebral numbers can only be accepted as average or generalised.

(d) The sample sizes are small and are thus liable to small sampling errors.

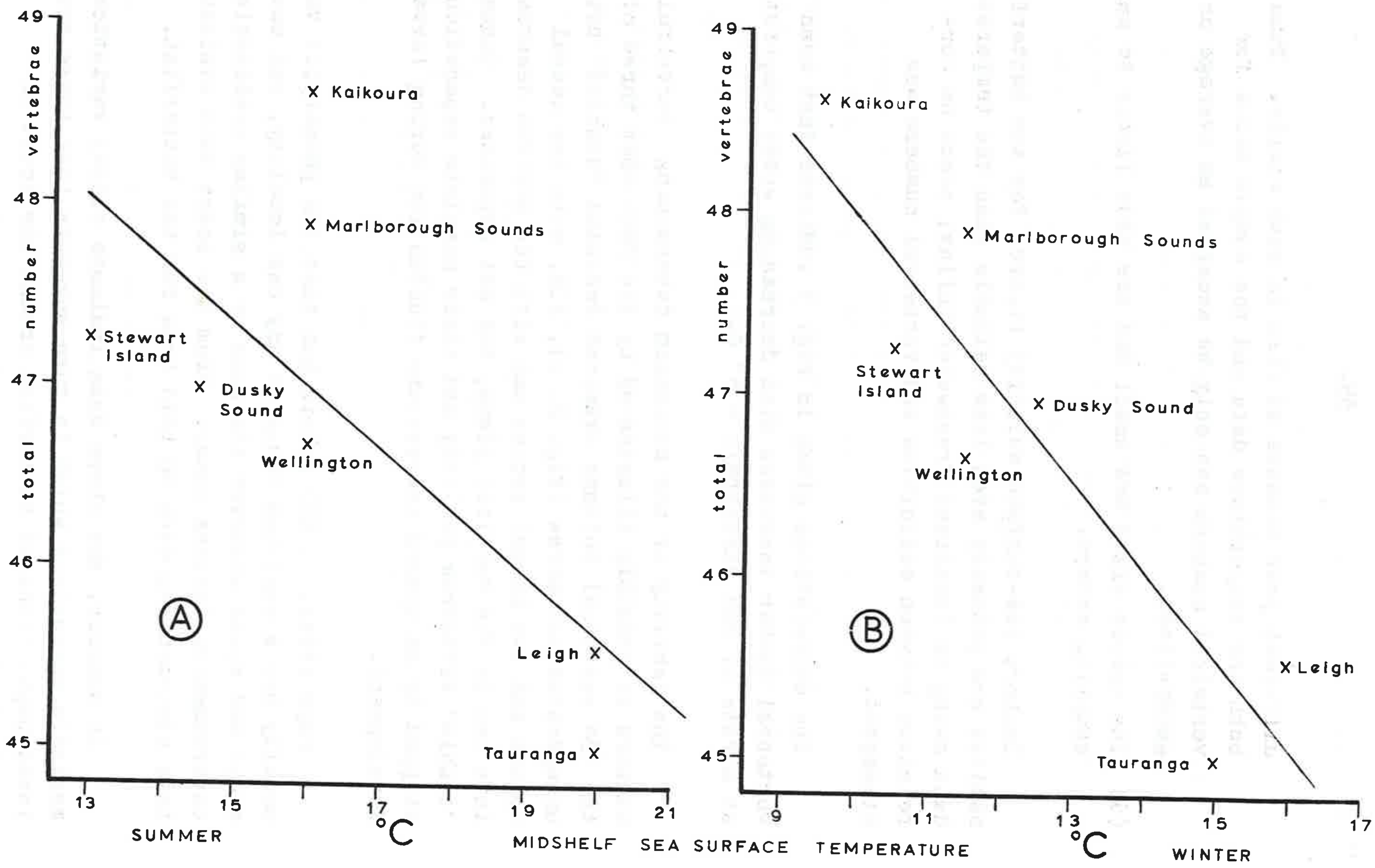
Inshore sea-surface salinity figures for the butterfish habitat are probably even less reliable than the temperature data owing to localised freshwater influx; hence no correlation between salinities and vertebral numbers was attempted.

The correlations given in Fig. 3 indicate that mean vertebral number increases with decreasing water temperature at a rate of one vertebra/2 - 3° C.

The lability of the mechanism determining vertebral numbers is possibly illustrated by the fact that three of the 134 vertebral columns examined included "doubled" but unseparated vertebrae (Fig. 2, C), i.e. with two neural spines and two haemal arches and with the centrum demarcated into two in the vertical plane, but not separated. These "double" vertebrae possibly had their complete separation stopped by an upward temperature fluctuation during larval development.

Mayr (1942, p. 63) points out that the phenotypic variant usually has a smallish range at any one locality, but occurs again and again whenever the same or a similar combination of environmental factors occur. From the scant data available this statement appears to hold true for the butterfish.

In summary, the above data indicate clinal variation of meristic characters which in turn suggests that there are local populations of butterfish around the coast of New Zealand.



49
48
47
46
45
total number vertebrae
X Kaikoura
X Marlborough Sounds
X Stewart Island
X Dusky Sound
X Wellington
Leigh X
Tauranga X
A
13
15
17
19
21
SUMMER
°C
49
48
47
46
45
total number vertebrae
X Kaikoura
X Marlborough Sounds
X Stewart Island
X Dusky Sound
X Wellington
X Leigh
Tauranga X
B
9
11
13
15
17
°C
WINTER
MIDSHELF SEA SURFACE TEMPERATURE

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