

Feeding ecology of the banded wrasse *Notolabrus fucicola* (Labridae) in southern New Zealand: prey items, seasonal differences, and ontogenetic variation

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Abstract *Notolabrus fucicola* Richardson, a large common labrid inhabiting shallow waters around New Zealand and southern Australia, were collected monthly (December 1996–February 1998) around Kaikoura on the east coast of the South Island, New Zealand. Their diet, temporal variation in prey and gut fullness, and ontogenetic differences were examined. *N. fucicola* is a generalist predator, the major prey items being bivalves, amphipods, and crabs, which varied temporally in their diet. There were size specific changes in their diet. Small fish (100–180 mm) ate mostly amphipods and isopods, whereas larger fish (>180 mm) ate mainly bivalves, crabs, and gastropods. There was a temporal variation in gut fullness but no significant difference between sexes.

Keywords diet; temperate; reef fish

INTRODUCTION

Labrids are conspicuous members of fish assemblages on tropical and temperate reefs and constitute a characteristic element of shallow-water faunas (Helfman et al. 1997). Although the biology

and ecology of tropical labrids have been studied extensively, little work has been done on the 21 labrid species found in New Zealand with the exception of the spotty, *Notolabrus celidotus* Block & Schneider (Jones 1980, 1981a,b, 1984a,b,c). The diet and feeding behaviour of several New Zealand temperate reef fish have been investigated, mainly around north-eastern New Zealand (see reviews in Choat 1982; Jones 1988). However, little work has been done on reef fishes along the east coast of the South Island, with the exception of Hickford & Schiel (1995).

Notolabrus fucicola is a large benthic carnivore (up to 60 cm and 5 kg) with the strong canine teeth and crushing pharyngeal mill characteristic of this genus (Helfman et al. 1997). This species is abundant on temperate reefs throughout New Zealand and southern Australia (Ayling & Cox 1987; Kuitert 1993) and thus has the potential to influence the abundance of benthic invertebrates on shallow reef systems. For this reason it is important to systematically analyse diet, including the influence of fish size and temporal variation on prey items consumed.

The aims of this study were to: (1) identify the main prey items of *N. fucicola*; (2) identify temporal differences in their diet; (3) determine ontogenetic changes in diet; and (4) compare gut fullness between sexes throughout the year. The composition of prey items will help to indicate the ecological role that *N. fucicola* may play in the nearshore environment.

METHODS

Study area

The Kaikoura Peninsula (42°25'11'S, 173°39'00'E) projects c. 4 km out to the sea from the eastern coast of the South Island of New Zealand (Fig. 1). Reefs in southern New Zealand differ biologically (algal species) and physically from those in the North Island (Schiel 1990). The stipitate kelp *Ecklonia radiata* dominates in the north, whereas in the south,

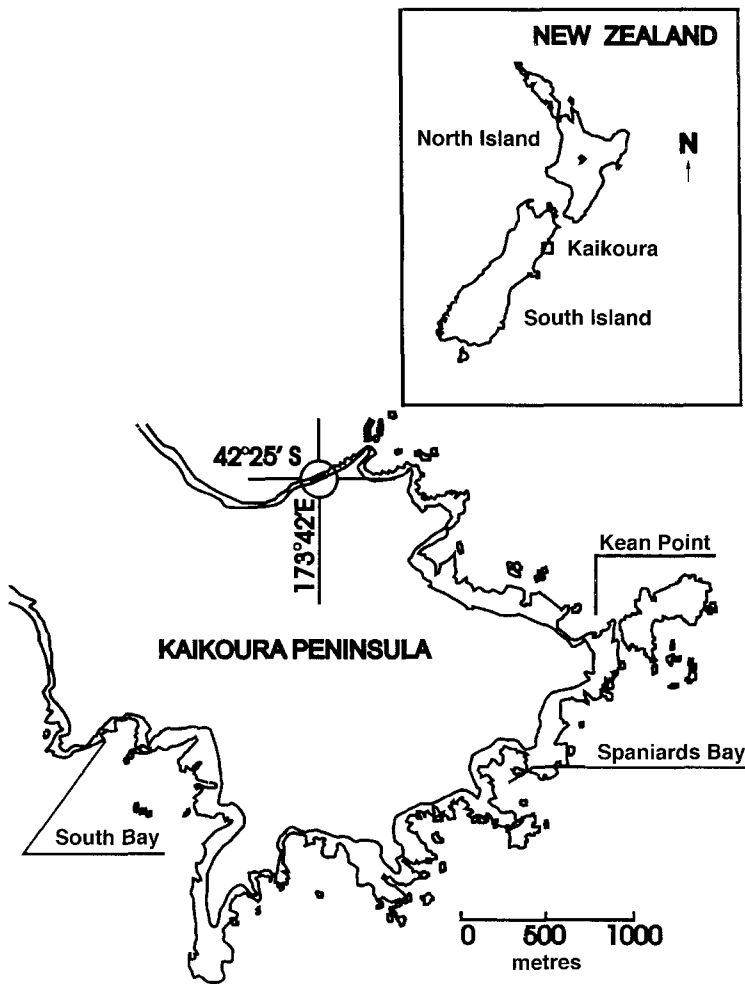


Fig. 1 Map of the Kaikoura Peninsula with an inset depicting its location in New Zealand.

the fucallean alga *Marginariella boryana* is the dominant algal species in the shallow subtidal zone (Schiel & Foster 1986). Also, reefs around Kaikoura generally have steeper topography than the gradually sloping reefs of many northern New Zealand areas.

General methods

Thirty fish per month were collected over 15 months (December 1996–February 1998) by spearing and angling. Spearing was the preferred technique because it enabled a representative size selection of fish to be taken from a population. Fishing rods were only used when spearing was not possible as a result of poor underwater visibility and different sized hooks were used in an attempt to get a less biased size range of fish. Although fishing may be selective towards larger, more dominant males we found no

significant difference in the temporal distribution of sizes caught. The sex, standard length (SL, mm), and weight (g) of each fish were recorded.

Four hundred and fifty guts were examined from fish ranging in length between 81 and 400 mm (SL). The contents of the entire digestive tract were removed, as labrids do not possess a morphologically differentiated stomach (Gillanders 1995). The contents were weighed and preserved in 20% alcohol. Because no one method of stomach analysis gives a complete picture of dietary importance (Hyslop 1980), several measurements were taken: (1) the frequency of occurrence of each prey item in the diet (recording the numbers of stomachs containing one or more individuals of each food category); (2) the percentage volume of each prey item in each gut (a subjective evaluation); and (3) the wet weight of the gut contents. The frequency

Table 1 Summary of dietary items, frequency of occurrence (*F*) (% of fish in which a prey item occurred) and mean % abundance of prey (*P*) (% of the total amount of prey in each fish) of 450 gut contents of *Notolabrus fucicola* sampled from December 1996 to February 1998 around Kaikoura, New Zealand (unident. = unidentified).

Prey category		<i>F</i> (%)	<i>P</i> (%)
Mollusca			
Bivalvia	<i>Aulacomya atra maoriana</i>	34.7	49
	<i>Modiolus areolatus</i>	4.4	43
	<i>Xenostrobus pulex</i>	2.6	35
Gastropoda	<i>Soletellina nitida</i>	0.2	1
	<i>Zeacumantus subcarinatus</i>	1.8	35
	<i>Trochus viridis</i>	0.7	20
	<i>Antisolarium egenum</i>	0.7	6
	<i>Maurea pellucida</i>	2.2	35
	<i>Cominella glandiformis</i>	2.4	3
	<i>Buccinum lineum</i>	1.8	3
	<i>Notoacmea pileopsis</i>	0.2	50
	unident. snail shells	13.5	30
	<i>Cellana radians</i>	1.3	20
	<i>Cellana ornata</i>	3.5	6
	unident. limpet	1.1	8
Polyplacophora	<i>Sypharochiton pelliserpentis</i>	2.2	30
	unident. chiton	0.2	16
Cephalopoda	<i>Notodarus sloanii</i>	0.2	58
Annelida			
Polychaeta	Sedentary	3.8	30
	Errant	7.7	23
Arthropoda			
Crustacea			
Cirripedia	<i>Chthamalus stellatus</i>	0.2	15
Amphipoda	Gammaridae	22.5	20
	Lysianassidae	2.2	30
	unident. amphipods	4.2	15
Isopoda	Valvifera	1.8	10
	Asellota	0.4	5
	Anthuridae	0.9	15
	Flabellifera	2.9	24
	Oniscoidea	4.9	19
	unident. isopods	0.4	19
Decapoda	<i>Plagusia chabrus</i>	5.7	35
	<i>Notomithrax peronii</i>	0.4	15
	<i>Notomithrax ursus</i>	0.2	72
	<i>Notomithrax minor</i>	0.2	40
	<i>Notomithrax</i> sp.	0.2	19
	<i>Trichoplatus huttoni</i>	0.9	76
	<i>Eurynolambrus australis</i>	0.2	15
	<i>Leptomithrax</i> sp.	0.4	15
	<i>Pilumnus novaezelandiae</i>	0.2	80
	<i>Hemigrapsus edwardsii</i>	0.7	15
	<i>Ovalipes catharus</i>	0.2	20
	<i>Halicarcinus varius</i>	0.2	15
	Hermit crab	0.2	5
	Crab larvae	0.4	2
	unident. crab fragments	18.8	25
	<i>Jasus edwardsii</i>	0.4	24
	<i>Euphausid</i> sp.	0.9	13
Echinoidea	<i>Evechinus chloroticus</i>	2.6	13

Table 1 (continued.)

Prey category		F(%)	P(%)
Thaliacea	Salp	11.5	31
Ascidiacea	Ascidian	1.8	15
Turbellaria	<i>Chromoplana</i> sp.	0.2	10
Vertebrata			
Teleostei	<i>Hippocampus abdominalis</i>	0.2	30
	unident. fish	2.6	40
Seaweeds	<i>Carpophyllum</i> sp.	10.4	6
	<i>Carpococcus linearis</i>	1.9	2
	<i>Plocamiaceae</i> sp.	2.6	9
	<i>Carpococcus linearis</i>	4.2	5
	<i>Corallina officinalis</i>	16.6	3
Stones		12.6	3
Empty guts		1.8	0

of occurrence gives an indication of the relative number of food categories present in the population (Hyslop 1980). Unfortunately, this method gives little indication of the relative amount of bulk of each food category present in stomachs and imparts a bias towards small, numerous prey types (Berg 1979). Recording the percentage volume of each prey item in each gut resolves this problem.

The entire gut contents were examined in a Petri dish under a dissecting microscope. Prey items were identified down to species level whenever possible but the level of identification depended on the completeness of the food organism and its condition. Soft-bodied prey, especially polychaetes, were particularly difficult to identify to species level because they were rarely in good condition. Prey items in an advanced state of digestion were not included in the analysis because it was not possible to determine prey type. To determine if gut fullness differed over the study and between the sexes, the fullness index (FI) was calculated from:

$$FI = \frac{W1}{W2} \times 100$$

where W1 is the weight of ingested food and W2 is the total fish weight (Berg 1979).

Analysis of variance (ANOVA) was used to test whether the major prey categories were ingested in significantly different proportions by fish over all months. Data were tested for homogeneity of variances by Cochran's test before analysis and data were transformed using $\log(x + 1)$ when necessary. In some cases variances could not be stabilised so a critical significance level of $P = 0.01$ was used to

lessen the chances of a Type 1 error. An ANOVA also tested whether fish size varied over time.

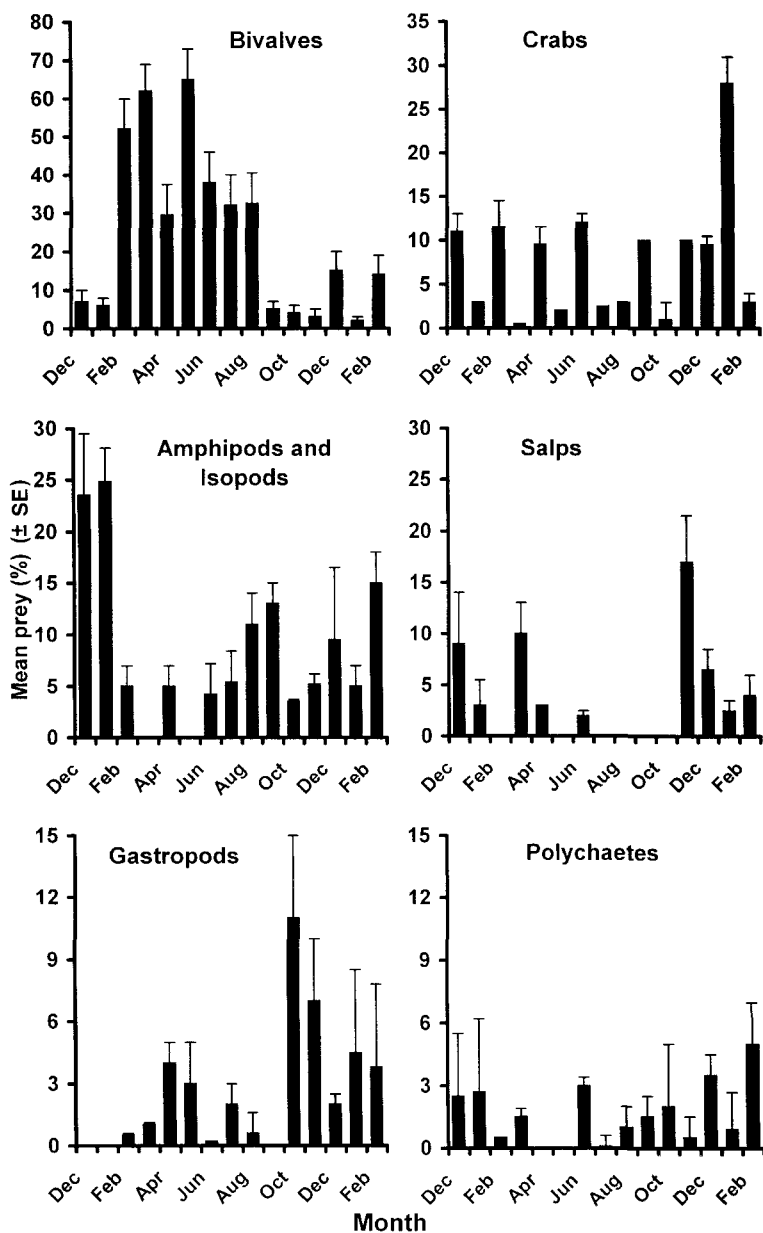
RESULTS

Prey items

Notolabrus fucicola was found to have a varied diet with 47 species of prey items identified from 12 families, but many unidentified species were also present (Table 1). The ribbed mussel, *Aulacomya atra maoriana*, was the main bivalve occurring in 34.7% of all fish with the hairy mussel *Modiolus aerolatus* (4.4%), and the little black mussel, *Xenostrobus pulex* (2.6%), present in smaller amounts. These bivalves occurred in high amounts (35–49%) in the guts. The red rock crab, *Plagusia chabrus*, was the dominant decapod occurring in 5.7% of fish. The high proportion of unidentified crab remains (mainly legs) (18.8%) in guts is likely to be due to the labrid behaviour of ripping legs off the carapace (Graham 1956).

Gastropods occurred in 23.3% of fish, usually in small to moderate amounts (1–50%) (Table 1). The majority of the gastropod shells were fragmented occurring in 13.5% of fish and this made species identification difficult. Polychaetes were found in 11.5% of the fish sampled, but most were in an advanced state of digestion and therefore could not be identified below ordinal level (Table 1). The small quantities of stones and seaweed found were likely to have been incidentally ingested while fish fed on other prey. Empty guts were relatively rare and were found in only 1.8% of fish.

Fig. 2 Mean prey percentage (\pm SE) of six major prey items in the guts of 450 *Notolabrus fucicola* sampled around Kaikoura, New Zealand, from December 1996 to February 1998 (note the different y-axes).



Seasonal patterns

Almost all prey categories varied significantly in their percentage volume in the gut contents over 15 months (Fig. 2). Only polychaetes ($F = 1.45$, $P = 0.321$) and gastropods ($F = 1.75$, $P = 0.298$) showed no significant variation over time. Chitons ($F = 1.96$, $P = 0.02$) and isopods ($F = 1.98$, $P = 0.018$) were not significant at $P < 0.01$. Bivalves were the dominant prey from February to August 1997 (Fig. 2). Peak densities of

amphipods in the guts occurred in summer (December 1996, January 1997, and February 1998) and declined after the January 1997 peak. Salps were only present in any numbers over the summer months, mainly November–December and March 1997 (Fig. 2). ANOVA found no significant difference in fish size over time thus temporal patterns are not confounded with fish size. See Fig. 3 for a graphical representation of the standard length of *N. fucicola* over the study.

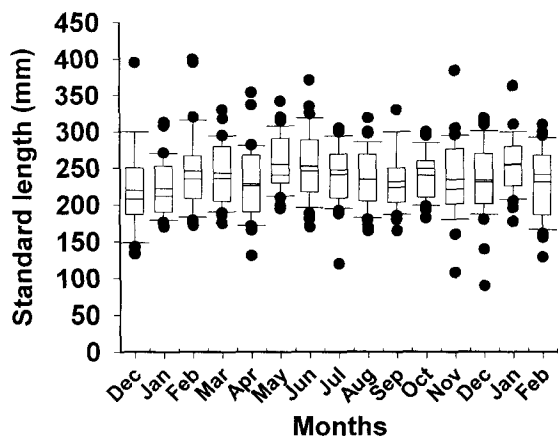


Fig. 3 Box and whisker plot showing the size distribution of *Notolabrus fucicola* from December 1996 to February 1998.

Ontogenetic changes

Both the frequency of occurrence (Fig. 4) and mean percentage of prey (Fig. 5) demonstrated that the principal prey of *N. fucicola* <180 mm were amphipods, isopods, and polychaetes. For fish sized 180–270 mm there was a transition in the diet away from these prey towards hard-bodied animals such as bivalves, crabs, and gastropods. Fish >270 mm preyed mostly on hard-bodied animals such as bivalves, crabs, and gastropods.

Gut fullness

The gut fullness of *N. fucicola* changed temporally, gradually declining from February to July. From July to September the FI increased then began to gradually decline until the conclusion of the study (Fig. 6). The overall patterns were similar for both sexes except in January 1997 when females had a substantially larger FI.

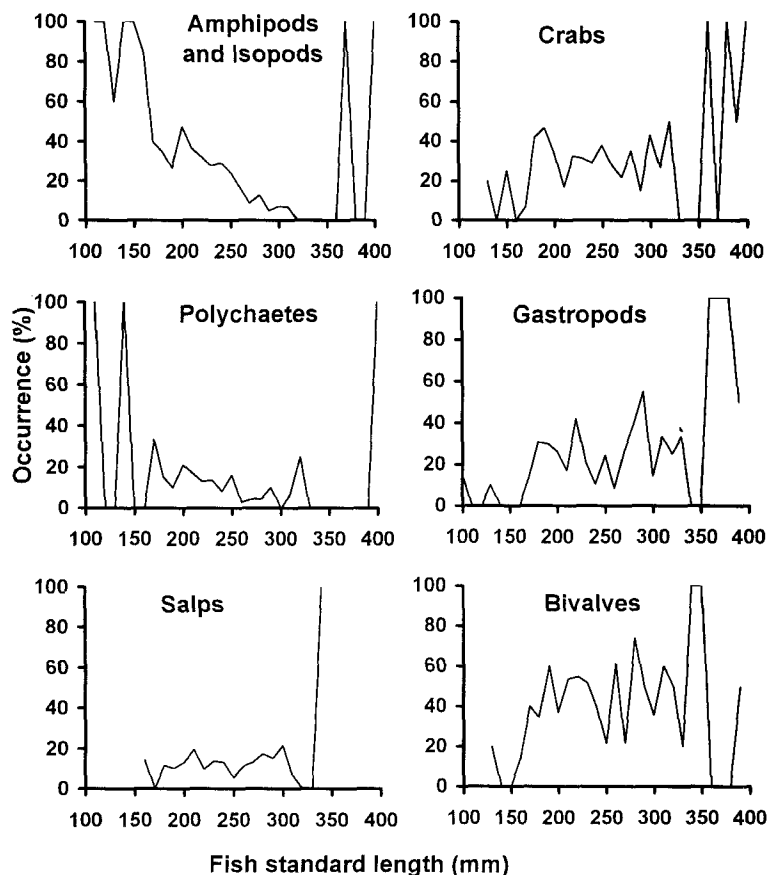
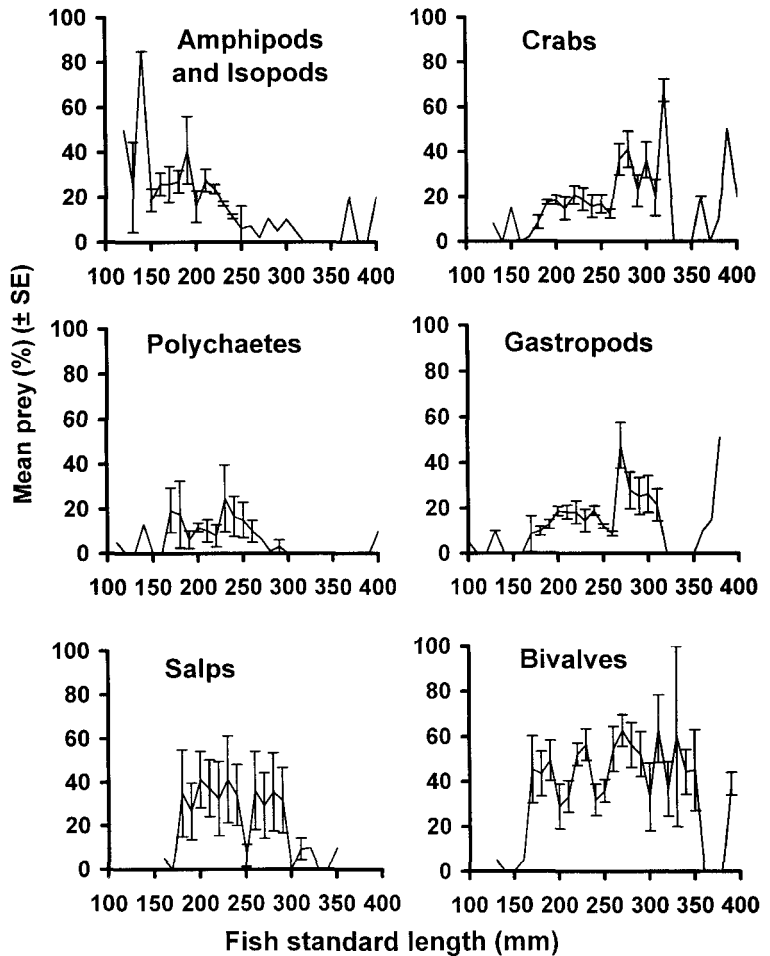


Fig. 4 Percentage of occurrence of six major prey categories, pooled across all seasons in the guts of 450 *Notolabrus fucicola*, divided into 10 mm size classes.

Fig. 5 Mean prey percentage (\pm SE) of six major prey categories, pooled across all seasons in the guts of 450 *Notolabrus fucicola*, divided into 10 mm size classes.



DISCUSSION

Notolabrus fucicola is primarily a carnivore feeding on a varied diet that consists mainly of bivalves and crustaceans. Our study varies from previous reports on the diet of *N. fucicola* conducted in north-eastern New Zealand where crabs, especially hermit crabs, were the main prey items with bivalves being only minor items (2%) (Thompson 1981; Russell 1983). Although crabs ranked second in the overall diet of *N. fucicola* in our study, bivalves were the predominant prey items identified. Differences between studies may reflect the size classes of fish collected. For example, Russell (1983) sampled only 15 fish, all >232 mm, which may account for the absence of amphipods in his study. In this study *N. fucicola* were sampled from rather different habitats and reef settings and we would expect opportunistic feeding from fish such as labrids to reflect the

abundance patterns of invertebrates that vary substantially across environmental gradients.

Temporal changes were found in the diet of *N. fucicola*, with almost all prey items showing significant variation over time. This is similar to *N. celidotus* with their minimum feeding rates occurring during July–October and the maximum rates during December–April (Jones 1984a). Many factors can influence seasonal variation in diet and feeding rate, the most important of which is variation in prey activity and abundance patterns (Jones 1988). For example, summer peaks occurred in amphipods and salps, and high volumes of bivalves occurred from February to August. Kingett & Choat (1981) also observed a summer (December) peak in abundance of gammarid amphipods and an autumn (April) peak in polychaete densities, which was reflected in the diet of the snapper *Pagrus auratus*. Changing water

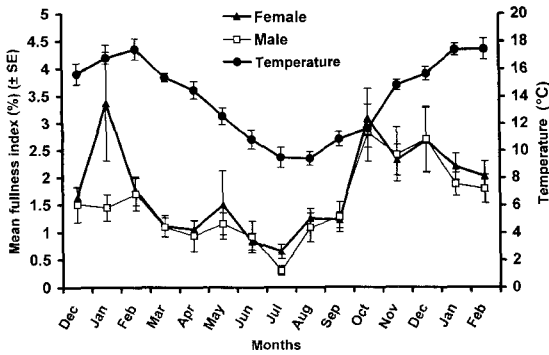


Fig. 6 Temperature ($^{\circ}\text{C}$) and mean fullness index (FI), (\pm SE) for male ($n = 172$) and female ($n = 278$) *Notolabrus fucicola* sampled around Kaikoura, New Zealand, from December 1996 to February 1998.

temperature may also be important as the annual mean temperature fluctuation around Kaikoura ranges from 8 to 18 $^{\circ}\text{C}$ (Davison & Van Berkel 1985). For example, several studies on wrasse in the Northern Hemisphere have found seasonal, temperature-related activity patterns, where few fish are active below 10 $^{\circ}\text{C}$ (Dipper et al. 1977; Costello 1991; Deady & Fives 1995).

Many reef fish undergo size-specific changes in foraging habits and diet, for example, from algal to rocky substrata (Jones 1988), as is also evident for *N. fucicola*. A shift in habitat often coincides with changes in fish morphology (Weatherly & Gill 1987) as their capacity to capture and ingest larger prey increases. Even though *N. fucicola* does not show significant variation with size across depth zones (Denny unpubl. data), behavioural observations indicate that the largest fish (>400 mm) spend more time swimming and foraging over rocky areas. Large fish (>300 mm) were observed swimming over intertidal rock flats, a behaviour seen in Australia where *N. fucicola* feeds on intertidal limpets (Odeja & Dearborn 1991). This is substantiated by the present study, which showed that this species fed on some strictly intertidal gastropod species, such as *Cellana* spp. and *Zacumantus subcarinatus*.

The gradual decline in the FI from summer to winter followed by an increase during spring reflects changes in the feeding rate throughout the year. These changes generally relate to seasonal variation in prey, water temperature, or reproductive activity (Choat 1982). For example, Jones (1980) found that the feeding rate of *N. celidotus* was lowest in winter between July and October and highest in summer.

In addition, the rate of feeding activity can decrease or cease as the fish become reproductively active (Deady & Fives 1995). The rapid rise in the FI in October 1997 coincided with the completion of the spawning season. *N. fucicola* may have been accumulating fat over the summer before the onset of spawning as there was a noticeable decline in the FI from the initial highs over summer until the onset of spawning. The low FI values in June and July coincided with the peak-spawning period of *N. fucicola* (Denny 1998). There was little evidence of sex differences in gut fullness. This suggests that males are not strongly territorial as differences between sexes are often observed when territorial males devote more time to defence during spawning (Gillanders 1995).

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