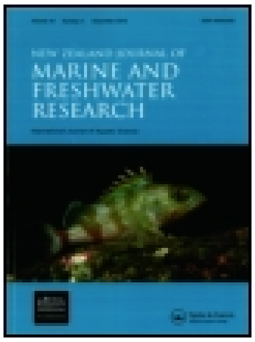

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POPULATION AND STANDING CROP ESTIMATES FOR ROCKY REEF FISHES OF NORTH-EASTERN NEW ZEALAND

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ABSTRACT

Estimates of the population and standing crop of fishes were made in six selected transect areas around Goat Island (174° 47′ 50″ E, 36° 16′ 10″ S), a typical rocky reef area on the coast of north-eastern New Zealand. There were considerable differences in the numbers of species and individuals between the sampling areas. Chance encounters with schools of "transient" fishes was a major source of variation between replicate censuses. Amongst the "resident" species, variation in numbers could be attributed to habitat differences. Bottom topography and algal cover are important factors affecting the distribution and abundance of reef fishes. Standing crop estimates of resident fishes ranged from $<0.001\ kg.m^{-2}$ (low relief bottom, sparse algal cover) to $0.103\ kg.m^{-2}$ (high relief bottom, extensive algal cover). These figures are similar to those obtained for Californian kelp beds and for coral reefs. Reef fish populations are susceptible to exploitation and the scarcity of larger fishes in two of the study areas could be attributed to spearfishing. Resident species are most vulnerable to spearfishing, and legal protection for these fishes is suggested.

INTRODUCTION

Population studies of New Zealand fishes have centred mainly around commercially important species. Because of the difficulties in adequately sampling inshore rocky areas using traditional methods (e.g., line fishing, trawling), little is known of reef fish populations. The advent of scuba diving and the development of suitable survey and collecting methods, however, has made possible direct observation of reef fishes, and in recent years scuba has been used increasingly to study New Zealand fishes (e.g., Doak 1972).

Scuba techniques were used in the present study to provide a general picture of the ecology of rocky reef fishes in a typical open coastal locality in north-eastern New Zealand. In this paper the fish populations and standing crop will be examined. The fish fauna itself and general habits of each species have been previously described (Russell 1969), and food and feeding relationships will be discussed in a later paper.

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METHODS

STUDY AREA

The study was carried out at Goat Island, near Leigh on the coast of north-eastern New Zealand (Fig. 1). Situated at the northernmost extremity of the Hauraki Gulf, Goat Island is exposed to the full influence of the South Pacific Ocean, and north-easterly swells prevail. Sea surface temperatures range from about 13°C in winter (August-September) to about 21°C in summer (January-February). The area is typical of most open coastal localities in northern New Zealand, with clean deep water (to 25 m) close inshore, and with a varied bottom topography, ranging from areas of open sand to heavily dissected reef. Morton & Chapman (1968) described Goat Island and its immediate environs, and Ayling (unpublished 1968) described the sublittoral biota.

POPULATION ESTIMATION

Population estimates of the fishes were obtained by Brock's (1954) visual censusing method. A 300 m^2 strip transect (30×10 m divided into two 5-m-wide lanes) was marked off along the bottom by means of lines. Using scuba, counts of the fishes within the transect area were made by two divers. Census data (species identifications, numbers of individuals, and their total lengths) were recorded on underwater writing boards. Both divers started at the same end of the transect, each diver following one lane. When time permitted, each diver on completion of his assigned lane, changed over to census the other lane, thus providing a replicate survey. There was no significant difference ($P > 0.05$) between replicate censuses, using the Wilcoxon matched-pairs signed-ranks test (Siegel 1956). In deeper water, or where the complexity of the rock bottom necessitated long searching time, it was not always possible to replicate censuses, and the estimates of both divers were combined. Small cryptic fishes such as trypterygiids and gobiesocids were ignored. Although numerically abundant, these fishes are virtually impossible to census accurately by visual counts.

Distinction was made between "transient" and "resident" species, based mainly on the observers' subjective impressions over all censuses. In general, transients were those fishes obviously roving about or just passing through the transect areas, while residents were those fishes observed actually living and feeding within the transect areas. Some diver-orientated behaviour was encountered; some species were attracted by the divers, while other species were frightened away. This, however, was taken into account in assessing the fish as either a transient or resident. The distinction is an important one as chance encounters with transient species introduced considerable variation in duplicate censuses, affecting biomass and standing crop estimates.

Biomass was calculated from length estimates using the approximate formula $W = KL^3$ (Brock 1954), where W = wet weight, K = the

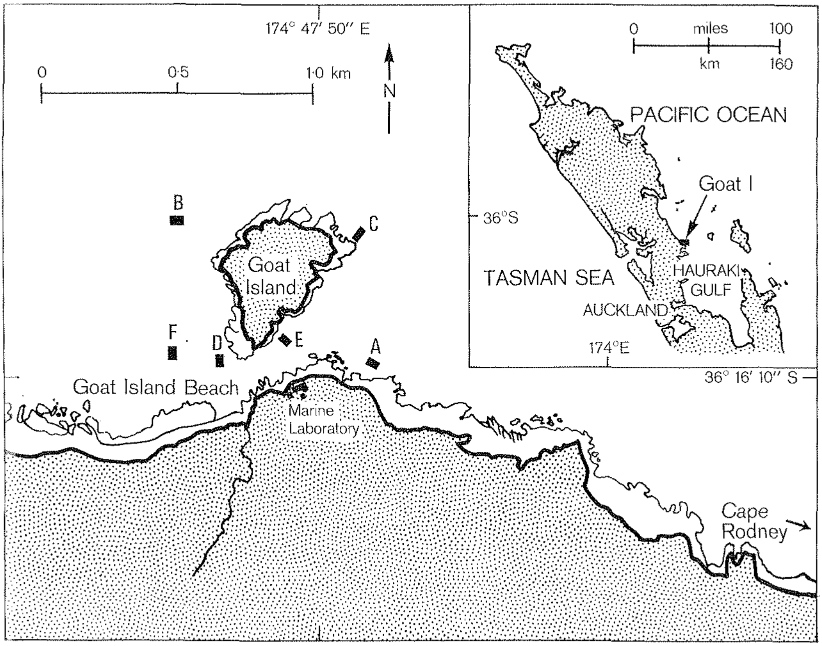

FIG. 1—Sketch map of the Goat Island area, showing the location of the 6 transects (A–F) along which reef fish were censused, November 1970 and February 1972. Heavy line indicates outline of coast, light line extent of exposed reef at MLWS. *Inset:* location of Goat Island on north-eastern coast of New Zealand.

species constant, based on the lengths and weights of collected specimens (see Russell unpublished 1971, appendix Ia, b), and L = total length (TL).

TRANSECTS

Strip transects were made in six different areas selected to include a variety of different bottom types and depths. Transects were initially made in two areas (Areas A, B on Fig. 1) during a preliminary study in November 1970. Two additional transects were made in the same areas and in a further four areas (Areas C, D, E, F on Fig. 1) in February 1972.

Transect A was in shallow water (7 m) on a broken rocky bottom comprising large boulders strewn about on a flat rock shelf. Algal cover, mainly *Carpophyllum maschalocarpum,* was limited to only a few of the boulders, and most of the cover on the open surfaces consisted of a low encrusting growth of coralline turf and small fleshy red algae. **Transect B** was in deeper water (12–17 m) down a boulder-strewn rocky slope. Algal cover was extensive, *Ecklonia radiata* forming a low canopy over about 80% of the bottom area. **Transect C** was located on

TABLE 1—Replicate censuses by two divers (BCR, AMA) of fish populations along Transect A, Goat Island, north-eastern New Zealand, 5 November 1970 and 2 February 1972 (weights estimated from length : weight data; *=transient species; –=absent).

SPECIES	NUMBERS BCR	NUMBERS AMA	SIZE RANGE (cm) BCR	SIZE RANGE (cm) AMA	WEIGHT (g) BCR	WEIGHT (g) AMA
5 November 1970						
Hoplostethus elongatus	3	6	5	5–10	21	59
**Caranx georgianus*	2	–	8	–	20	–
Upeneichthys porosus	2	4	10	15–23	36	432
Chrysophrys auratus	4	3	15	20–30	200	460
**Scorpis violaceous*	62	122	5–15	5–15	732	1 325
Pempheris adspersa	27	19	4–10	4–10	225	79
**Nemadactylus douglasii*	2	–	75	–	8 000	–
Cheilodactylus spectabilis	–	3	–	35–50	–	3 400
Chironemus marmoratus	11	13	13–25	20–30	835	2 630
Pseudolabrus celidotus	11	22	8–30	10–30	1 040	2 660
P. fucicola	1	3	20	15–25	200	670
Parapercis colias	5	6	10–23	13–20	282	424
Scorpaena cardinalis	3	8	8–10	8–20	42	267
Navodon convexirostris	3	3	23	23	480	480
AVERAGE (including transients)	173		..		12 499 (standing crop 0.042 kg.m^{-2})	
AVERAGE (excluding transients)	80		..		11 561 (standing crop 0.025 kg.m^{-2})	
2 February 1972						
Hoplostethus elongatus	1	11	10	8–10	13	108
**Caranx georgianus*	–	1	–	20	–	86
**Decapterus koheru*	280	260	8–10	8–10	2 000	1 800
Upeneichthys porosus	3	2	15	15–20	150	170
Chrysophrys auratus	2	4	38–50	13–50	2 375	2 275
**Girella tricuspidata*	–	14	–	28–30	–	4 998
**Scorpis violaceous*	250	225	10	8–10	5 000	3 825
Pempheris adspersa	46	100	5–10	8–10	279	990
Cheilodactylus spectabilis	3	2	12–45	30–45	2 815	1 875
Chironemus marmoratus	14	12	12–25	15–28	2 130	2 730
Pseudolabrus celidotus	5	11	15–23	8–25	595	1 310
P. fucicola	10	5	10–38	20–33	3 225	1 550
Coris sandageri	–	1	–	12	–	30
Parapercis colias	6	5	20–25	25–30	1 045	1 520
**Trachurus novaezelandiae*	4	4	10	10	40	40
Scorpaena cardinalis	–	2	–	10–15	–	81
Navodon convexirostris	2	3	15–25	23–28	340	900
AVERAGE (including transients)	644		..		22 123 (standing crop 0.074 kg.m^{-2})	
AVERAGE (excluding transients)	125		..		13 228 (standing crop 0.044 kg.m^{-2})	

the south-eastern point of Goat Island down a steep rock face, running from shallow water (3 m) to a boulder-strewn sandy bottom at 20 m. A vertical cleft ran the length of the transect, widening about half way down the face (12 m) to form a deep vertical crevice just large enough for a diver to enter. Cover in the shallower part of the transect (to 10 m) consisted of a sparse cover of *Carpophyllum* and turf algae, with scattered small plants of *Ecklonia radiata*. Below this, a low encrusting growth of sponges and polyzoans covered the rock face. The tumbled boulders at the base of the slope provided a number of small holes and caverns. **Transect D** was in shallow water (5 m) on a broken rocky bottom on the western side of Goat Island. Algal cover was sparse. *Carpophyllum maschalocarpum* was limited to a few boulders, and most of the rocky surface was covered with encrusting coralline algae. **Transect E** was laid across a heavily dissected reef in shallow water (5 m) in the channel between Goat Island and the mainland. Algal cover was extensive, with a dense cover of *Carpophyllum maschalocarpum* and *Ecklonia radiata* over most of the reef. A wide crevice ran the length of the transect, and a number of cracks and small caverns running off the main fissure provided a complex series of interstices. **Transect F** was in shallow water (5 m) on a flat rocky bottom about 500 m off Goat Island Beach. Bottom cover consisted of a low cover of coralline turf and small encrusting sponges interspersed with a few short tufts of *Sargassum* and stunted *Ecklonia radiata*.

RESULTS

Transect A

Two surveys were made in this area, the first in November 1970 and the second in February 1972 (Table 1). On the first survey a total of 14 species were recorded and 17 on the second. Twelve species were regarded as residents and 11 of these occurred in both censuses. Pooling the data of each observer, there was no significant difference between the resident populations in 1970 and 1972 ($P > 0.05$, Wilcoxon matched-pairs signed-ranks test). Standing crops (excluding transient species) of $0.025\ kg.m^{-2}$ (November 1970) to $0.044\ kg.m^{-2}$ (February 1972) were not significantly different ($P > 0.02$, χ^2 goodness-of-fit; Siegal 1956).

Transect B

Two surveys were made in this area, in November 1970 and in February 1972 (Table 2). On the first survey 21 species, including 17 residents were recorded. On the second survey 24 species, including 18 residents were recorded. Nineteen species, including 16 residents, occurred in both censuses. Pooling the data of each observer, there was no significant difference between the resident populations in 1970 and 1972 ($P > 0.05$, Wilcoxon matched-pairs signed-ranks test). Standing crops (excluding transient species) of $0.073\ kg.m^{-2}$ (November 1970) and $0.103\ kg.m^{-2}$ (February 1972) were not significantly different ($P > 0.02$ χ^2 goodness-of-fit).

TABLE 2—Combined data from replicate censuses by two divers (BCR, AMA) of fish populations along Transect B, Goat Island, north-eastern New Zealand, 6 November 1970 and 8 February 1972 (weights estimated from length : weight data; * = transient species)

SPECIES	NUMBERS	SIZE RANGE (cm)	WEIGHT (g)
6 November 1970			
Gymnothorax prasinus	2	92	3 800
Hoplostethus elongatus	24	8–10	300
Ellerkeldia huntii	3	12–15	147
Caesioperca lepidoptera	7	13–15	375
**Caranx georgianus*	21	23–25	4 760
**Decapterus koheru*	500	15	16 500
Upeneichthys porosus	12	15–25	1 475
**Girella tricuspidata*	50	40	45 500
**Scorpis violaceous*	30	12–25	1 118
Pempheris adspersa	30	8–10	333
Aplodactylus arctidens	1	38	907
Cheilodactylus spectabilis	2	40–60	4 175
Chironemus marmoratus	8	12–28	1 730
Chromis dispilus	21	2–15	776
Odax pullus	1	10	12
Pseudolabrus miles	6	10–20	930
P. celidotus	16	10–25	1 475
P. fucicola	5	25–10	2 945
Parapercis colias	1	26	240
Scorpaena cardinalis	10	10–15	204
Navodon convexirostris	28	3–25	1 925
TOTAL (including transients)	778	..	89 627 (standing crop 0.299 kg.m^{-2})
TOTAL (excluding transients)	177	..	21 749 (standing crop 0.073 kg.m^{-2})
8 February 1972			
Gymnothorax prasinus	3	75–120	8 614
Hoplostethus elongatus	59	5–10	551
**Zeus australis*	3	30–45	2 820
Ellerkeldia huntii	2	15–20	202
Caesioperca lepidoptera	5	15–18	430
**Caranx georgianus*	7	20	602
**Decapterus koheru*	3 000	8	18 000
**Seriola lalandi*	4	90–110	23 000
**Arripis trutta*	3	50	3 000
Upeneichthys porosus	9	15–25	1 680
Chrysophrys auratus	3	13–25	225
**Scorpis violaceous*	448	8–20	9 240
Pempheris adspersa	96	5–12	1 158
Aplodactylus arctidens	1	38	988
Cheilodactylus spectabilis	2	50–60	5 500
Chironemus marmoratus	8	12–28	1 600
Chromis dispilus	17	6–15	540
Pseudolabrus miles	3	25–28	975
P. celidotus	9	18–28	1 635
P. fucicola	3	15–38	1 125
Coris sandageri	1	38	2 200
Parapercis colias	1	25	250
Scorpaena cardinalis	10	10–20	541
Navodon convexirostris	10	23–25	2 545
TOTAL (including transients)	3 707	..	87 421 (standing crop 0.291 kg.m^{-2})
TOTAL (excluding transients)	242	..	30 759

TABLE 3—Census of the fish population along Transect C, Goat Island, north-eastern New Zealand, 2 February 1972 (weights estimated from length : weight data; * = transient species)

SPECIES	NUMBERS	SIZE RANGE (cm)	WEIGHT (g)
Conger wilsoni	1	152	10 535
Lotella rhacina	1	20	103
Hoplostethus elongatus	21	8	158
**Zeus australis*	1	25	249
Ellerkeldia huntii	1	20	147
Caesioperca lepidoptera	1	15	65
Upeneichthys porosus	11	15–25	1 050
Chrysophrys auratus	2	12	100
**Girella tricuspidata*	80	38	46 480
**Scorpis violaceous*	300	10	6 000
Pempheris adspersa	17	10–12	230
Aplodactylus arctidens	1	30	600
**Nemadactylus douglasii*	1	45	1 250
Cheilodactylus spectabilis	6	30–60	8 300
Chironemus marmoratus	15	12–30	2 750
Chromis dispilus	2	5	10
Pseudolabrus celidotus	15	8–25	1 720
P. fucicola	2	20–30	800
Parapercis colias	4	8–30	545
Scorpaena cardinalis	8	8–20	400
Navodon convexirostris	8	8–30	1 560
TOTAL (including transients)	498	..	83 052 (standing crop 0.277 kg.m^{-2})
TOTAL (excluding transients)	116	..	29 073 (standing crop 0.097 kg.m^{-2})

Transect C

A total of 21 species was recorded from this area (Table 3). Although only 4 species were transients they accounted for a high proportion of the total number and biomass. Excluding transient species, standing crop was estimated at 0.097 kg.m^{-2}. In both species composition and standing crop of resident species, Transect C was similar to Transect B. The lower number of resident individuals in C can be explained by differences in topography; the bottom in Transect C was less broken and there were fewer hole-dwelling fishes.

Transect D

A total of 13 species, including 4 transients, were recorded from this area (Table 4). The number of resident individuals was low; replicate censuses showed that an average of only 39 individuals were residents. This low number can be partly attributed to the fact that there were fewer hole-dwelling fishes, but there was also a notable absence of larger fishes (e.g., *Cheilodactylus spectabilis*) that were common elsewhere. Standing crop, excluding transient species, was 0.013 kg.m^{-2}.

TABLE 4—Replicate censuses by two divers (BCR, AMA) of fish populations along Transect D, Goat Island, north-eastern New Zealand, 3 February 1972 (weights estimated from length : weight data; * = transient species; – = absent).

SPECIES	NUMBERS		SIZE RANGE (cm)		WEIGHT (g)	
	BCR	AMA	BCR	AMA	BCR	AMA
**Hyporhampus ihi*	80	65	20	20	4 000	3 250
Lotella rhacina	1	–	15	–	41	–
Hoplostethus elongatus	1	–	8	–	7	–
**Caranx georgianus*	55	30	15	18	1 856	1 620
**Decapterus koheru*	800	1 000	8	8	4 800	6 000
Upeneichthys porosus	2	2	18–20	20	200	250
**Scorpis violaceous*	51	45	8–12	8	785	675
Pempheris adspersa	7	16	8–10	10	80	168
Chironemus marmoratus	7	9	15–25	18–28	990	1 565
Pseudolabrus celidotus	11	12	8–23	5–25	1 205	1 075
P. fucicola	1	3	18	18–25	150	650
Parapercis colias	–	1	–	28	–	430
Navodon convexirostris	2	4	23–25	8–23	525	360
AVERAGE (including transients)	1 104		..		15 341 (standing crop 0.051 kg.m^{-2})	
AVERAGE (excluding transients)	39		..		3 848 (standing crop 0.013 kg.m^{-2})	

TABLE 5—Census of the fish population along Transect E, Goat Island, north-eastern New Zealand, 8 February 1972 (weights estimated from length : weight data; * = transient species)

SPECIES	NUMBERS	SIZE RANGE (cm)	WEIGHT (g)
Hoplostethus elongatus	5	8	38
**Caranx georgianus*	1	10	10
**Decapterus koheru*	540	8	3 240
Upeneichthys porosus	4	20–23	630
**Scorpis violaceous*	80	6–10	1 450
Pempheris adspersa	304	6–10	1 760
Aplodactylus arctidens	1	51	2 388
Chironemus marmoratus	31	10–30	5 740
Odax pullus	1	30	250
Pseudolabrus celidotus	25	5–25	1 535
P. fucicola	3	25–38	1 700
Scorpaena cardinalis	2	15–20	220
TOTAL (including transients)	997	..	18 961 (standing crop 0.063 kg.m^{-2})
TOTAL (excluding transients)	376	..	14 261 (standing crop 0.048 kg.m^{-2})

TABLE 6—Census of the fish population along Transect F, Goat Island, north-eastern New Zealand, 8 February 1972 (weights from length : weight data)

SPECIES	NUMBERS	SIZE RANGE (cm)	WEIGHT (g)
Chrysophrys auratus	2	12–15	90
Upeneichthys porosus	1	18	75
Parapercis colias	1	18	75
TOTAL	4	..	240 (standing crop <0.001 kg.m^{-2})

Transect E

A total of 12 species, including 3 transients, was present on a combined survey of this area by two divers (Table 5). By comparison with other shallow water areas this reef area was very broken and there were large numbers of individuals of hole-dwelling species. However, larger fishes such as *Cheilodactylus spectabilis* and *Navodon convexirostris* were notably absent. Standing crop, excluding transient species, was 0.048 kg.m^{-2}.

Transect F

Only three species, comprising a total of four individuals were recorded from this rather featureless area of reef (Table 6). The standing crop was low, less than 0.001 kg.m^{-2}.

DISCUSSION

The distribution of fishes at Goat Island was discussed by Russell (1969) and a general schema relating distributions to major reef zones and habitats proposed. The importance of bottom topography in determining the distribution of rocky reef fishes is further borne out by the present results. Comparison of rankings of habitat topographic complexity with ranked numbers of species, numbers of individuals, and fish standing crops (Table 7) shows a significant positive correlation (Spearman r_s). Similar relationships have been found for fishes on coral reefs (e.g., Talbot & Goldman 1972).

The physical characteristics of the habitat affect the distribution of fishes in several ways. The degree of sculpturing of the reef largely determines the availability of shelter: few reef fishes range further than visual distance from the reef; and caves, holes, and crevices provide homes for many species as well as temporary refuges from roving predators. At night, shelter is a critical resource, most reef fishes moving close to the bottom or seeking cover, and the availability of suitable resting sites may decisively affect survival (Hobson 1968). Rocky substrates also support a rich invertebrate fauna, and this is an important food source for many fishes (author's unpublished data) and undoubtedly

TABLE 7—Rankings (parenthetical values) of numbers of resident species, numbers of individuals, and standing crop of fishes compared with complexity of the various bottom topographies ranked according to their degree of sculpturing (i.e., high relief ranked as 1 and low relief as 6); correlation by Spearman r_s between habitat complexity and all three population parameters is significant at $P < 0.05$ (* = estimates of numbers of species and individuals and of standing crop averaged for these areas).

TRANSECT AREA	TOPOGRAPHIC COMPLEXITY	NUMBER OF SPECIES	NUMBER OF INDIVIDUALS	STANDING CROP ($kg.m^{-2}$)
A*	4	11.5 (3)	102.5 (4)	0.035 (4)
B*	1	17.5 (1)	209.5 (2)	0.088 (2)
C	2	17 (2)	116 (3)	0.101 (1)
D	5	9 (4.5)	39 (5)	0.013 (5)
E	3	9 (4.5)	376 (1)	0.048 (3)
F	6	3 (6)	4 (6)	0.001 (6)

contributes also to the high standing crop of fishes associated with reef areas. The type of benthic growth on the reef is additionally important. In Area B for instance, where there was dense kelp cover, roving schools of the herbivorous *Girella tricuspidata* comprised up to 51% of the total fish biomass. Algal cover clearly has a direct influence on the distribution of herbivorous fishes, but the presence of large alga probably also improves the habitability of rocky reefs for fishes in general. Large canopy-forming alga such as *Ecklonia radiata* have a modifying effect on the reef environment, damping the effects of wave action and surge, as well as offering substantial shelter and additional foraging space for many species (Quast 1968a).

Estimates by Quast (1968b) and Miller & Geibel (1973) of populations of Californian kelp-bed fishes provide the only quantitative comparison with other temperate reef areas. Their estimates are based primarily on underwater transects, although Quast combined his visual census data also with the results of 3 quantitative rotenone collections. Californian kelp beds have a similar number of species (61 species, Quast 1968b) to the New Zealand study reefs (62 species, Russell 1969) and standing crop estimates also are similar. Quast's (1968b) average standing crop (0.035 $kg.m^{-2}$) is very close to the estimates of resident fishes in Area A (mean of 0.035 $kg.m^{-2}$), although it is somewhat less than Area B (mean of 0.088 $kg.m^{-2}$) which in terms of algal cover is probably more comparable to a kelp bed. Miller & Geibel's (1973) estimates of the standing crop of fishes on Monterey Bay reefs, on the other hand, are higher than for Quast's southern California areas. They report the standing crop (including mid-depth and kelp-canopy fishes) as exceeding 0.112 $kg.m^{-2}$. In large part, these different figures probably reflect real population differences related to differences in the character of the various habitats, but some variation may be due simply to the fact that the sampling methods were unstandardised.

TABLE 8—Comparison of standing crop estimates of rocky reef fishes at Goat Island with those of other biotopes (†=calculated from dry weight assuming dry weight is 20% of wet weight (Vinogradov 1953); (*=average estimate).

LOCATION AND REFERENCE	BOTTOM TYPE	STANDING CROP (kg.m^{-2})
Southern New England, U.S.A. (Merriman & Warfel 1948)	Soft bottom	0.002–0.023 (0.009*)
English Channel (Harvey 1950)	Soft bottom	0.005
Hawaii (Brock 1954)	Fringing coral reef: open sand, broken rock, coral reef, reef flat.	0.001–0.184
Eniwetok Atoll, central Pacific (Odum & Odum 1955)	Coral reef: sand, shingle, complex coral head.	0.0005–0.011†
Bermuda (Bardach 1959)	Coral reef: patchreef.	0.049*
Virgin Islands (Randall 1963)	Fringing coral reef: boulders, coral.	0.160
Texas (McFarlane 1965)	Open beach: sand	0.003 (winter) 0.012 (summer)
Red Sea (Clarke *et al.* 1966)	Fringing coral reef: mixed rock, sand, coral.	0.035
Southern California (Quast 1968b)	Kelp bed: broken rocky bottom, dense algal cover.	0.035*
One Tree Island, Great Barrier Reef (Talbot & Goldman 1972)	Coral reef: various coral habitats.	0.043–0.390
Monterey Bay, California (Miller & Geibel 1973)	Kelp bed: broken rocky bottom, dense algal cover, rocky reef.	0.001–>0.112
North-eastern New Zealand (Present study)	Rocky reef: open, low relief bottom–broken, high relief bottom with dense algal cover.	<0.001–0.103 (excluding transients) <0.001–0.299 (including transients)

In spite of sampling differences, a rough comparison of standing crop estimates from rocky reefs and kelp beds with those from other reef biotopes is given in Table 8. Fish standing crops on rocky reefs are significantly higher than non-reef biotopes, e.g., 5–15 times greater than on representative North Atlantic fishing grounds (Stevenson & Marshall 1974). However, the standing crops of fishes from temperate reef habitats are surprisingly similar to those of coral reefs, despite the much higher diversity of species in tropical areas. Thus, there may be little difference in net production between tropical and temperate reef fish communities.

Although reef areas support large numbers of fishes and high standing crops, they are very vulnerable to exploitation. Most reef fishes are non-migratory, many species spend their whole lives on the same small patch of reef, and they are thus more susceptible to fishing pressures than stocks of pelagic or wandering demersal species. The problem is especially severe for small isolated reefs, and there are numerous examples where reef fish populations have suffered marked local depletion through overfishing (e.g., Clutter 1971; Johannes 1975). Certain methods of exploitation such as spearfishing may be particularly damaging. At Goat Island, the effects of spearfishing were evident in two areas (Areas D and E), both of which are within easy swimming distance of Goat Island Beach and are heavily spearfished during summer. Compared with less accessible reef areas (e.g., Area A) there was a notable scarcity of larger fishes such as *Cheilodactylus spectabilis* and *Navodon convexirostris*. These species are commonly taken by skindivers and, like most reef fishes, can be virtually eliminated from an area by indiscriminate spearfishing. The long-term effects of removal of these larger fishes from reef communities is difficult to assess, but possible consequences include reduced stocks, depressed age-size structure of the populations, and, by removal of the larger predators, alteration of the reef community as a whole. For some species (e.g., *Coris sandageri*) which occur only in small localised populations at Goat Island and other coastal areas of northern New Zealand, the threat of local extinction also is very real.

The establishment of marine national parks provides protection for fishes in some areas, but there remains the need for many species to be protected from spearfishing outside these areas. The recognition of marine fishes as native wildlife and according legal protection similar to other endangered wildlife might be a first step. Because the majority of reef fishes can be classified as residents and are therefore endangered by spearfishing, a large list of protected species is likely to be impracticable and from a management point of view, a declared list of fishable species is probably more feasible. As a basis it might include only transient species.

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