Diversity and biogeography of coastal fishes of the East Cape Region of New Zealand

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Cover: The dive boat *Tu Taua* during the survey at station E07, Boat Cove, Lottin Point, East Cape Region, on 1 May 1992. *Photo: C.D. Roberts*

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ABSTRACT

A fish survey was carried out along 300 km of coast in the East Cape Region (ECR), North Island, between Whakatane (Bay of Plenty) and Gisborne (Poverty Bay) New Zealand during 1992–1999. Sampling, using mainly rotenone ichthyocide and handspear, was carried out at 0–21 m depth by teams of 4–7 divers who spent c. 200 hrs underwater collecting fish specimens and recorded identification and habitat data. A total of 148 fish species (114 genera; 65 families) were recorded in inventory lists supported by voucher specimens. Of these, 107 shallow reef fish species were analysed to compare diversity and composition in four ECR subareas: East Coast, coastal Bay of Plenty (BOP), inshore BOP islands, and offshore BOP islands. No significant difference was found between the East Coast and the coastal BOP stations, and between the BOP inshore and offshore island stations; but there was a significant difference between all coastal stations (East Coast and BOP) and all island stations (inshore and offshore) using ANOVA and Tukey *post hoc* comparisons. Complementary results were obtained with Jaccard's pair-wise comparison between composition of reef fish faunas, which indicated that offshore BOP islands were the least similar to coastal BOP and the East Coast (46% species shared respectively); and the East Coast and coastal BOP were the most similar (79% species shared). Most reef fishes in the ECR (78%) were widespread New Zealand species; and there was a moderate northern component (20%) and small southern component (2%). There were progressive changes in composition moving from west to east and from offshore to inshore, with a reciprocal decrease in northern species and increase in widespread species, and a small increase in southern species. Northern species reached their limit of distribution variously at White Island, coastal BOP, East Cape, and East Coast; southern species reached their limits at East Cape. All these results provide strong support for a wide biogeographic transition throughout the ECR, and refute a narrow biogeographic boundary.

Keywords: coastal fishes, rotenone sampling, specimen collections, species diversity, rare species, new species, biogeography, East Cape, New Zealand

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1. Introduction

Research on the marine biota of New Zealand carried out over the last 50 years has shown the East Cape Region (ECR), from Whakatane to Gisborne (Fig. 1), to be an important biogeographic feature influencing the distribution, composition, and diversity of intertidal, coastal and shelf communities, including algae (Moore 1949, 1961), molluscs (Powell 1961; Dell 1962), echinoderms (Pawson 1961, 1965; Baker 1968) and fishes (Moreland 1959). Early regional biogeographic work in New Zealand centred on the description of marine provinces (e.g. Powell 1961; Knox 1963), with almost complete agreement that East Cape defined the boundary between the Aupourian (Auckland or Northern) Province and the Cookian Province to the south, a division still in use today (Morton 2004: 186). Subsequent biogeographic research (e.g. Dell 1962; Pawson 1965) focussed more on the description and analyses of distribution patterns of species and areas of endemism around New Zealand, but nevertheless continued to show East Cape to be a major biogeographic feature. The nature of this feature however has varied substantially between studies, ranging from a well-defined barrier (e.g. Pawson 1961: 11, 1965: 248), poorly defined boundary (e.g. Dell 1962: 48; Knox 1963: 396), well-defined boundary (e.g. Moreland 1959: 30; Baker 1968: 6), to a methodological boundary line for subdivision of the coast in biogeographic studies of the New Zealand region (e.g. King et al. 1985: fig. 1; Paulin & Roberts 1993: fig. 88; Francis 1996: 37).

For some groups, such as algae (Moore 1961; Adams 1994), echinoderms (Pawson 1965) and fishes (Waugh 1973: fig. 11.1; Paulin & Roberts 1993; Francis 1996), there is evidence that northern species—some widely Australasian or Indo-Pacific and some endemic to a relatively small area of New Zealand—reach the southern limit of their distribution at or near East Cape. Conversely, southern and central New Zealand species extend north to East Cape. However, this generalisation may be overly simplistic (Morton & Miller 1968: 336) and there have not been adequate surveys of key marine groups to assess the species present and their biogeographic relationships. Hypotheses of the ECR supporting marine habitats with boundary or transitional marine biota have not, therefore, been adequately tested. Walls (1995) identified an information gap for the 'transition zone between East Cape and Hawkes Bay', and recommended that research should target the area.

The fish team from the Museum of New Zealand Te Papa Tongarewa (Te Papa) has been carrying out a long-term programme to survey and sample fishes in New Zealand coastal waters. Opportunistic fieldwork to collect and preserve fishes from the ECR began in the 1980s. Comprehensive fieldwork involving teams of divers, began in the early 1990s as part of a joint Museum of New Zealand/Department of Conservation (DOC) programme to survey, collect and inventory coastal marine reef fishes. Since then, fieldwork has been carried out for from one to two weeks during summer in 1992, 1993, 1998, and 1999, in the area between Gisborne and the eastern Bay of Plenty, including sites at nearshore and offshore islands.

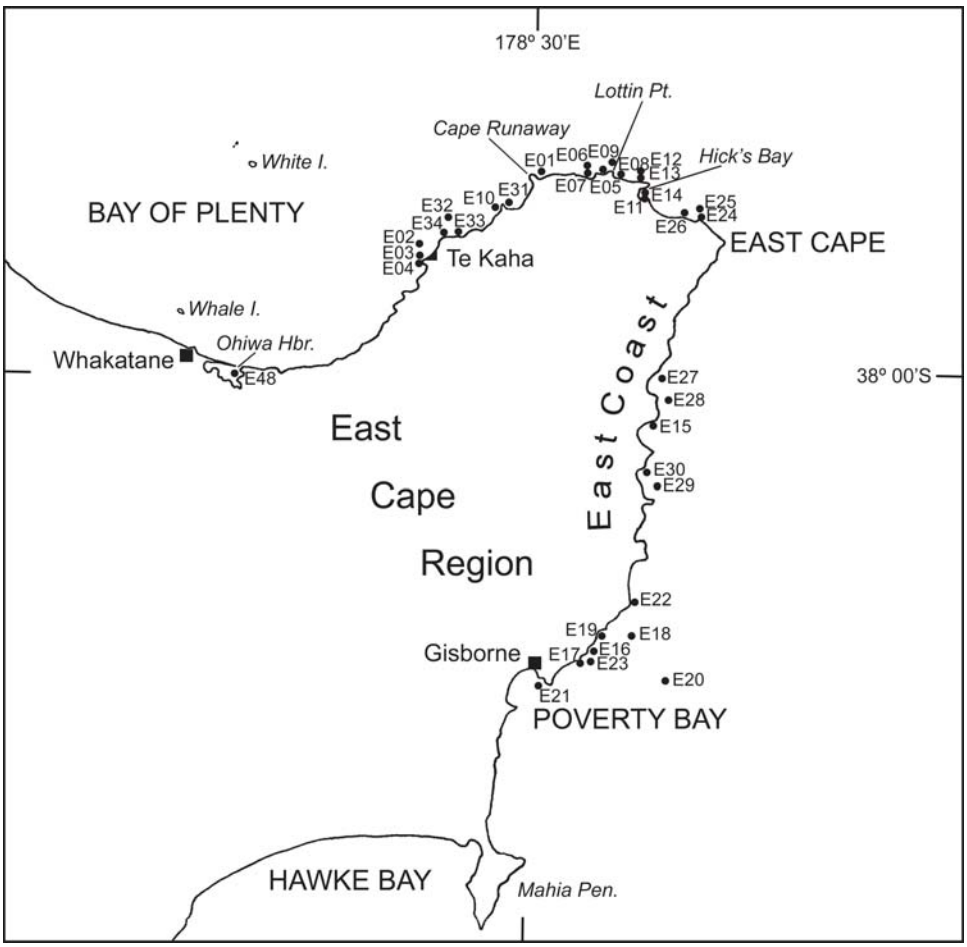


Figure 1. Locations of coastal stations sampled in the East Cape Region during the 1992, 1993, and 1999 fish surveys.

For the coastal fish fauna, the survey sought to answer several questions about diversity and distribution of reef fishes in the ECR. The answers to these questions will assist the Department of Conservation assess the value and location of sites for marine reserves in the region, and provide essential baseline data that can be used in monitoring programmes.

Currently there is one marine reserve in the ECR: Te Tapuwae o Rongokako, 16 km north of Gisborne. Other marine protected area proposals are being investigated. The ECR study area falls within two DOC Conservancies: East Coast/Hawkes Bay and Bay of Plenty.

2. Objectives

The main aim of the present study was to survey and comprehensively sample the coastal and island reef fish fauna in the ECR of New Zealand, to provide baseline information on fish diversity, station inventories, and to seek evidence for an East Cape biogeographic boundary or transition area. Our research proposal (DOC Science Investigation no. 2282) identified the following objectives:

- To document the coastal fish species present in the ECR and their distributions by collecting fishes from selected sites using established sampling techniques.
- To preserve and retain voucher specimens for deposit in the National Fish Collection at Te Papa to support the species listed in the inventories, and to contribute to ongoing biosystematic research programmes.
- To assess the scientific importance of the species diversity and distributions.
- To provide a detailed report to DOC containing habitat information, species inventories, species diversity analysis, and biogeographic analysis.
- To assess the evidence for a biogeographic boundary or transition in the ECR.

3. Methods

3.1 SURVEY METHODS

The survey methods used by the Te Papa fish team in New Zealand coastal waters have been documented in several reports and publications (e.g. Paulin & Roberts 1990; Roberts et al. 1991, 2005; Roberts & Stewart 1992; Paulin & Roberts 1994a, b; Willis & Roberts 1996). Fieldwork during the present study comprised comprehensive collecting of coastal and island fishes using rotenone and spear on scuba or snorkel, supplemented by fishing with rod and line, during four 5–9 day periods in 1992–1999. Similar rotenone-based sampling methods have been widely used overseas (e.g. Lardner et al. 1993; Smith 1973). Rotenone is an ichthyocide considered to be environmentally benign because it is chemically unstable and breaks down rapidly in water, degrading faster with heat and light, as well as becoming inactive with dilution and dispersal (Ling 2003; Roberts et al. 2005). Experiments in coastal waters have shown that populations of fishes and invertebrates sampled by rotenone quickly recover through recruitment from adjacent areas (Willis & Roberts 1996; Polivka & Chotkowski 1998). Rotenone is particularly effective in sampling small cryptic species that form a large and speciose component of coastal fish faunas. Its controlled use by the Te Papa fish team and assistants was carried out under

special permits from the Ministry of Fisheries and DOC (in marine reserves) in accordance with the objectives of the Museum of New Zealand Te Papa Tongarewa Act (1992).

Stations surveyed by snorkel (0–3 m depth) and scuba (2–21 m depth), were within intertidal or subtidal reefs which usually contain the greatest diversity of fishes. Sampling stations were selected based on degree of shelter from prevailing waves and current at the time, and the presence of diverse rocky reef habitat. Two 500 g bags of rotenone powder were mixed into thick, heavier-than-water slurry, and squirted into holes and crevices in the reef, and among macro-algal fronds. A weighted buoy line marked the location of each sample station. Divers worked in relays of pairs observing and collecting fishes until the station was finished, usually after a total collecting period of about two hours, which included about 20 min. after the last fishes had been collected. Some large fishes, mostly unaffected by rotenone, were caught at the station using a hand spear. Fish species seen, but not collected, were also recorded on the station sheets. In addition, we used rod and line fishing, and opportunistic collecting from boats with dip nets. Rotenone stations were also carried out in shallow subtidal areas by snorkel divers, and in intertidal rockpools using nets and hand collecting. A station description, including depth profile, exposure and dominant fauna and flora was made for each sample station. Diving data (entry time, duration, maximum depth, dive profile) were recorded and monitored, following safe scientific diving practice (Flemming & Max 1996).

3.2 FISH COLLECTION AND PRESERVATION

Fish specimens were held in an ice/seawater slurry and provisionally identified when sampling was finished at each station. Small fishes were then fixed directly in 10% formalin; medium–large fishes were either bagged and frozen (1992 and 1993 surveys) or (if on a vessel at sea) held in an ice slurry for a few days before being frozen on return to land (1998 and 1999 surveys). Checklists of fishes from all sample sites were compiled shortly after completion of each station.

All specimens were registered and preserved in either 70% ethanol (small, jar-sized fishes) or 50% isopropanol (medium–large, drum or tank-sized fishes) at Te Papa as voucher specimens supporting species inventories and regional analyses.

3.3 FISH IDENTIFICATION

Voucher specimens were registered into the National Fish Collection (NFC) at Te Papa and the field identifications checked. Identifications were aided by comparison with specimens already held in the NFC, by reference to identification guide books to New Zealand and Australian fishes, specialist taxonomic papers in scientific journals, and unpublished keys and diagnostic information.

Some fish families and species groups still require substantial taxonomic research. Consequently, a number of our coastal reef fishes, even common ones, are not identifiable to species, or can only be assigned provisional species names. Voucher specimens supporting the species inventories from the present survey are therefore important for future reference. They enable current identifications to be validated or changed, and also provide an important source of comparative material on which future taxonomic studies and revisions can be based.

Fish species are listed here following the popular and scientific nomenclature of Roberts et al. (in press), except for the family Muraenidae, which follows Böhlke & McCosker (2001); higher classification follows Nelson (1994).

3.4 SURVEY AREAS, DATES, EFFORT, AND VESSELS

3.4.1 All surveys

1992–1999—Stations on coastal reefs were accessed in 1992 and 1993 directly from the shore where access was available or by sea using the 4.4 m Te Papa dive boat *Beryx* in tandem with the 6 m DOC vessel *Tu Taua*. Stations in the Whale Island and White Island areas (1998–1999) were sampled using the 8 m charter boat m.v. *Ma Cherie* operated from Whakatane.

During the period 1992–1999, a total of 234 diver hours were spent working underwater (200 hrs on scuba, 34 hrs on snorkel), at a total of 48 stations, comprising 35 stations on scuba (4–21 m deep), 9 stations on snorkel (0–3 m deep), and 3 intertidal rockpool stations (0–1 m deep) and one estuary station (0–1 m deep).

3.4.2 East Cape area

1992 survey—The 1992 survey, carried out during the period from 29 April to 7 May, experienced difficult weather conditions, which made sea access from the boat launching sites difficult, especially along the East Coast. In addition, overcast weather significantly reduced underwater visibility. The Bay of Plenty side was workable on scuba, but several dives on the East Coast were aborted because of high sea state and turbidity.

A total of 104 hours were spent observing and collecting underwater by up to seven divers. Table 1 shows the dates and locations of the 17 stations sampled (E01–E17) between Cape Runaway and Gisborne, plus the number of fish species collected and observed (range per station: 9–43). The locations of these stations are plotted in Fig. 1.

1993 survey—The weather during the 1993 survey, carried out during the period 20–28 January, was the opposite of that experienced in 1992. Diving conditions along the East Coast were excellent, and three stations (E24–E26) were able to be conducted at exposed sites almost on East Cape itself. Another two deeper dives were made offshore, but habitat suitable for collecting was not found. The Bay of Plenty to the west experienced choppy seas, but the

TABLE 1. LOCALITY DATA, COLLECTING METHODS AND SPECIES DIVERSITY AT STATIONS SAMPLED DURING THE 1992 FISH SURVEY OF THE EAST CAPE REGION.

STN.	LOCALITY	DEPTH (m)	METHODS	DATE	SPECIES	
					COLLECTED	TOTAL
E01	S.E. of Cape Runaway 37°32.9′S, 178°00.3′E	8–12	RO	29 Apr	27	39
E02	Kaipiro Reef, Maraetai Bay, Te Kaha 37°42.6′S, 177°41.7′E	19–21	RO, HS	30 Apr	16	22
E03	Wharekura Pt, Maraetai Bay, Te Kaha 37°43.5′S, 177°41.6′E	4–6	RO, HS	30 Apr	31	34
E04	Wharekura Pt. Maraetai Bay, Te Kaha 37°43.5′S, 177°41.6′E	1–3	RO, HS	30 Apr	15	15
E05	Waiaka Bay, Lottin Pt 37°32.9′S, 178°08.7′E	15–20	RO, HS	1 May	24	32
E06R	Mid-tide pool, Upokongaruru, Lottin Pt 37°33.0′S, 178°08.0′E	0–0.5	RO	1 May	13	13
E07	Boat Cove, Upokongaruru, Lottin Pt 37°33.0′S, 178°08.0′E	0–2	RO, HS	1 May	28	31
E08	S. of Midway Pt E. of Lottin Pt 37°32.6′S, 178°12.9′E	15–17	RO, HS, HL	2 May	28	32
E09	Tohora pirau, Lottin Pt 37°32.7′S, 177°10.0′E	7–10	RO, HS, HL	2 May	38	43
E10	W. Orete Pt, Waihau Bay 37°36.0′S, 177°54.0′E	11–12	RO	3 May	21	29
E11R	Mid-tide pools, Onepoto Bay, Hick's Bay 37°35.6′S, 178°18.1′E	0–0.5	RO	3 May	9	9
E12	W. Matakaoa Pt, Hick's Bay 37°32.1′S, 178°17.3′E	9–12	RO, HS	4 May	23	30
E13R	Rock pools, W. Matakaoa Pt, Hick's Bay 37°32.1′S, 178°17.3′E	0–1	RO	4 May	20	20
E14	Rock gut, Onepoto Bay, Hick's Bay 37°35.6′S, 178°18.1′E	0–3	RO	4 May	19	21
E15	N. end Tokomaru Bay 38°06.9′S, 178°20.4′E	0–1	RO	5 May	16	20
E16m	Low tide reef Pariokonohi Pt, north of Gisborne 38°36.5′S, 178°12.1′E	0–1.5	RO	6 May	14	16
E17	Low tide reef, Tatapouri, Gisborne 38°38.8′S, 178°08.9′E	0–3	RO	7 May	12	18

HL = rod and line; HS = hand spear; RO = rotenone; R = rockpool station; m = marine reserve station; Collected = number of species with at least one voucher specimen; Total = includes species seen, but not collected.

lower sediment loading there meant that sampling work on scuba could still be carried out effectively and safely.

Six divers spent a total of 74 hours underwater. Table 2 shows the dates and locations of the 17 stations surveyed and sampled (E18–E34) between Gisborne and Whanarua Bay, plus the number of fish species collected and observed (range per station: 21–38). The locations of these stations are plotted in Fig. 1.

TABLE 2. LOCALITY DATA, COLLECTING METHODS, AND SPECIES DIVERSITY AT STATIONS SAMPLED DURING THE 1993 FISH SURVEY OF THE EAST CAPE REGION.

STN.	LOCALITY	DEPTH (m)	METHODS	DATE	SPECIES	
					COLLECTED	TOTAL
E18	Monowai Reef, Gisborne 38°35.9′S, 178°16.7′E	15–21	RO	20 Jan	17	30
E19	Pouawa Reef, Gisborne 38°36.9′S, 178°11.8′E	6–8	RO	20 Jan	23	28
E20	Ariel Reef, Gisborne 38°43.6′0S, 178°17.9′E	10–13	RO	21 Jan	9	25
E21	Tuamotu I., Poverty Bay 38°42.2′S, 178°02.4′E	4–7	RO	21 Jan	19	22
E22	The Gables 38°31.8′S, 178°17.9′E	14–17	RO	22 Jan	15	21
E23	Tatapouri, Gisborne 38°39.2′S, 178°09.9′E	6–8	RO	22 Jan	19	27
E24	Horoera Point, East Cape 37°38.5′S, 178°29.1′E	0–3	RO	23 Jan	21	26
E25	Off Horoera Point, East Cape 37°37.8′S, 178°28.9′E	8–10	RO	24 Jan	15	23
E26	Between Te Araroa & Horoera, East Cape 37°37.6′S, 178°25.0′E	0–3	RO	24 Jan	27	28
E27	NE Waipiro Bay 38°00.0′S, 178°23.1′E	21	RO, HN	25 Jan	19	24
E28	Between Motuahiauru Rock & Koutunui Head 38°03.7′S, 178°22.2′E	9	RO	25 Jan	30	33
E29	Outside Motuoroi I., Anaura Bay 38°15.2′S, 178°21.1′E	10–13	RO	26 Jan	22	23
E30	Shark Bay, north Anaura Bay 38°13.5′S, 178°19.7′E	4–6	RO	26 Jan	26	31
E31	Waihau Bay 37°36.8′S, 177°54.6′E	4–6	RO	27 Jan	22	24
E32	Outer Whanarua Bay 37°40.0′S, 177°46.7′E	15–21	RO, HS	28 Jan	14	23
E33	Eastern Whanarua Bay 37°40.5′S, 177°47.4′E	8	RO, HS	28 Jan	29	38
E34	Western Whanarua Bay 37°40.9′S, 177°47.2′E	2	RO	28 Jan	26	31

HN = hand net; HS = hand spear; RO = rotenone; Collected = number of species with at least one voucher specimen; Total = includes species seen, but not collected.

3.4.3 Bay of Plenty islands

1998 survey—In 1998, sampling at Rurimu Islets, Whale Island, White Island and Volkner Rocks was carried out opportunistically during the period 1–5 June on lee shores around each island. The high cost of boat charters limited the number of sites sampled to six.

Six divers spent a total of 23 hours underwater. Table 3 shows the dates and locations of the six stations (E35–E40) surveyed and sampled among the inshore and offshore island groups, plus the number of fish species collected and observed (range per station: 33–44). The locations of these stations are plotted in Fig. 2.

1999 survey—Offshore areas not adequately sampled in 1998 were re-visited and surveyed during the period 22–27 April 1999. In addition, one estuarine station (E48) was sampled onshore at Ohiwa Harbour.

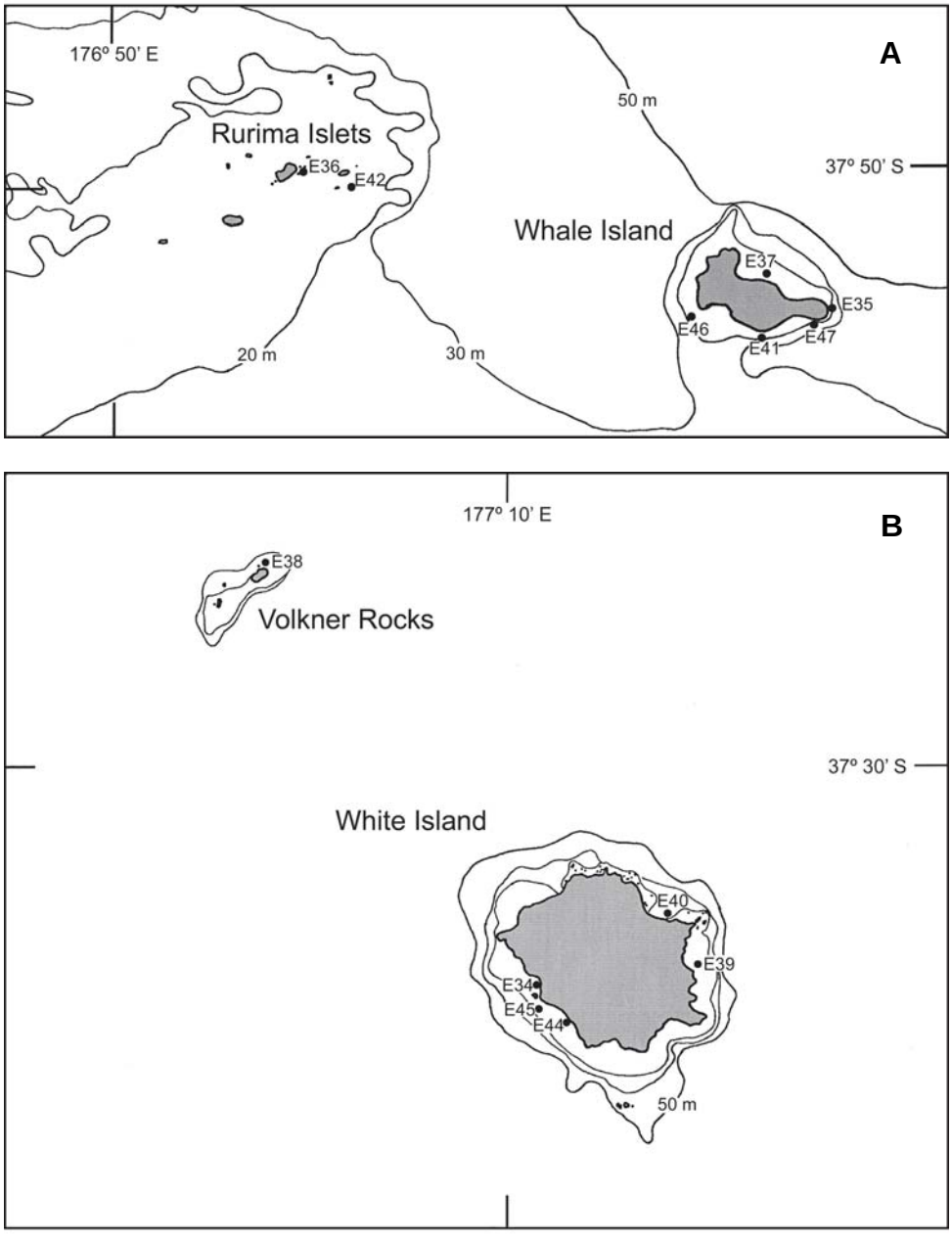


Figure 2. Location of stations sampled at Bay of Plenty islands during the 1998 and 1999 fish surveys. **A**. Inshore islands. **B**. Offshore islands. Isobaths shown are at 20, 30, and 50 m depth.

Six divers spent a total of 33 hours underwater. Table 4 shows the dates and locations of the eight stations (E41–E48) surveyed, plus the number of fish species collected and observed (range per station: 28–40, plus 12 spp. at Ohiwa Harbour). The locations of these sites are plotted in Fig. 2.

TABLE 3. LOCALITY DATA, COLLECTING METHODS AND SPECIES DIVERSITY AT STATIONS SAMPLED DURING THE 1998 FISH SURVEY OF BAY OF PLENTY INSHORE AND OFFSHORE ISLANDS.

STN.	LOCALITY	DEPTH (m)	METHODS	DATE	SPECIES	
					COLLECTED	TOTAL
E35	Archway, east corner, Whale I. 37°51.44′S, 176°59.39′E	12–17	RO	01 Jun	27	35
E36	Rurima Islets 37°49.78′S, 176°52.64′E	7–10	RO	02 Jun	26	34
E37	North Bay, Whale I. 37°51.05′S, 176° 58.57′E	13–15	RO, HL	03 Jun	23	35
E38	Volkner Rocks 37°28.51′S, 177°08.12′E	7–13	RO, HS	04 Jun	27	44
E39	East side, White I. 37°31.16′S, 177°11.67′E	13–15.5	RO	04 Jun	22	37
E40	North-east Bay, White I. 37°38.59′S, 177°11.49′E	15–20	RO	05 Jun	23	36

HL = rod & line; HS = hand spear; RO = rotenone; Collected = number of species with at least one voucher specimen; Total = includes species seen, but not collected.

TABLE 4. LOCALITY DATA, COLLECTING METHODS AND SPECIES DIVERSITY AT STATIONS SAMPLED DURING THE 1999 FISH SURVEY OF BAY OF PLENTY INSHORE AND OFFSHORE ISLANDS.

STN.	LOCALITY	DEPTH (m)	METHODS	DATE	SPECIES	
					COLLECTED	TOTAL
E41	South of Whale I. 37°51.7′S, 176° 58.44′E	8–12	RO, HL	22 Apr	32	38
E42	Rurima Islets 37°50.04′S, 176°53.45′E	5–10	RO, HL	22 Apr	22	40
E43	Nursery Cove, White I. 37°31.41′S, 177°10.37′E	5–16	RO, HS	23 Apr	25	40
E44	Off Homestead Pt, White I. 37°31.76′S, 177°10.69′E	8–14	RO, HS	23 Apr	23	32
E45	South-west corner, White I. 37°31.26′S, 177°10.20′E	11–18	RO	24 Apr	19	32
E46	West end, Whale I. 37°51.05′S, 176°57.63′E	12–16	RO, HS	24 Apr	20	30
E47	MacEvans Bay, Whale I. 37°51.56′S, 176°59.12′E	12–17	RO	26 Apr	30	39
E48E	Opp. Tern I., Ohiwa Harbour 37°50.0′S, 177°09.6′E	0–1	RO	27 Apr	11	12

HL = rod & line; HS = hand spear; RO = rotenone; Collected = number of species with at least one voucher specimen; Total = includes species seen, but not collected. E48E = estuary station.

3.5 STATISTICAL ANALYSES

The ECR study area was divided into four survey areas: East Coast (south of East Cape); coastal Bay of Plenty (west of East Cape); Whale Island and Rurima Islets (Bay of Plenty inshore islands); and White Island and Volkner Rocks (Bay of Plenty offshore islands). Fishes recorded within these four areas are listed by sample station in the Appendices. Species diversity (total numbers of species that were recorded at each of the sampling areas) was analysed using One-Way Analysis of Variance (ANOVA). This was undertaken to test differences between the four survey areas, in particular either side of East Cape. Individual differences between areas were then tested using Tukey *post hoc* pairwise comparisons, in an attempt to determine variation between areas. All statistical analyses were undertaken using STATISTICA (Statsoft Inc. 2001).

Reef fish communities at pairs of the above survey areas were compared using the Jaccard's index (Ludwig & Reynolds 1988). The index represents the proportion of species in common between two survey areas and, thus, reflects similarities in species composition. The Jaccard's index is unbiased, even in small sample sizes (Ludwig & Reynolds 1988), such as for the two BOP island areas. Values for the index range from 0.0 (no species in common) to 1.0 (identical species composition).

The formula used was: $Sj = a/(a + b + c)$
Where:

Sj = Jaccard's similarity index

a = number of species that are shared by both survey area

b = number of species that are unique to first survey area

c = number of species that are unique to the second survey area.

4. Results

4.1 STATIONS SURVEYED AND FISHES RECORDED

A total of 47 marine sample stations (3 rockpool to 1 m; 44 sublittoral to 21 m) and one estuarine station (0–1 m) were carried out in the ECR during 1992–1999 (Tables 1–4). The survey area covered a coastal distance of approximately 300 km between Whakatane (Bay of Plenty) and Gisborne (Poverty Bay) (Fig. 1). In addition, two Bay of Plenty island groups were sampled: the nearshore Whale Island and Rurima Islets (7 sample stations), and the offshore White Island and Volkner Rocks (6 sample stations) (Fig. 2). One offshore site was sampled on the East Coast: Ariel Reef (E20), off Gisborne (Fig. 1). It was attempted to spread the sample stations evenly throughout the study region, but this was affected by inclement weather and sea conditions, site inaccessibility from shore or boat, time and funding constraints, and the extent of rocky reef habitat. Nevertheless, there was a good spread of sample stations either side of East Cape.

An inventory of fish species recorded at each station is given by family and area in Appendices 1–3. These lists, totalling 148 fish species, are supported by over 8,000 preserved specimens collected during the study and include additional records of 24 species, mostly based on holdings in the NFC. During the four survey periods, 124 fish species in 82 genera and 53 families were collected or observed in marine and estuary habitats in the ECR. Greatest fish species diversity was found at subtidal stations, which had 15–44 spp. (mean 29.8) per station. Lowest diversity was found in the one estuary sampled (12 spp.); and intertidal rockpools were also low with 9–20 (mean 14.0) per station. Within subtidal stations, the nearshore and offshore BOP island stations had the highest diversity with 22–40 (mean 35.8) spp. and 32–44 (mean 42.7) spp., respectively; while coastal stations were lower: BOP stations had 15–43 (mean 28.9) spp.; and East Coast stations had 16–33 (mean 24.5) spp. The one offshore East Coast station at Ariel Reef had 25 spp., which is comparable to the mean for the coastal stations.

One reef fish sampled is a first record for New Zealand (and is undergoing taxonomic study):

Spotted pipefish *Stigmatopora* sp. A (family Syngnathidae)

10 specimens (juveniles and adults) collected at 2–12 m depth at 5 coastal stations, extending from Whanarua Bay, west of Cape Runaway (E34), to Tuamotu Island, Poverty Bay (E21) (Appendix 1). It is distinct from all known New Zealand species, but its identity is currently uncertain. This pipefish has characters (dorsal fin rays counts, trunk ring counts, and colour pattern) that suggest it is closely related to *S. argus* from southeast Australia (Dawson 1982).

Two coastal reef fish species collected are new to science:

Halfbanded perch *Hypoplectrodes* sp. B (family Serranidae)

42 specimens collected at 5 stations, within the survey area limited to reefs around White Island (Appendix 3). A relatively well-known northern species that currently lacks a scientific name, and is probably a new species.

Pygmy sleeper *Thalasseleotris iota* (family Eleotridae)

Widespread at 20 stations, both coastal and offshore (Appendices 1–3). These specimens have contributed to a formal description of this new species (Hoese & Roberts 2005).

Three coastal reef species are particularly rare:

Giant triplefin *Blennodon dorsale* (family Tripterygiidae)

2 specimens were collected during the survey—one caught at 8–10 m depth near East Cape (station E25), and one caught at 4–7 m depth near Gisborne (station E21) (Appendix 1). This species is rarely seen because it prefers the most exposed sites and is resistant to the effects of rotenone. Mostly known from west coast sites (Roberts et al. 2005); one previous record from the western BOP (Paulin & Roberts 1992).

Bluntnose clinid *Cologrammus flavescens* (family Clinidae)

Recorded in the present study (Appendix 1) based on 15 specimens from Hick's Bay held in the NFC. A very rare clinid (Paulin & Roberts 1992: 97), similar to the orange clinid (*Ericentrus rubrus*) in coloration and behaviour. It has been taken at one station south of Hawke Bay in 1991 (Roberts &

Stewart 1992), and off Stewart Island and Chatham Island (Te Papa unpubl. data).

Pink clingfish *Modicus minimus* (family Gobiesocidae)

One specimen collected at 15–17 m depth at one station (E08), east of Lottin Point (Appendix 1). This is the second record of the species north of Taranaki Bight and Cook Strait, where it was previously only known from Whangaroa Harbour at 20 m (Hardy 1983).

4.1.1 Intertidal fish fauna

Three rockpool stations were sampled (Table 1). All were close to East Cape, at Lottin Point (E06) and Hick's Bay (E11 and E13), reflecting poor sampling weather for sublittoral stations at the time, and the high degree of exposure of the area. A total of 23 fish species were recorded (range 9–20 species per station); all extended into the shallow sublittoral and none were confined to the intertidal rockpool habitat.

Station E06 comprised four small pools at mid-tide level 0.5 m deep, with little habitat structural diversity. A total of 104 fish specimens, 21–127 mm SL, were collected, dominated by the twister (*Bellapiscis medius*, n = 30), olive rockfish (*Acanthoclinus fuscus*, n = 23) and common triplefin (*Forsterygion lapillum*, n = 15). Station E11 was similar to E06, but with slightly more broken rock and turfing coralline algae present. A total of 165 fish specimens, 18–159 mm SL, were collected, dominated by the robust triplefin (*Grahamina capito*, n = 61), twister (n = 41), olive rockfish (*Acanthoclinus fuscus*, n = 19) and juvenile spotty (*Notolabrus celidotus*, n = 19). These fishes are intertidal specialists able to tolerate extremes of environmental conditions and restricted habitat (Paulin & Roberts 1992).

Station E13 was a much larger pool (1 m deep), located in the lower intertidal zone, and had a greater diversity of rocky habitat and algae than those sampled in E06 and E11. This was reflected by larger numbers of species (n = 20) and specimens collected (n = 380) with a greater number of larger (12–379 mm SL) fishes. Species taken in greatest numbers were the common triplefin (*Forsterygion lapillum*, n = 149), longfinned triplefin (*Ruanoho decemdigitatus*, n = 45), variable triplefin (*Forsterygion varium*, n = 39) and juvenile spotty (*Notolabrus celidotus*, n = 32).

4.1.2 Estuarine fish fauna

A single estuarine stony sand-flat station (E48) was sampled in Ohiwa Harbour at the end of the 1999 survey. A total of 13 fish species and 196 specimens were collected. The majority of fishes were small (21–83 mm SL), but a few attained a large size, e.g. kahawhai (*Arripis trutta*, 350–450 mm SL, released) and the soft bottom specialists: shortfinned worm eel (*Scolecenchelys australis*, 401 mm TL), spotted stargazer (*Genyagnus monopterygius*, 72–125 mm SL), and yellowbelly flounder (*Rhombosolea leporina*, up to 377 mm SL). Other soft-bottom specialists taken were: estuary stargazer (*Leptoscopus macropygus*), speckled sole (*Peltorhampus latus*), sand flounder (*Rhombosoleia plebia*). Numerically dominant species were the schooling species yelloweyed mullet (*Aldrichetta forsteri*, n = 71) and *Girella tricuspidata* (n = 25); and the benthic species exquisite goby (*Favonigobius exquisitus*, n = 37) and robust triplefin

Grahamina capito (n = 19). A single striped clingfish (*Trachelochismus melobesia*, n = 1) and a few estuarine goby (*F. lentiginosus*, n = 4) were also collected. The estuarine triplefin (*G. nigripenne*) was not collected, due to relatively high salinity at the sample station and the low volume of freshwater entering the harbour (King et al. 1985). The presence of high salinity was further supported by the capture of striped clingfish and spotted stargazer, which are primarily marine and intolerant of low salinities.

4.2 SURVEY AREA ACCOUNTS

To better describe the diversity of fishes and help test hypotheses about East Cape as a biogeographic boundary, the ECR was divided into four areas: East Coast (south of East Cape to Poverty Bay); coastal Bay of Plenty (west of East Cape to Whakatane); Bay of Plenty inshore islands (Whale Island and Rurima Islets); and Bay of Plenty offshore islands (White Island and Volkner Rocks) (Fig. 2). These four areas were sampled at different times throughout the survey period. Most coastal stations were sampled during the 1992 and 1993 surveys; and most island stations were sampled during the 1998 and 1999 surveys. If the East Cape was a biogeographic boundary, then major differences should have been found between the fish fauna on either side of that boundary. Conversely, if there is no boundary present in the East Cape Region surveyed, then few or no major differences would be expected to be found between the areas, especially the two relatively well-sampled East Coast and coastal Bay of Plenty areas.

4.2.1 East Coast

A total of 13 stations at 0–21 m depth were sampled along the East Coast, three in March 1992 (E15–E17) and 10 in January 1993 (E18–E23, E27–E30); station locations are plotted in Fig. 1. Fish species diversity ranged from 16–33 recorded per station, with 9–30 collected per station. A total of 91 marine fish species in 72 genera and 43 families were recorded from this area (Appendix 1). These included 16 species recorded from the Te Tapuwae O Rongokako Marine Reserve (E16, 0–1.5 m depth), which was sampled by rotenone and snorkel at low tide (prior to its gazetting in 1999).

Sample sites had high to moderate exposure to swell and onshore winds, flat low tide rock platforms with stones and boulders, sand and pebbles; hard sandstone and softer mudstone (papa) reefs extended into the sublittoral. Shallow (0–5 m) reefs supported macroalgae stands, including *Carpophyllum flexuosum, C. maschalocarpum, Cystophora retroflexa, Hormosira banksii, Lessonia variegata*; and an understorey with *Caulerpa* spp., *Zonaria turneriana,* and coralline turf. Deeper (6–21 m) reefs, boulders and rocks supported patches of macroalgae, including *Ecklonia radiata* and *Carpophyllum flexuosum*; hard reef with gutters and rock jumbles held sponges, bryozoan clumps, rock lobster *Jasus edwardsii*, and kina barrens with *Evechinus chloroticus*. Some exposed sites, often associated with papa rock, had a high sediment load in the water, severely reducing visibility.

The most common reef fishes (most frequent and abundant) were eight cryptic species: red scorpionfish (*Scorpaena papillosa*), and a suite of seven triplefins (*Forsterygion lapillum*, *F. varium*, *Notoclinops caerulepunctus, N. segmentatus*, *Notoclinus compressus, Ruanoho whero*, *R. decemdigitatus*); and four larger, more visible species: spotty (*Notolabrus celidotus*), scarlet wrasse (*Pseudolabrus miles*), marblefish (*Aplodactylus arctidens*) and rockcod (*Lotella rhacina*).

4.2.2 Coastal Bay of Plenty

A total of 18 stations at 0–21 m depth were sampled in the coastal BOP: 11 in April 1992 (E01–E05, E07–10, E12, E14), and 7 in January 1993 (E24–E26, E31–E34). Station locations are plotted in Fig. 1. Fish species diversity ranged from 15 to 43 recorded per station, with 14–38 collected per station. A total of 102 marine fish species in 79 genera and 42 families were recorded from this area (Appendix 1).

Marine sample sites had from high to moderate exposure to swell and onshore winds, extensive hard reefs, with complex broken structure with holes, gutters and fractures, cliffs, and rock jumbles with patches of fine sand extending from low tide to over 21 m depth. Shallow (0–5 m) sublittoral reefs were covered with stands of macroalgae, such as *Carpophyllum maschalocarpum, Cystophora torulosa, Ecklonia radiata*, and an understorey of *Zonaria turneriana*, coralline turf, and crustose coralline algae. Deeper (6–21 m) subtidal areas had dense stands of macroalgae, including *Ecklonia radiata* and mixed stands of *Carpophyllum, Cystophora* spp., and *Lessonia variegata*; invertebrates included sponges *Ancorina alata,* crabs *Plagusia chabris,* rock lobster *Jasus edwardsii,* sea cucumber *Stichopus mollis*, bryozoan clumps, and kina *Evechinus chloroticus*. The seawater was generally clear, with good visibility for collecting, except during periods of high onshore wind.

The most common reef fishes were 8 cryptic species: slender roughy (*Optivus elongatus*), red scorpionfish (*Scorpaena papillosa*), a suite of 7 triplefins (*Forsterygion lapillum, F. varium, Notoclinops segmentatus, Notoclinus compressus, N. fenestratus, Ruanoho decemdigitatus, R. whero*), and orange clinid (*Ericentrus rubrus*); and 4 larger, more visible species: spotty (*Notolabrus celidotus*), red moki (*Cheilodactylus spectabilis*), rockcod (*Lotella rhacina*) and rough leatherjacket (*Parika scaber*).

4.2.3 Inshore Bay of Plenty islands

These inshore islands (8–9 km off the coast) were sampled at 7 stations at 5–17 m depth: 3 in June 1998 (E35–E37) and 4 in April 1999 (E41–E42, E46–E47). Station locations are plotted in Fig. 2A. Fish species diversity ranged from 34–40 recorded per station, with 20–32 collected per station. A total of 71 marine fish species in 59 genera and 36 families were recorded from this area (Appendix 2).

Extensive reef areas were dominated by large boulders, many with deep undercuts and caves, and surrounded by sandy gravel. Boulder tops were covered in a dense forest of the macroalgae *Ecklonia radiata* and *Carpophyllum* spp.; the sides with sponges *Ancorina* and *Polymastia* spp., brachiopods, turbanshell *Cookia*, and kina. Although the area is very exposed

to surge from ocean swell, water movement was substantially dampened within the main reef areas. Underwater visibility was good, but reduced by suspended sediment.

The most common reef fishes were 11 cryptic species: grey brotula (*Bidenichthys beeblebroxi*), northern bastard cod (*Pseudophycus breviuscula*), slender roughy (*Optivus elongatus*), red scorpionfish (*Scorpaena papillosa*), stout rockfish (*Acanthoclinus marilynae*), and a suite of 7 triplefins (*Forsterygion flavonigrum, F. malcolmi, F. varium, Karalepis stewarti, Notoclinops segmentatus, Obliquichthys maryannae, Ruanoho whero*); and 4 larger, more visible species: spotty (*Notolabrus celidotus*), red moki (*Cheilodactylus spectabilis*), twospot demoiselle (*Chromis dispila*), and rough leatherjacket (*Parika scaber*).

4.2.4 Offshore Bay of Plenty islands

These offshore locations (50–55 km off the coast) were sampled at 6 stations at 5–20 m depth: 3 in June 1998 (E38–E40) and 3 in April 1999 (E43–E45). Station locations are plotted in Fig. 2B. Fish species diversity ranged from 32–44 recorded per station, with 19–27 collected per station. A total of 67 marine fish species in 55 genera and 33 families were recorded from this area (Appendix 3).

Reefs form substantial stacks and undercut cliffs with large gutters filled with boulders and rocks. The reefs and tops of boulders are covered with stands of macroalgae, including *Ecklonia radiata*, *Carpophyllum* spp., and *Lessonia variegata*. Cliff faces and the sides of boulders supported a variety of invertebrates, including cup corals, crinoids and kina. There was moderate to very high exposure to oceanic swell and wind; and strong currents present around headlands. The seawater was generally very clear, but visibility was reduced substantially in some areas when fine sediment (volcanic ash) was disturbed by divers.

The most common reef fishes were 11 cryptic species: pink brotula (*Brosmodorsalis persicinus*), slender roughy (*Optivus elongatus*), red scorpionfish (*Scorpaena papillosa*), halfbanded perch (*Hypoplectrodes* sp. B), stout rockfish (*Acanthoclinus marilynae*), a suite of 5 triplefins (*Forsterygion lapillum*, *Karalepis stewarti*, *Notoclinops caerulepunctus*, *N. segmentatus*, *N. yaldwyni*), and pygmy sleeper (*Thalasseleotris iota*); and 6 larger more visible species: beardie (*Lotella phycis*), sweep (*Scorpis lineolata*), blue maomao (*S. violacea*), twospot demoiselle (*Chromis dispila*), red pigfish (*Bodianus unimaculatus*), and rough leatherjacket (*Parika scaber*).

4.3 FISH DIVERSITY

4.3.1 Cumulative species graphs

The cumulative numbers of marine fish species recorded in the East Cape Region are graphed in Figs 3 and 4.

Coastal East Cape Region—The number of species recorded increased rapidly during the first 9 sample stations, and then continued to increase at a slower, but consistent rate for the remaining 25 stations (Fig. 3). The last 3 stations

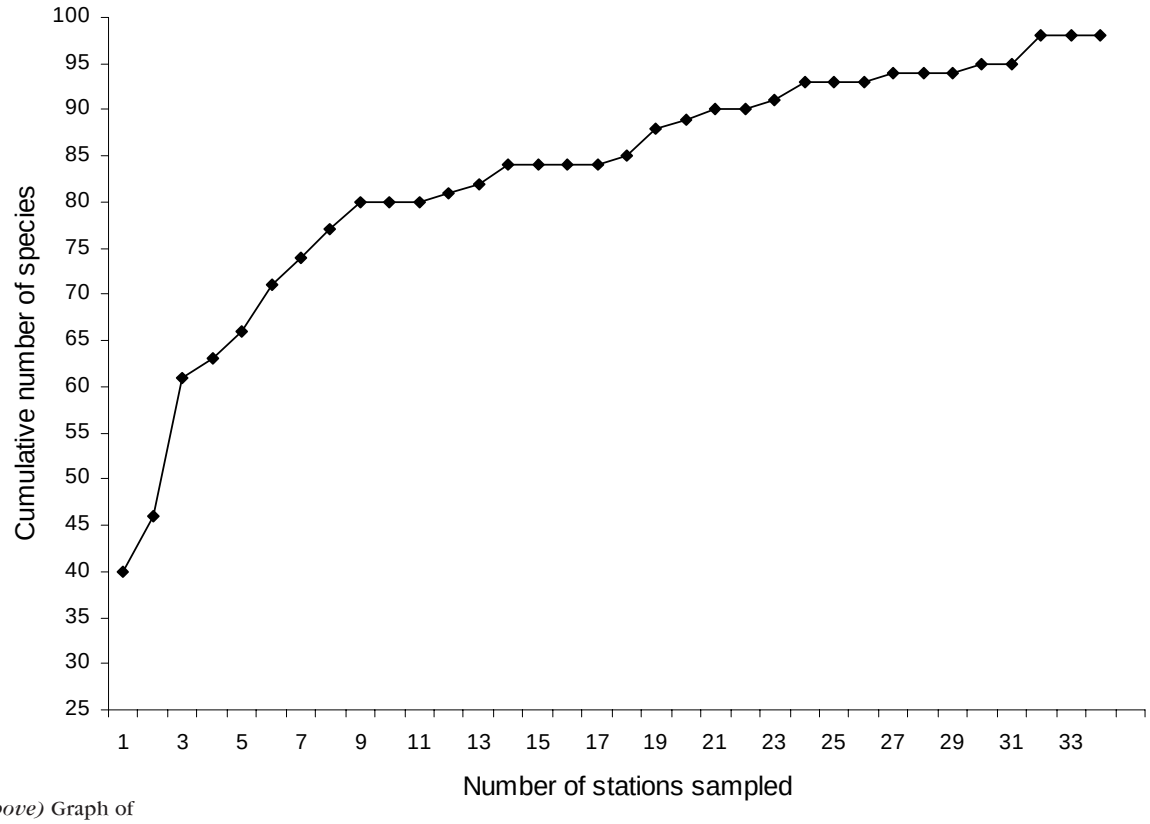
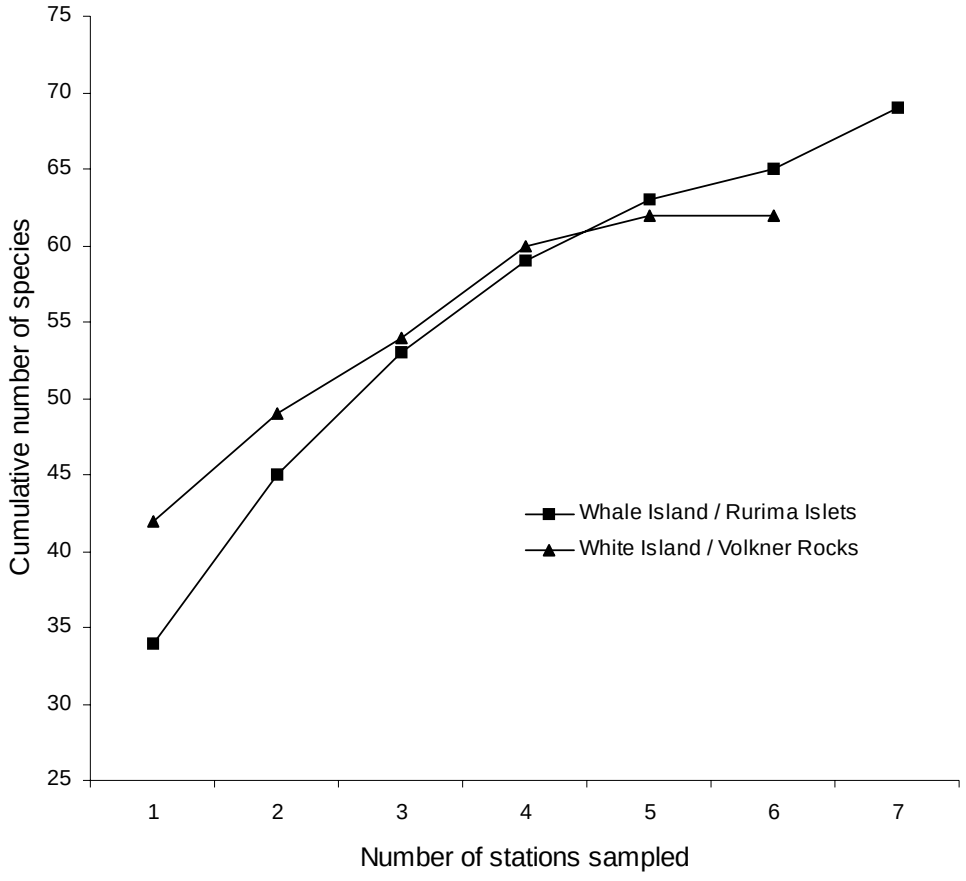


Figure 3. *(Above)* Graph of cumulative numbers of reef fish species recorded in the coastal East Cape Region (coastal BOP and East Coast).

Figure 4. *(Right)* Graphs of cumulative numbers of reef fish species recorded in Bay of Plenty island survey areas (Whale Island area = nearshore; White Island area = offshore).



showed no further increase in numbers of species (maximum of 97 spp.), indicating the start of an asymptote. The cumulative species curve suggests that sampling intensity was adequate to reflect the species diversity present in coastal reefs of the ECR. What is remarkable about this graph is that it shows the considerable effort required (over 30 sample stations) to adequately describe the high species diversity in this 300 km coastal area. Further sampling, will no doubt discover additional species, as indicated by the presence of several fish species in the NFC, but not collected from the area during this survey; e.g. mado (*Atypichthys latus*), bluntnose clinid (*Cologrammus flavescens*), and slender boxfish (*Polyplacapros tyleri*) (Appendix 1).

Bay of Plenty islands—The cumulative species curves for the two island areas are similar (Fig. 4). The first and last stations of each island group are slightly different, but both curves show a fast rate of increase to at least the fifth sample station. The curve for the Whale Island area continues unchanged to the seventh station (maximum of 69 spp.), whereas the curve for the White Island area flattens at the sixth station (maximum of 62 spp.). Neither curve shows a clear indication of reaching an asymptote, suggesting that sampling intensity was not adequate to capture the full diversity of reef fishes likely to be present in the two areas. Several additional species were added from records based on the NFC at Te Papa. Sampling additional sites in these island groups would therefore almost certainly produce more fish species. Because the area of each is relatively small, the number of additional sample stations required is unlikely to be as large (30+) as suggested by the curve for the East Cape Region (Fig. 3). However, sampling these locations is logistically difficult and expensive, requiring a team of divers to live aboard a large charter vessel for several days. The present sample data are, therefore, used for these analyses, but interpreted with caution because fish diversity higher than that found so far is probably present within these two areas.

4.3.2 Species diversity with effort, depth, and area

Effort—Collecting and recording effort is measured here simply as the cumulative number of diver hours spent working underwater at each sample station, either on snorkel or scuba. Effort varied between 1.5–6.6 (mean 4.1) hours per station, with most variability the result of numbers of divers available, efficiency of rotenone, diversity of reef habitat, diversity of fishes present, and water clarity. It is probable that the variability in numbers of species collected and recorded is a good measure of the actual diversity present, because the collecting methodology aims for total collection of samples, which is generally achieved. For all stations, sampling effort continued well past the time that the last species was collected or recorded. Nevertheless, as might be expected there is a general trend for more fish species to be recorded (and collected) with more sampling effort (Fig. 5A and B). However, that does not necessarily mean that more effort (time spent sampling) at a station will translate into more fish species. Rather, the sampling methodology using relays of divers enables sufficient flexibility of effort so that the numbers of fish species present can be sampled until most have been either collected or recorded, regardless of low or high diversity. Deeper than about 25 m this relationship breaks down, as scuba divers have less time to work (less air at increased pressure and less time on

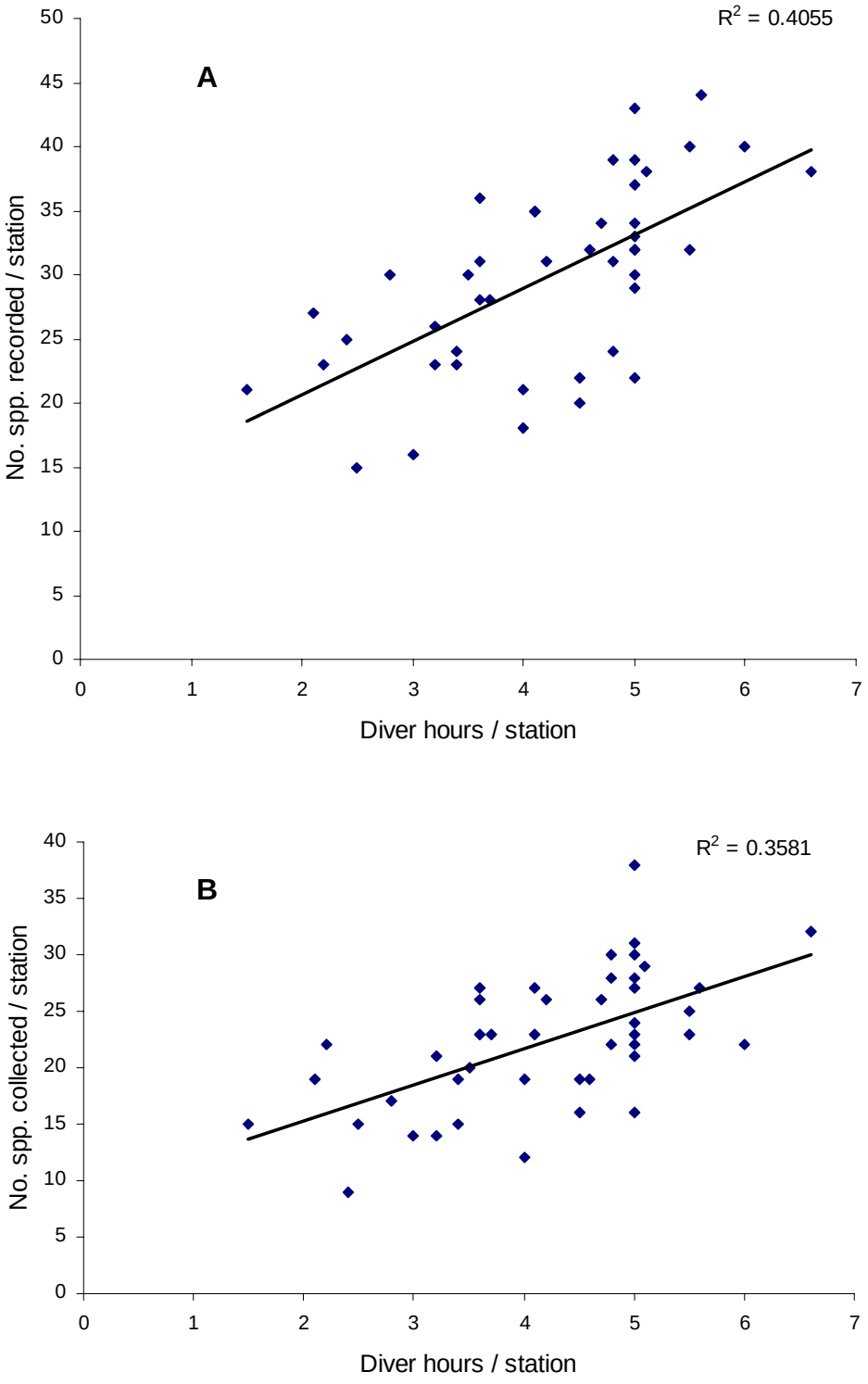
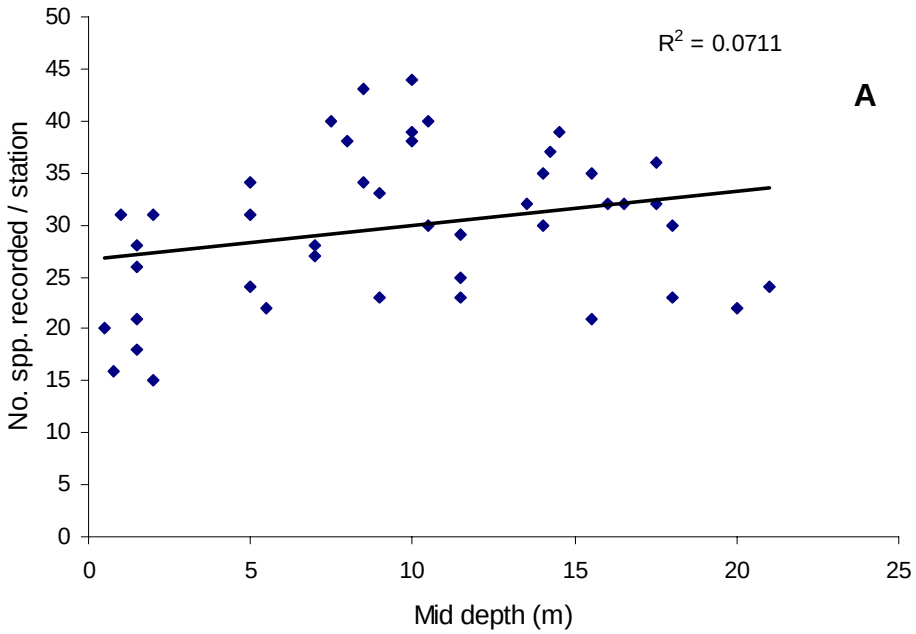


Figure 5. Scatter graphs showing relationship between sampling effort and number of fish species. **A**. Recorded per station. **B**. Collected per station.

dive tables), and more relays of diver pairs would be needed to collect and record an accurate number of species.

Depth—Based on data from 44 marine sample stations in the East Cape Region sampled by divers at 0–21 m (mean 10.8 m) depth, there appears to be no clear relationship between species diversity and depth. The trend line in a plot of the number of species recorded per station and mid depth (Fig. 6A) shows a slight increase in species with depth, but this trend has a poor correlation (R^2 =



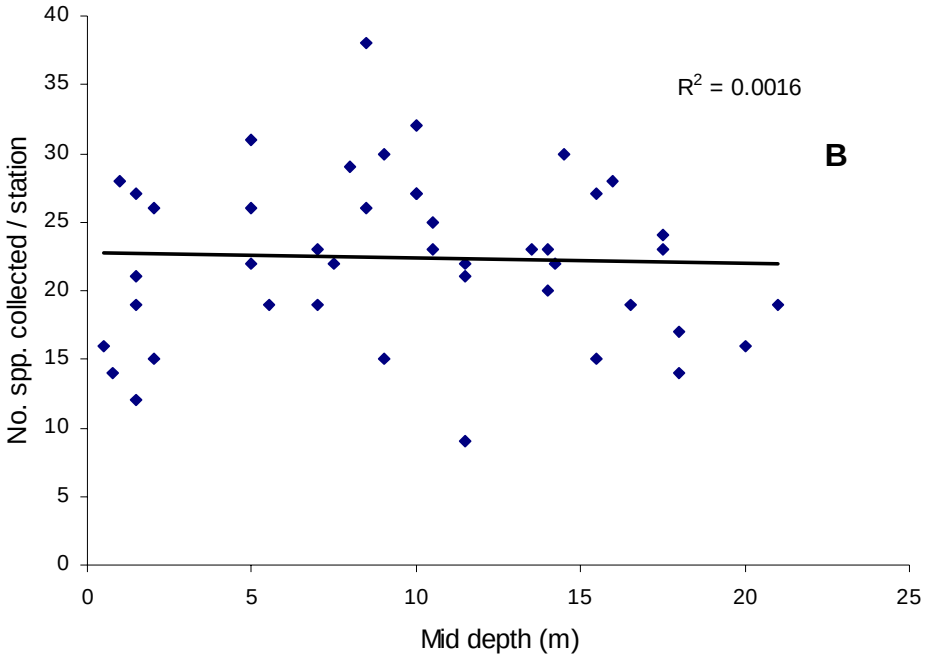


Figure 6. Scatter graphs showing relationship between depth (station mid depth) and number of marine fish species. **A**. Recorded per station. **B**. Collected per station.

0.071) with the data. For the number of species collected per station (Fig. 6B) there is a near horizontal trend line and very low correlation ($R^2 = 0.002$) with the data, which has wide scatter. The observation that slightly fewer species are recorded at 0–5 m is probably due to the greater difficulty in observing fishes (= numbers recorded) in shallow water, due to a combination of lower visibility due to wave action, less bottom time on snorkel and less area in view, than at the deeper stations. The wide scatter of values plotted (Fig. 6A and B), are almost certainly the result of variability in collector efficiency and habitat variability.

Area—Four main areas in the ECR were surveyed during the 1992–1999 period. Two areas, East Coast and coastal BOP, were contiguous along c. 300 km of

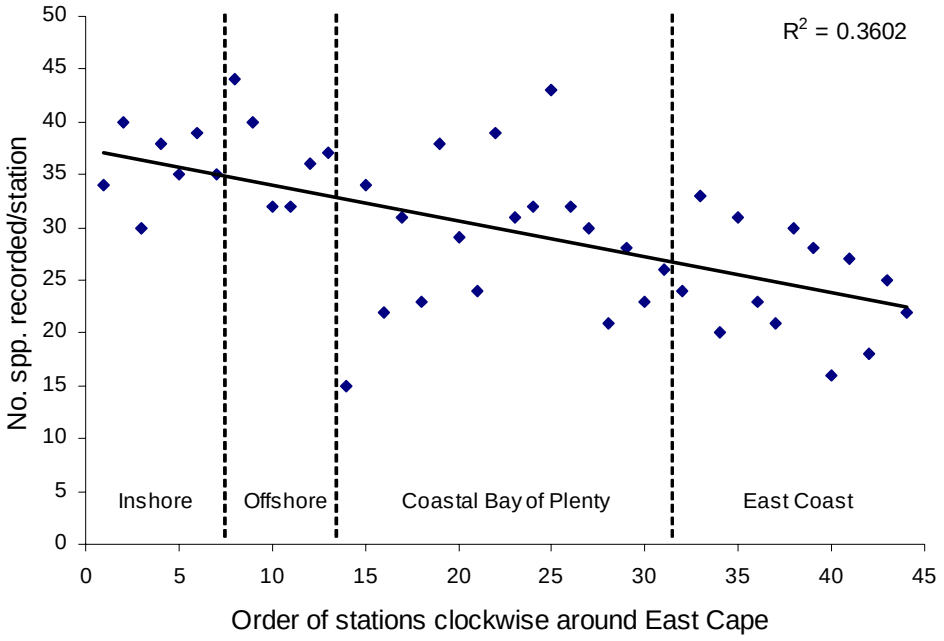


Figure 7. Scatter graph showing relationship between East Cape Region location and marine fish species recorded per sample station (N = 44). Dashed vertical lines separate four areas: Inshore = Rurima Islets and Whale Island; Offshore = Volkner Rocks and White Island; coastal BOP = Maraetai Bay–Horoera Point; East Coast = Waipiro Bay–Poverty Bay.

coastline either side of East Cape, extending from Poverty Bay to Whakatane; and two were island groups located inshore and offshore within the eastern BOP. All areas had extensive reef habitats that were generally rich in algae and invertebrates. Such habitats usually support a rich and diverse fish fauna, and indeed 15–44 (mean 29.5) fish species were recorded per station. A plot of fish diversity recorded for 44 marine stations ordered from west to south around East Cape (Fig. 7), shows a trend line of decreasing species numbers from the BOP to Poverty Bay. There is a reasonably good spread of stations within the area and a moderate amount of scatter, as reflected in a correlation of $R^2 = 0.36$. Therefore, diversity of reef fishes decreases with increasing distance around and south of East Cape, in the descending order of BOP islands, coastal BOP, East Coast. The station with the greatest number of reef fishes was at Volkner Rocks (E38) with 44 species recorded (27 collected and a very high 17 observed) (Table 3). The second highest was at Lottin Point (E09) with 43 fish species recorded (based on a very high 38 collected and 5 observed) (Table 1).

4.3.3 Statistical differences between survey areas

Significant differences in species diversity (total number of species present) were detected between the four survey areas (ANOVA: $F_{(3,40)} = 9.39$, p.= 0.0008). Individual area differences were also detected using *post hoc* Tukey tests (Table 5). Analyses of the means and standard deviations of fishes recorded indicated that the East Coast and coastal Bay of Plenty pair were not significantly different. The number of fishes recorded on the East Coast differed significantly from White Island and Volkner Rocks (p = 0.0006) and Whale Island and Rurima Islets (p = 0.0009). Coastal Bay of Plenty differed significantly from White Island and Volkner Rocks (p = 0.003), but did not differ from Whale Island and Rurima Islets (p = 0.052).

Significant differences in species composition were detected between the four survey areas. Comparisons of six area pairs showed close agreement between

TABLE 5. SUMMARY OF MEAN NUMBERS (AND STANDARD DEVIATION) OF FISH SPECIES PRESENT PER STATION DURING THE EAST CAPE AREA STUDY, ORDERED BY INCREASING SPECIES RICHNESS.*

AREA	YEAR	NUMBER OF STNS	MEAN NO. SPP. PER STN (S.D.)	TUKEY TEST†
East Coast	1992/93	13	24.2 (5.15)	a
Coastal Bay of Plenty‡	1992/93	18	28.9 (7.20)	a, c
Whale Island and Rurima Islets	1998/99	7	35.9 (3.44)	b, c
White Island and Volkner Rocks	1998/99	6	36.8 (4.67)	b

* Tukey *post hoc* test shows statistically significant differences between areas.
† Areas that have the same letter do not differ from one another at the 5% level using Tukey *post hoc* tests.
‡ Excluding three rockpool stations (E06, E11, E13) and one estuary station (E48).

their similarity/dissimilarity values and Jaccard's Index (Table 6). The area pair with the most similar species composition was coastal BOP and East Cape (73 spp. shared); the least similar was White Island and Coastal BOP (47 spp. shared). These data fall into three groups (in increasing similarity order): White Island–Coastal BOP and White Island–East Coast (both 0.46 JI); White Island–Whale Island, Whale Island–East Coast and Whale Island–Coastal BOP (0.57–0.61 JI); and Coastal BOP–East Coast (0.79 JI) (Table 6). These results for species composition closely mirror those for species diversity comparisons between the four areas. Hence, East Coast and Coastal BOP were independently found to be most similar in reef fish diversity and composition.

4.3.4 Taxonomic diversity

Fishes recorded from the ECR are mostly bony fishes (Division Teleostei, 145 species) with just 3 cartilaginous species (Class Chondrichthys) observed. The most speciose families of fishes were: triplefins (Tripterygiidae, 19 spp.), clingfishes (Gobiesocidae, 9 spp.), wrasses (Labridae, 6 spp.), perches (Serranidae, 5 spp.) and drummers (Kyphosidae, 5 spp.); 4 families (Moridae, Sygnathidae, Scorpaenidae, Plesiopidae) had 4 species; 4 families (Bythitidae, Cheilodactylidae, Pomacentridae, Clinidae) had 3 species; 6 families had 2 species; and 22 had one (Appendices 1–3). The dominance of triplefins and clingfishes is characteristic of the New Zealand costal reef fish fauna (Paulin & Roberts 1992, 1993; Willis & Roberts 1996; Roberts et al. 2005, in press).

TABLE 6. PAIR-WISE COMPARISONS OF REEF FISHES BETWEEN FOUR SURVEY AREAS IN THE EAST CAPE REGION.

AREA PAIR	SPECIES PER AREA	TOTAL SPP.	SIMILARITY, SPP. SHARED (%)	DISSIMILARITY, SPP. NOT SHARED (%)	JACCARD'S INDEX
White Island–Coastal BOP	62, 88	103	47 (45.6)	**56** (54.4)	0.46
White Island–East Coast	62, 77	96	44 (46.3)	51 (53.7)	0.46
White Island–Whale Island	62, 65	81	46 (56.8)	35 (43.2)	0.57
Whale Island–East Coast	65, 77	90	52 (57.8)	38 (42.2)	0.59
Whale Island–Coastal BOP	65, 88	95	58 (61.1)	37 (38.9)	0.61
Coastal BOP–East Coast	88, 77	92	**73** (79.3)	21 (20.7)	**0.79**

Bold = highest similarity/dissimilarity and index values.

TABLE 7. TAXONOMIC DIVERSITY OF MARINE FISH SPECIES SAMPLED IN THE EAST CAPE REGION.

AREA	NUMBER OF STNS	FAMILES	GENERA	SPECIES
East Coast	13	43	72	91
Coastal Bay of Plenty*	18	42	79	102
Whale Island and Rurima Islets	7	36	59	71
White Island and Volkner Rocks	6	33	55	67

* Excluding three rockpool stations (E06, E11, E13) and one estuary station (E48).

A comparison of the taxonomic diversity of families, genera, and species between the four survey areas is given in Table 7. The values indicate two groupings: a coastal group of coastal BOP (42 families: 79 genera: 102 spp.) and the East Coast (43: 72: 91); and an island group comprising inshore BOP islands (36: 59: 71) and offshore BOP islands (33: 55: 67). The coastal group has a slightly higher ratio of species to families (2.1 and 2.4 respectively by area) compared to the island group (both 2.0). Ratios of genera to families in the four areas are very similar (1.7–1.9 and 1.6–1.7 respectively by area). In general, the level of taxonomic diversity follows that of species diversity, but taxonomic diversity is almost certainly affected by the total number of stations sampled, especially where sampling effort was not adequate to reflect species diversity (such as the two island areas).

4.4 ICHTHYOFAUNAL COMPOSITION

4.4.1 Species numbers and composition

Relatively few differences were found in species numbers and ichthyofaunal composition between the two coastal areas. In contrast, substantial differences were found between coastal and island areas surveyed. For example, differences in species numbers between coastal and island areas can be seen in the five most speciose fish families (Table 8).

Hence, the two coastal areas were richer overall (35–37 spp., cf. 25–26 spp. and had greater diversity of triplefins and clingfishes. Inshore BOP islands were similar to coastal areas in numbers of wrasses, perches, and drummers. The offshore BOP islands were slightly richer in wrasses and perches.

TABLE 8. DIFFERENCES IN SPECIES NUMBERS BETWEEN COASTAL AND ISLAND AREAS SURVEYED FOR THE FIVE MOST SPECIOSE FISH FAMILIES IN THE EAST CAPE REGION.

FAMILY (TOTAL NO. SPP.)	EAST COAST	COASTAL BOP	INSHORE ISLANDS*	OFFSHORE ISLANDS†
Triplefins, Tripterygiidae (19)	18	19	11	11
Clingfishes, Gobiesocidae (9)	8	8	5	3
Wrasses, Labridae (6)	4	4	4	5
Perches, Serranidae (5)	2	2	2	4
Drummers, Kyphosidae (5)	3	4	4	2

* Whale Island and Rurima Islets.

† White Island and Volkner Rocks.

In addition to species diversity, species composition can be very different between areas. The greatest difference in composition was seen between the two coastal areas and the two island areas. In triplefins, the main cause of difference was an absence of a suite of species at both the inshore and offshore sites (*Belapiscis lesleyae*, *B. medius*, *Blennodon dorsale*, *Cryptichthys jojettae*, *Gilloblennius tripennis*, *Grahamina* spp., *Notoclinus fenestratus*, *Ruanoho decemdigitatus*). Clingfishes were similarly less abundant at island sites (e.g. *Diplocrepis puniceus*, *Gastroscyphus hectoris*, *Trachelochismus pinnulatus* were absent), although the Whale Island area had two species (*Modicus minimus*, *Haplocylix littoreus*) that were not present at White Island and Volkner Rocks.

Major differences in composition in the wrasses, perches, and drummers were hidden by numbers alone because several species present at the BOP islands (in particular the offshore sites) were absent from the coastal areas. For example, the following fishes were present in the White Island area, but absent elsewhere in the ECR: *Acanthistius cinctus*, *Caprodon longimanus*, *Hypoplectrodes* sp. B (Serranidae); *Coris sandayeri*, *Notolabrus inscriptus* (Labridae); *Gymnothorax porphyrus* (Muraenidae); *Lotella phycis* (Moridae); *Chromis hypsilepis* (Pomacentridae), *Canthiogaster callisterna* (Tetraodontidae).

4.4.2 Dominant and abundant species

Contributing to changes in faunal composition between areas are changes in the suite of dominant and frequently occurring reef fish species. The 10 most numerous and frequently recorded species in each survey area are shown in Table 9. The red scorpionfish and blue-eyed triplefin were most frequently taken in all four areas; the variable, spectacled and common triplefins occurred in three survey areas, being present in the two coastal areas but absent from one or other of the island areas. Most of these more numerous and frequently occurring fish species occurred in two or more areas and were widespread within the coastal ECR. Hence the dominant reef fish faunas of the East Coast and the coastal BOP were very similar in numbers and frequency of capture. No species were confined to either of the two coastal regions. In contrast, dominant reef fishes in the island areas included some different species (e.g. stout rockfish *Acanthoclinus marilynae*, twospot demoiselle *Chromis dispila*) or species that are either unique (beardie *Lotella phycis*, halfbanded perch *Hypoplectrodes* sp. B) or most abundant (Yaldwyn's triplefin *Notoclinops yaldwyni*) in the offshore island area (Table 9).

4.5 FISH DISTRIBUTIONS

Distribution patterns shown by 107 species of coastal reef fishes recorded during the present study (Appendices 1–3) are summarised below. No fishes could be classified as being unique or endemic to the ECR, or any sub-region within that area; but one has a poorly known distribution. Comparison with distributions defined for the whole New Zealand region (Paulin & Roberts 1993; Francis 1996) showed that most fishes sampled had widespread New Zealand distributions, with a substantial northern component and a few southern species (Table 10).

TABLE 9. TEN MOST NUMEROUS AND FREQUENTLY SAMPLED MARINE REEF FISHES IN THE FOUR SURVEY AREAS OF THE EAST CAPE REGION.

AREA/ RANK*	COMMON AND SPECIES NAME	NO. STATIONS PRESENT	% STATIONS PRESENT
East Coast (13 stns)			
1	Red scorpionfish *Scorpaena papillosa*	13	100
2	Variable triplefin *Forsterygion varium*	12	92
3	Blue-eyed triplefin *Notoclinops segmentatus*	12	92
4	Spectacled triplefin *Ruanoho whero*	11	85
5	Common triplefin *Forsterygion lapillum*	9	69
6	Longfinned triplefin *Ruanoho decemdigitatus*	8	62
7	Brown topknot *Notoclinus compressus*	8	62
8	Spotty *Notolabrus celidotus*	8	62
9	Bluedot triplefin *Notoclinops caerulepunctus*	6	46
10	Orange clinid *Ericentrus rubrus*	4	31
Coastal Bay of Plenty (18 stns)			
1	Red scorpionfish *Scorpaena papillosa*	18	100
2	Variable triplefin *Forsterygion varium*	18	100
3	Spectacled triplefin *Ruanoho whero*	16	89
4	Spotty *Notolabrus celidotus*	14	78
5	Blue-eyed triplefin *Notoclinops segmentatus*	14	78
6	Brown topknot *Notoclinus compressus*	14	78
7	Common triplefin *Forsterygion lapillum*	11	61
8	Longfinned triplefin *Ruanoho decemdigitatus*	11	61
9	Slender roughy *Optivus elongatus*	9	50
10	Orange clinid *Ericentrus rubrus*	8	44
Whale Island area (7 stns)			
1	Red scorpionfish *Scorpaena papillosa*	7	100
2	Variable triplefin *Forsterygion varium*	7	100
3	Spectacled triplefin *Ruanoho whero*	7	100
4	Mottled triplefin *Forsterygion malcolmi*	7	100
5	Leatherjacket *Parika scaber*	7	100
6	Stout rockfish *Acanthoclinus marilynae*	7	100
7	Slender roughy *Optivus elongatus*	6	86
8	Blue-eyed triplefin *Notoclinops segmentatus*	6	86
9	Northern bastard cod *Pseudophycus breviuscula*	6	86
10	Yellowblack triplefin *Forsterygion flavonigrum*	4	57
White Island area (6 stns)			
1	Red scorpionfish *Scorpaena papillosa*	6	100
2	Blue-eyed triplefin *Notoclinops segmentatus*	6	100
3	Stout rockfish *Acanthoclinus marilynae*	6	100
4	Bluedot triplefin *Notoclinops caerulepunctus*	6	100
5	Slender roughy *Optivus elongatus*	6	100
6‡	Beardie *Lotella phycis*	6	100
7	Common triplefin *Forsterygion lapillum*	5	83
8†	Yaldwyn's triplefin *Notoclinops yaldwyni*	5	83
9	Twospot demoiselle *Chromis dispila*	5	83
10‡	Halfbanded perch *Hypoplectrodes* sp. B	4	67

* Rank 1–10 = most numerous to 10th most numerous (sum of specimens collected in area).

† Abundant in one area, a few specimens only taken in other areas.

‡ Unique to one area of survey.

TABLE 10. BIOGEOGRAPHIC GROUPINGS OF REEF FISHES RECORDED FROM THE EAST CAPE REGION, BASED ON 107 MARINE REEF SPECIES.

NEW ZEALAND DISTRIBUTION	EAST CAPE REGION DISTRIBUTION	NUMBER OF SPECIES	PERCENT-AGE
Widespread	On both sides of East Cape	69	64.5
Northern	Northern	35	32.7
Type 1:	BOP offshore islands (not to East Cape)	12	11.2
Type 2:	BOP coastal waters (not to East Cape)	8	7.5
Type 3:	Past East Cape and along East Coast	15	14.0
Southern	East Coast to East Cape	2	1.9
Unknown	Few stations	1	0.9
Total		107	100.0

4.5.1 Northern (n = 35 spp., 32.7%)

Species considered to be northern in distribution occur north of the ECR, but have differing southern limits so may be on both sides of East Cape. These fishes can be categorised into three subgroups: Type 1–3, reflecting increasing southern-most limits, as follows.

Type 1—Northern species recorded at offshore islands, but absent from eastern coastal BOP and the East Coast (Fig. 8A and B). White Island appears to be at the southern-most limit for this group. These total 12 species (11.2% of ECR reef

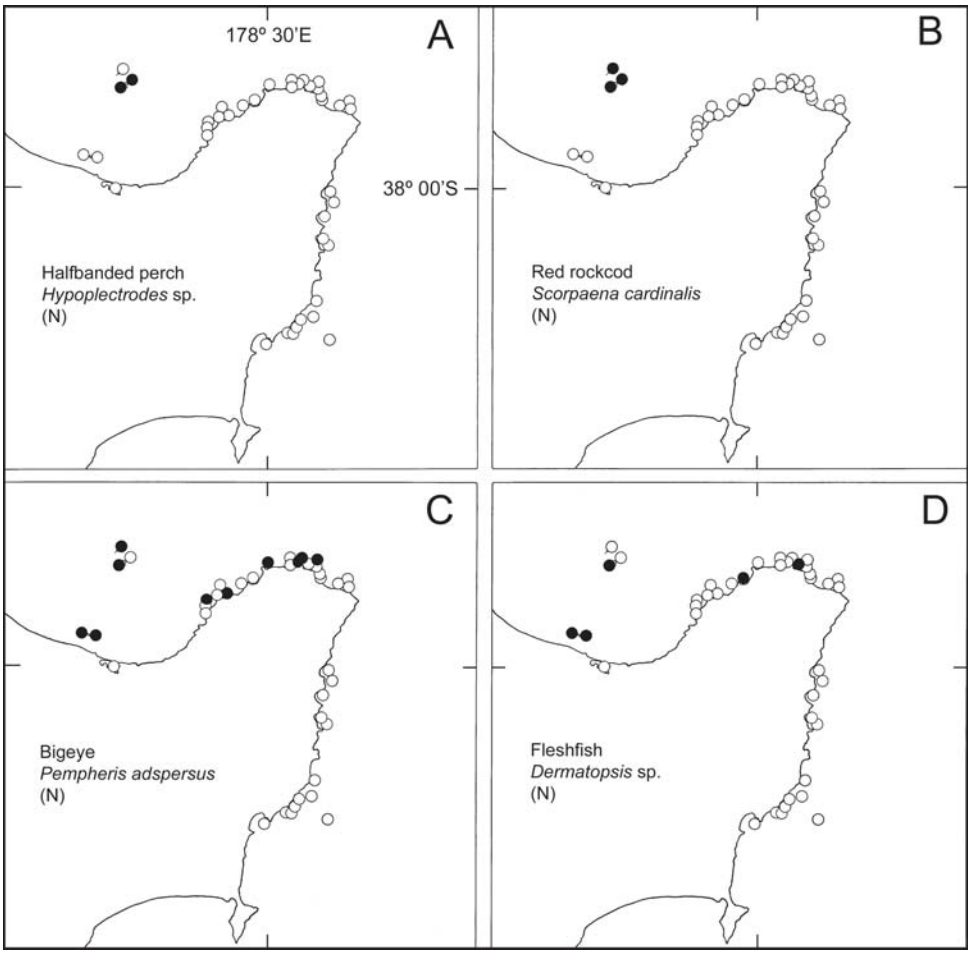


Figure 8. Distributions of Northern (N) reef fishes in the East Cape Region (● = present; ○ = absent from sample stations). **A** & **B**. Northern species Type 1: found at offshore islands. **C** & **D**. Northern species Type 2: not extending past East Cape.

fishes): the lowfin moray (*Gymnothorax porphyreus*), beardie (*Lotella phycis*), Raoul scorpionfish (*Maxillacosta raoulensis*), red rockfish (*Scorpaena cardinalis*), yellowbanded perch (*Acanthistius cinctus*), halfbanded perch (*Hypoplectrodes* sp. B), pink maomao (*Caprodon longimanus*), koheru (*Decapterus koheru*), onespot demoiselle (*Chromis hypsilepis*), green wrasse (*Notolabrus inscriptus*), Sandager's wrasse (*Coris sandayeri*) and the clown toado (*Canthigaster callisterna*).

Type 2—Northern species that occur in coastal BOP, but do not extend beyond East Cape (Fig. 8C and D). These total 8 species (7.5% of ECR reef fishes): yellow moray (*Gymnothorax pracinus*), fleshfish (*Dermatopsis macrodon*), longfin boarfish (*Zanclistius elevatus*), mado (*Atypichthys latus*), silver drummer (*Kyphosus sydneyanus*), red pigfish (*Bodianus unimaculatus*), bluntnose clinid (*Collogramus flavescens*) and bigeye (*Pempheris adspersus*). Two non-reef fishes (not included in the analyses) were the exquisite goby (*Favinogobius exquisitus*) and estuarine goby (*F. lentiginosus*).

Type 3—Northern species that occur in coastal BOP and extend south of East Cape (Fig. 9A–D). These total 15 species (14.0% of ECR reef fishes): northern conger eel (*Conger wilsoni*), grey brotula (*Bidenichthys beeblebroxi*), pink brotula (*Brosmodorsalis persicinus*), northern bastard cod (*Pseudophycis breviuscula*), snapper (*Pagrus auratus*), red mullet (*Upeneichthys lineatus*), parore (*Girella tricuspidata*), blue maomao (*Scorpis violacea*), hiwihiwi (*Chironemus marmoratus*), porae (*Nemadactylus douglasi*), twospot

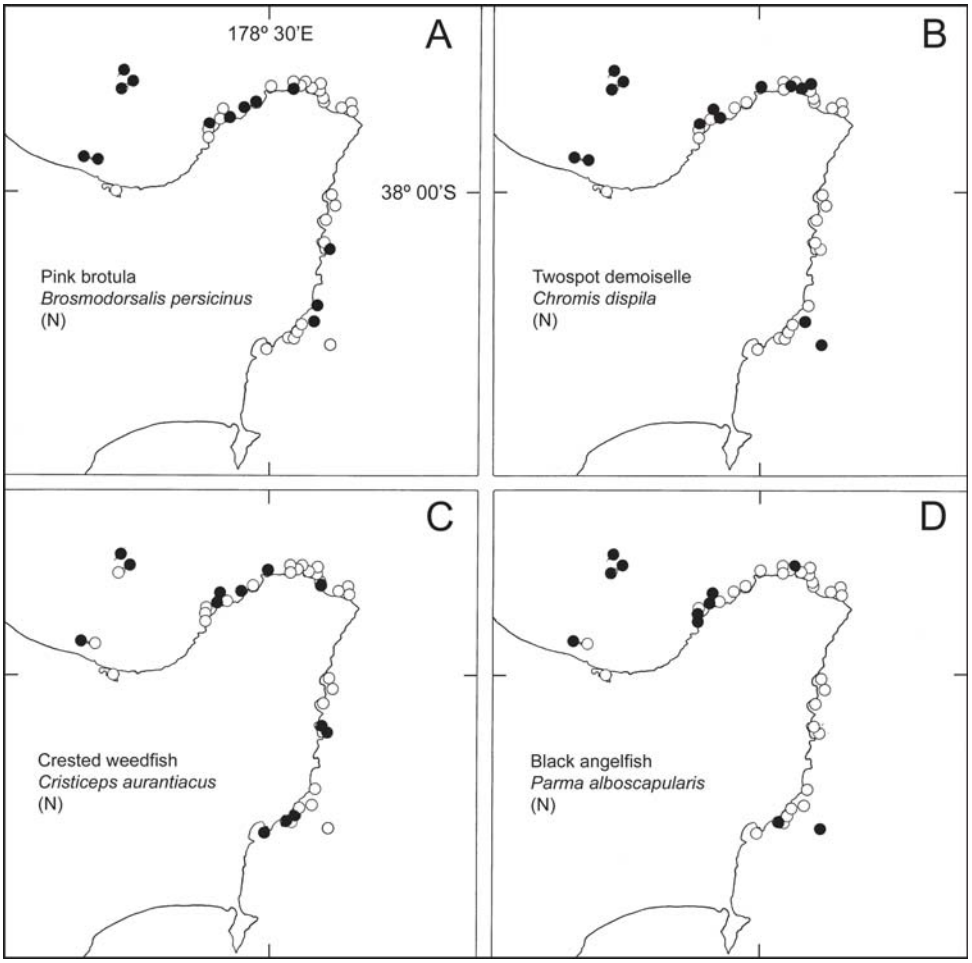


Figure 9. Distributions of Northern (N) reef fishes in the East Cape Region (● = present, ○ = absent from sample stations). **A–D**. Northern species Type 3: all extending south of East Cape.

demoiselle (*Chromis dispila*), black angelfish (*Parma alboscapularis*), clinid (*Cristiceps auranticus*), orange clinid (*Ericentrus rubrus*) and crested blenny (*Parablennius laticlavius*).

4.5.2 Widespread (n = 69 spp., 64.7%)

Species with widespread distributions occur on both sides of East Cape (Fig. 10A and B), and north and south of the ECR. The majority of reef species caught or observed during the study fall into this category. They are benthic (usually cryptic) or demersal (usually free-ranging) and all reef-associated. Benthic examples are: olive rockfish (*Acanthoclinus fuscus*), black rockfish (*Acanthoclinus littoreus*), stout rockfish (*Acanthoclinus marilynae*), common triplefin (*Forsterygion lapillum*), variable triplefin (*Forsterygion varium*), mottled triplefin (*Forsterygion malcolmi*), bluedot triplefin (*Notoclinops caerulepunctus*), blue-eyed triplefin (*Notoclinops segmentatus*), Yaldwyn's triplefin (*Notoclinops yaldwyni*), brown topknot (*Notoclinus compressus*), topknot (*Notoclinus fenestratus*), urchin clingfish (*Dellichthys morelandi*), striped clingfish (*Trachelochisma melobesia*) and lumpfish (*Trachelochisma pinnulatus*). Demersal examples are: tarakihi (*Nemadactylus macropterus*), marblefish (*Aplodactylus arctidens*), spotty (*Notolabrus celidotus*), banded wrasse (*Notolabrus fucicola*), scarlet wrasse (*Pseudolabrus miles*), butterfish (*Odax pullus*) and bluecod (*Parapercis colias*).

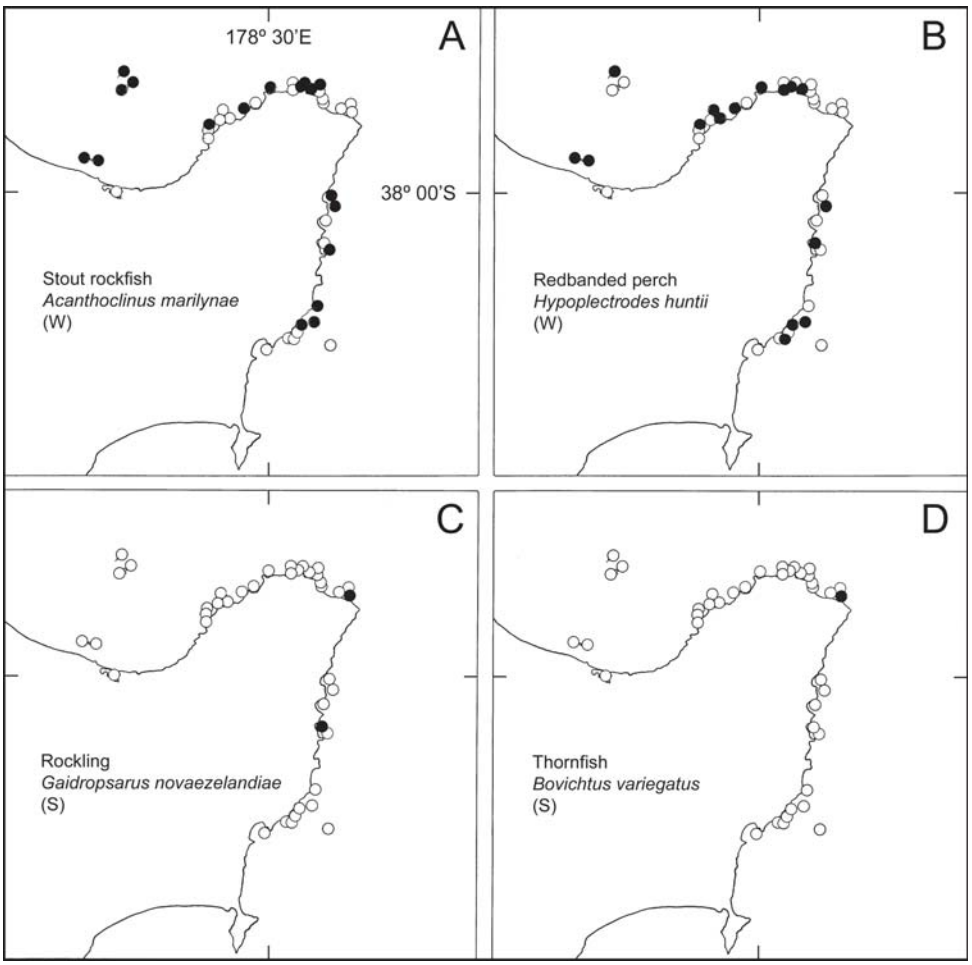


Figure 10. Distributions of reef fishes in the East Cape Region (● = present, ○ = absent from sample stations). **A** & **B**. Widespread species (W): found both sides of East Cape. **C** & **D**. Southern species (S): extending north to East Cape, but not to Bay of Plenty.

4.5.3 Southern (n = 2 spp., 1.9%)

Species with southern distributions occur south of the ECR, and have their northern limit on the East Coast or near East Cape (Fig. 10C and D). Two species (1.9% of ECR reef fishes) recorded during the present study have a southern distribution. The rockling (*Gaidropsarus novaezelandiae*) was taken at two stations, one (E30) at Anaura Bay on the middle East Coast and one (E24) at Horoera Point just north of East Cape. An additional previous record was from station (B2) at Passage Rock, Bare Island, during the 1990–1991 Hawke Bay fish survey (Roberts & Stewart 1992). The thornfish (*Bovichtus variegatus*) was recorded based on a single capture (stn E24) at Horoera Point north of East Cape. The nearest published record for the thornfish is from Tokomaru Bay, East Coast (Hardy 1988), which makes our record at Horoera Point its most northern limit known. Further south, it is relatively abundant off the west coast of the South Island, the outer fiords, Stewart Island, Otago, and the Chatham Islands.

4.5.4 Unknown (n = 1 sp., 0.9%)

The distribution of the spotted pipefish (*Stigmatopora* sp. A) is unknown because of its uncertain taxonomic status. It was taken at 5 stations around East Cape (Appendix 1). Both further field collecting and collection-based research are required to accurately establish its distribution in New Zealand coastal waters.

4.5.5 Northern fishes with southern limit on East Coast

Northern fish species, which extend down the East Coast (see Appendix 1), are important as indicator species that help define the biogeographic nature of the ECR. A total of 15 species of Northern: Type 3 reef fish have been identified during the present study. Several of these are mainly known from juveniles or sub-adults on the East Coast, and have presumably originated from adult populations west of East Cape, in the BOP and beyond. Examples of these, together with an indication of their southern limits, are as follows.

A juvenile northern conger eel (*Conger wilsoni*, Congridae) was captured northeast of Waipiro Bay (stn E27). Another was taken at Paoanui Point, south of Hawke Bay (Roberts & Stewart 1992; stn N02) and represents the southern limit for the species. This northern species had previously been recorded having a southern limit at East Cape (Castle 1964).

Pink brotula (*Brosmodorsalis persicinus*, Bythitidae) was taken near Anaura Bay (stn E29), at the Gables (stn E22) and Monowai Reef (stn E18) (Fig. 9A). All were adult specimens. The capture of a single adult specimen at Mahia Peninsula (Te Papa unpubl.) represents the southern limit of the species along the East Coast.

Juveniles and sub-adult northern bastard cod (*Pseudophycis breviusculus*, Moridae) were recorded near Koutunui Head (stn E28), northeast Waipiro Bay (stn E27), Tatapouri (stn E23) and Tuamotu Island (stn E21). This species extends as far south as Napier on the East Coast (Paulin 1983) and was also taken twice off Paoanui Point, south of Hawke Bay (Roberts & Stewart 1992; stns N02 and N06).

Slender roughy (*Optivus elongatus*, Trachichthyidae) extended as far south as Poverty Bay (stn E21). The capture of a single sub-adult specimen at Mahia Peninsula (Te Papa unpubl.) represents the southern limit of the species along the East Coast.

Juvenile porae (*Nemadactylus douglasi*, Cheilodactylidae) have been recorded at Waipiro Bay (stn E27) and at Pauanui Reef south of Hawke Bay (Roberts & Stewart 1992; stn N02).

Twospot demoiselle (*Chromis dispila*, Pomacentridae) was recorded from Monowai Reef (stn E18) and Ariel Reef (stn E20) off Gisborne (Fig. 9B), which appear to be the southern limit of the species. It was not taken at Mahia Peninsula (Te Papa unpubl. data), nor during the Hawke Bay survey in 1991 (Roberts & Stewart 1992).

Juvenile black angelfish (*Pama alboscapularis*, Pomacentridae) were collected at Tatapouri (stn E17) and seen nearby at offshore Ariel Reef (stn E20) (Fig. 9D). Juveniles were also taken further south at Mahia and Napier in 1991 (Roberts & Stewart 1992), but did not appear to survive the following winter (C. Duffy, DOC Napier, pers. obs.).

Juvenile and sub-adult crested weedfish (*Cristiceps auranticus*, Clinidae) were taken in moderate numbers at 6 stations (E28, E30, E29, E16, E17 and E21) along the East Coast (Fig. 9C). Its southern limit is south of Aramoana, Hawke Bay (Roberts & Stewart 1992; stn N07).

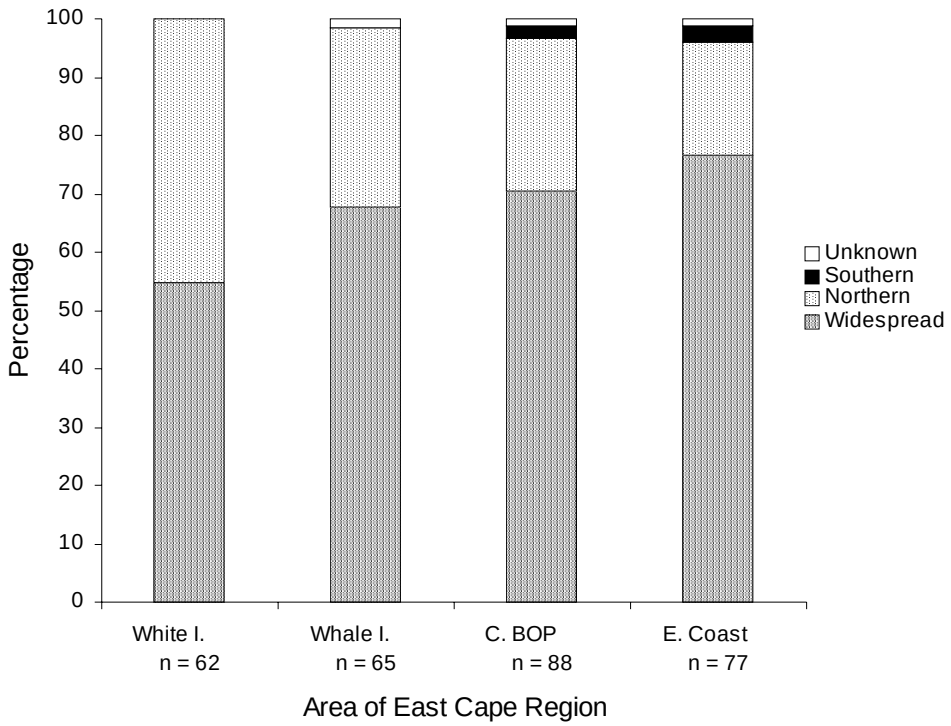
The crested blenny (*Parablennius laticlavius*, Blenniidae) was taken at Tokomaru Bay (stn E15) and extends south of Hawke Bay to Paoanui Point (Roberts & Stewart 1992; stn N02), where it appears to be at its southern limit.

Most of the above northern species also occur in temperate south-eastern Australian waters or/and at the Kermadec Islands. The New Zealand mainland endemic is the pink brotula. No tropical or subtropical species were recorded during the present survey. However, Francis (1996: 44, 2001: 13) listed some additional examples of northern (subtropical and warm temperate) fishes reported to straggle as far as Hawke Bay, for example: yellow moray (*Gymnothorax prasinus*, Muraenidae), pink maomao (*Caprodon longimanus*, Serranidae), and Lord Howe coralfish (*Amphichaetodon howensis*, Chaetodontidae).

4.5.6 Biogeographic composition of reef fish faunas

The biogeographic composition of the reef fish faunas sampled at the four survey areas in the ECR is compared in Fig. 11. The main result is a progressive change with a more-or-less reciprocal increase in widespread species and decrease in northern species. Southern species are present in the East Coast and coastal BOP (just north of East Cape) areas, but not at the BOP islands. The offshore island area (White Island and Volkner Rocks) has the highest number of northern species (45.2%) and lowest number of widespread species (54.8 %), followed by the inshore BOP islands (Whale Island and Rurimu Islets) and coastal BOP, which are similar in composition.

Figure 11. Biogeographic composition of reef fishes in the East Cape Region.



5. Discussion

The main aims of the present study were to survey and sample the coastal reef fish fauna of the ECR between Whakatane and Poverty Bay, to provide baseline knowledge of fish diversity in the form of vouchered station inventories and to seek evidence of the East Cape biogeographic boundary or transition. The Te Papa–DOC surveys carried out during 1992–1999 were the most comprehensive fish surveys to date in the ECR and the results presented here provide a valuable baseline of taxonomic, biodiversity, biogeographic and ecological information with which to assess new sites in the region and to compare changes over time at the same sites.

5.1 FISH DIVERSITY

5.1.1 East Cape Region

The diversity of coastal reef fishes in the ECR is very high. Comparison of mean and ranges of species recorded per sample station with other areas of New Zealand surveyed with similar methods show that all four areas of the ECR have the highest values found to date (Table 11). The numbers of species recorded from stations at the two BOP island areas are exceptionally high, particularly considering the relatively few sample stations collected (6–7). Eight stations worked off Tauranga, in the mid-BOP (Te Papa unpubl. data) only produced a

TABLE 11. NUMBER OF FISH SPECIES RECORDED PER STATION IN THE EAST CAPE REGION AND OTHER COASTAL AREAS OF NEW ZEALAND.

AREA	DEPTH (m)	NO. OF STNS	NO. OF SPP. PER STN		SOURCE
			MEAN	MIN.–MAX.	
Mid-BOP	0–20	8	17.8	6–25	Te Papa unpubl. data (1986)
White Island	5–20	6	**42.7**	32–44	Present study
Whale Island	5–17	7	**35.8**	22–40	Present study
Coastal BOP	0–21	18	**28.9**	15–43	Present study
East Coast	0–21	13	**24.5**	16–33	Present study
Hawke Bay	0–23	18	14.1	5–20	Roberts & Stewart (1992)
Haast–Buller	0–5	8	10.0	3–20	Roberts et al. (2005)
Haast–Buller	6–20	2	20.0	13–26	Roberts et al. (2005)
Cascade–Haast	0–5	10	19.0	15–25	Roberts et al. (2005)
Cascade–Haast	6–20	6	23.0	15–29	Roberts et al. (2005)
Milford Sound	6–25	12	17.8	13–24	Roberts et al. (2005)

Bold = four highest values.

mean of 17.8 and a maximum of 25 species per station. Similarly, 18 stations around Hawke Bay to the south of the ECR produced a mean of 14.1 and a maximum of 20 species per station. On the West Coast of the South Island, reef fish diversity is lower than the ECR, with only Cascade–Haast (6–20 m depth), at mean 23.0 and maximum of 29 species per station, approaching the value for the East Coast (mean 24.5, max. 33 per station), which is the lowest for the ECR (Table 11).

In addition to high numbers of fish species collected per sample station, the total numbers of fishes recorded in each area of the ECR are high when compared to other areas. The East Coast with 91 reef fishes and the coastal (eastern) BOP with 102 species are among the highest known for the North Island (Table 12). Only the number of fish species recorded for the Poor Knights Islands (n = 96) (Russell 1971; Doak 1972) and for the large area encompassing much of eastern Northland and the outer Hauraki Gulf islands (n = 104) (Brook 2002) are of comparable high value. Because of differences in the size of survey areas, different levels and types of effort, and different survey methods employed (observation versus collection), these surveys are not ideal for comparison. Surveys of New Zealand coastal fishes have not been standardized. This can be problematic because visual surveys can seriously underestimate the numbers of crypto-benthic species on the one hand (e.g. Willis 2001), and it is probable that rotenone-based sampling underestimates large benthic and demersal fishes, on the other (C. Roberts, pers. obs.). The results of these two methodologies are not, however, mutually exclusive. On the contrary, they can be complementary, as seen at White Island. The underwater observations on fishes by Grace (1975) together with the rotenone collections made during the present study, give a total of 85 species for White Island and Volkner Rocks.

The four areas of the ECR are rich in fish species (Table 12). The numbers of fishes in the two coastal areas (East Coast, n = 91; coastal BOP, n = 102) and the two island areas of the ECR (Whale Island, n = 71; White Island, n = 85) are

TABLE 12. SURVEYS OF REEF FISHES AROUND THE NORTH ISLAND OF NEW ZEALAND.

AREA	NUMBER OF SPP.	NUMBER OF FAMILES	MAIN METHOD*	SOURCE
Karikari Peninsula	64	33	Obs	Willan et al. (1979)
Poor Knights Islands	76	42	Obs	Russell (1971)
Poor Knights Islands	96	44	Obs	Doak (1972)
Leigh marine reserve	33	13	RO	Willis (2001)
Hen Island	51	25	Obs & RO	Willis (1995)
Three Kings–Gt Barrier Island	104	39	Obs	Brooks (2002)
Aldermen Islands	65	38	Obs	Grace R. (1973)
Tairua (incl. inshore islands)	40	27	Obs	Grace A. (1974)
White Island†	55	29	Obs	Grace R. (1975)
White Island†	67	33	RO & obs	Present study
Whale Island	71	36	RO & obs	Present study
Coastal BOP	102	42	RO & obs	Present study
East Coast	91	43	RO & obs	Present study
Cook Strait (rockpools)	26	9	RO	Willis & Roberts (1996)

* Obs = underwater observations on scuba; RO = rotenone. The order of the two indicates the dominant method.

† The sum of these two lists gives a total of 85 species for White Island.

among the highest numbers recorded in reef fish surveys around the North Island. Given the number of sample stations at the two island areas were not adequate to provide representative samples of the fish fauna (see cumulative species graphs in Figs 3 and 4), it is almost certain that reef-fish diversity at these areas is higher than the present data indicate.

Fish numbers and diversity increases with reef structural diversity in rockpools (Willis & Roberts 1996) and sublittoral reefs (Willis & Anderson 2003). Whilst there is little doubt that an increase in the diversity of rocky reef habitat (e.g. more heterogeneous form, greater number of microhabitats, greater range of biotic dominants such as algae and sponges) will increase the diversity of fishes living there, it seems unlikely that this alone would be responsible for the magnitude of increase in species diversity per station found in the ECR. Other factors are likely to be influencing the fish diversity. One is an increase in northern species progressively around the coast (Fig. 11) and recorded by other fish studies in the region (Paulin & Roberts 1993; Francis 1996); another is the cumulative influences of the warm East Auckland Current and East Cape Current, and the cooler Southland Current in bringing a rich supply of larval fishes into the region. However, probably the most important factor in maintaining a high diversity of fishes and other biota in the ECR is the 'ecotone' or edge effect (Odum 1971) of a transition between the northern New Zealand reef biota and the central New Zealand reef biota (see section 5.2 Biogeographic transition area, below).

5.1.2 New records of fishes for the East Cape Region

Paulin & Roberts (1992) illustrated the distributions of New Zealand rockpool fishes, and gave spot locations on maps for 65 species in the coastal eastern BOP, and 45 species from the East Coast. Paulin & Roberts (1993) provided a

biogeographic analysis of rockpool and sublittoral fringe reef fishes in the two areas: Bay of Plenty (n = 72 spp.) and Gisborne to Hawke Bay (East Coast not included) (n = 64 spp.); their total for the ECR was 77 species of rockpool fishes. Francis (1996) analysed the distributions of reef fishes in the New Zealand region and documented two large biogeographic areas: Cape Maria van Diemen to East Cape (n = 167 spp.) and East Cape to Palliser Bay (n = 115 spp.). His total for the two, which included the ECR, was 177 reef fish species, but the areas were too large to ascertain which species occurred within the ECR. In the present study the biogeographic areas surveyed were smaller and separated into two: coastal BOP (n = 102 spp.) and East Coast (n = 91 spp.). The total for the coastal ECR was 124 reef fishes.

All these studies are in agreement that there are relatively more fishes occurring west of East Cape than south of East Cape, even though there was considerable variation in source of fish records, fish habitats surveyed, and geographic areas grouped.

Most of the present verifiable lists of fishes represent first records for their respective localities and also for the wider area, because very little survey work has been published for the ECR. We estimate that our inventories contain about 40 new records for each of the two coastal areas: coastal BOP and East Coast. The records for Whale Island and Rurima Islets fishes (n = 71 spp.) are all new; about half of the records for White Island and Volkner Rocks fishes (n = 67) are new.

5.1.3 White Island fishes

The reef fishes of the offshore White Island and Volkner Rocks area differed markedly from all the other three areas surveyed. This fish fauna had the highest diversity per sample station (up to 44 species), and was statistically different from all other coastal areas (Table 5), species composition was statistically most dissimilar to all other areas (Table 6) and was distinct in species frequency and abundance (Table 9), having some species unique to that area. This is consistent with a broad pattern of diversity of fishes and other warm temperate-subtropical biota in North-eastern New Zealand where offshore island locations have reef fish communities with richer species composition and abundance than those at inshore islands and coastal areas (e.g. Brook 2002; Choat & Ayling 1987; Jones 1988; Walls 1995). Causative factors are unknown, but include a combination of physical and biotic habitat characteristics, recruitment and settlement patterns (Jones 1988), and larval transport by coastal and ocean currents, in particular the warm East Australian Current (EAC) from subtropical areas such as Norfolk Island (Francis 1996).

The high diversity of fishes has been attributed to the presence of many tropical, subtropical and warm temperate (northern) fishes, in combination with widespread species (Francis 1996). This is clearly true at White Island where about 50% of the fishes belong to these northern species, and about 50% are widespread species. Grace (1975) remarked 'that the incidence of fish species with strong subtropical affinities is high at White Island, as at the Poor Knights and the Aldermen Islands'; 58% of his list comprised northern species. No doubt many of the northern fishes are sourced from northern New Zealand waters in the EAC, some possibly from Norfolk Island, such as speckled moray

(*Gymnothorax obesus*), silver drummer (*Kyphosus sydneyanus*) and onespot demoiselle (*Chromis hypsilepis*). A few subtropical fishes at White Island are not found at Norfolk Island, but are present at the Kermadec islands, such as Raoul scorpionfish (*Maxillicosta raoulensis*) and crimson cleanerfish (*Suezichthys aylingi*).

Many subtropical species at White Island occur at both Norfolk and the Kermadec Islands, so could be sourced from either area. While the EAC does not favour movement from the Kermadec Islands, at times this must occur to enable Kermadec endemics to be carried into New Zealand coastal waters, e.g. Kermadec scorpionfish (*Maxillacosta raoulensis*), Kermadec demoiselle (*Chrysiptera rapanui*) and Kermadec scalyfin (*Parma kermadecensis*) (Francis 2001). This model must be considered possible in certain years for subtropical fish recruitment at White Island, in addition to the more accepted model of recruitment via the EAC.

5.1.4 Coastal stations with high species diversity within the ECR

The 10 coastal sample stations with the highest species diversity are listed in Table 13. The total number of fish species recorded range from 44 to 31 (mean 34.4) per station, which is very high. These particularly rich stations range from the mid eastern BOP around to the mid East Coast. Clumping is evident for seven of these stations in two areas: Maraetai Bay–Whanarua Bay around Te Kaha (3 stations: E03, E33, E34), and at Lottin Point (four stations: E05, E07, E08, E09); one rich station at Cape Runaway (E01) could be grouped with those from Lottin Point (Fig. 1). There are two isolated rich stations on the East Coast; at Koutunui Head (E28), and Shark Bay (E30) (Fig. 1). The ten stations are spread across a wide depth range, from 0–2 m to 15–20 m, and these occur together in close proximity at Lottin Point, suggesting that the location may be an important influence on fish diversity, rather than the depth. The biotic and abiotic factors that affect diversity at these sites warrant further investigation.

TABLE 13. COASTAL SAMPLE STATIONS WITH HIGHEST DIVERSITY OF FISH SPECIES.

	STN NO.	LOCALITY	DEPTH (m)			NUMBER OF SPP.		
			MIN	MAX	MEAN	COLL.*	SNC†	TOTAL‡
1	E09	Lottin Point	7.0	10.0	8.5	38	5	43
2	E01	Cape Runaway	8.0	12.0	10.0	27	12	39
3	E33	Whanarua Bay	8.0	8.0	8.0	29	9	38
4	E03	Maraetai Bay	4.0	6.0	5.0	31	3	34
5	E28	Koutunui Head, East Coast	9.0	9.0	9.0	30	3	33
6	E05	Lottin Point	15.0	20.0	17.5	24	8	32
7	E08	Lottin Point	15.0	17.0	16.0	28	4	32
8	E30	Shark Bay, East Coast	4.0	6.0	5.0	26	5	31
9	E34	Whanarua Bay	2.0	2.0	2.0	26	5	31
10	E07	Lottin Point	0.0	2.0	1.0	28	3	31

* Coll. = number of species collected.

† SNC = number of species seen not collected.

‡ Total = total number of species present at station (sum of Coll. and SNC).

All of these stations rich in fish species are also rich in other marine taxa, living on a broken hard rocky reef structure that is rich in microhabitats. For example, Lottin Point, which has the highest number of rich stations (four) and one was the coastal station with the highest number of fish species (E09, 43 spp.), is nearly an island of Cretaceous basalt that supports a marine reef community with high ecological and biogeographical interest (Morton 2004). It has been suggested by Morton (2004: 182) that Lottin Point has similar features to the offshore island chain of northeast New Zealand (Three Kings to White Island) being close to the shelf edge, with clear oceanic water, little freshwater influence, high exposure to wave action, strong currents, upwelling, low seasonal temperature range, influenced by the warm EAC, and extended reef habitat with steep subtidal cliffs.

5.2 BIOGEOGRAPHIC TRANSITION AREA

The present study supports previous research that shows the East Cape Region (ECR) to be an important biogeographic feature influencing the distribution, composition, and diversity of intertidal, coastal and shelf communities. However, descriptions of this feature have varied substantially, ranging from a well-defined barrier, poorly defined boundary, well-defined boundary, transition zone, to a methodological boundary line (see section 1. Introduction). Two objectives of the present survey were for the first time to carry out a comprehensive survey of the coastal reef fishes, and based on this new information, to assess the evidence for a biogeographic boundary or transition in the ECR. The number and geographic distribution of the sample stations, and the inventories obtained, are representative of the coastal reef fish fauna and provide a comprehensive dataset to test and describe the biogeographic nature of the ECR.

If there is a biogeographic barrier or boundary in the ECR, then some specific types of distributions would be evident. Those species directly influenced by the barrier or boundary would not cross it. Hence, a different suite of species would be expected to occur either side of the boundary. In addition, based on the biogeographic principle that general patterns have general explanations, this pattern would be expected in a range of marine taxa, not just fishes. Although widespread species would occur on either side of the boundary, the influence of this limiting biogeographic feature would be expected to be readily detectable in a key portion of the fauna and flora. There should be a close relationship shown between the number of marine species at their distributional limits and the intensity of the biogeographic effect. A barrier or boundary would, therefore, cause the distributional limits of 'indicator' species to coincide at the same location, or at least within a narrow band.

Conversely, if there is a more gradual biogeographic transition in the ECR, then a different pattern of distribution would be found. In particular, the distributional limits of 'indicator' species would not coincide at the same location, but would occur progressively throughout the area forming a recognisable transition zone. The results of the present study, together with

those of other marine groups, can be assessed objectively to test the competing hypotheses of an ECR boundary or transition.

This study has revealed several independent diversity and distributional characteristics of the coastal reef fauna that refute the presence of a biogeographic boundary and support a transition zone in the ECR. These characteristics are as follows:

- Diversity of reef fishes decreases progressively with increasing distance around and south of East Cape (Fig. 7).
- Differences in species diversity (mean and S.D.) per sample station between coastal BOP and East Coast were not statistically different (Table 5).
- Species composition was not significantly different between coastal BOP and East Coast (Table 6); these two areas were most similar in composition, with 73 fish species shared.
- Taxonomic diversity (numbers of families, genera, and species) was most similar between coastal BOP and East Coast (Table 7); this was also seen at the family level for the five most speciose families (Table 8).
- Ichthyofaunal composition was most similar at coastal BOP and East Coast; the suite of species that characterise the reef fauna, due to their abundance and frequency of occurrence, was almost identical (Table 9).
- No fish species was confined to either the coastal BOP or East Coast area.
- Most (64.7%) of the ECR reef fishes had widespread distributions, so clearly the East Cape is no barrier to these species.
- Over one-third (34.4%) of the ECR reef fishes had biogeographically informative distributions. Of these, fishes with northern distributions comprised the major component (32.7%), and exhibited their southern limits progressively around the ECR (Figs 8 and 9).
- Comparison of biogeographic compositions of ECR reef fishes showed a decrease in northern species and a reciprocal increase in widespread species progressively around the ECR (Fig. 11).

Based on these nine characteristics shown by ECR reef fishes, on the one hand, and the complete absence of any form of barrier or defined boundary features, on the other, it is concluded that the ECR is an area of biogeographic transition for fishes with northern distributions. The northern and southern limits of this transition zone have not been clearly determined, but are probably outside the area investigated. This is particularly so for species with southern distributions, which mostly lie south of the ECR (Paulin & Roberts 1993; Francis 1996). Only two southern species were recorded in the present study, which alone are insufficient to support a meaningful biogeographic analysis.

A number of previous studies on other marine taxa support the present conclusion that the ECR is a transition zone. Knox (1963, 1975) summarised the results of New Zealand marine biogeographic research and documented distribution patterns of marine algae and invertebrates (corals, crabs, amphipods, echinoderms, molluscs) in the intertidal, sublittoral and shelf regions. Knox (1963: 367, 1975: 384) stated:

> 'It is evident that there are two main centres of distribution, a warm water one in the north and a cold water one in the south. From each of these centres characterised by endemic and non-endemic species confined to

them, numbers of species extend varying distances north and south, **forming an extensive transition zone** which is related to the fluctuations in hydrological conditions of the mixed waters along the central east coast.' [Our emphasis]

In spite of the concept of a provincial boundary on the east coast that 'lies in the vicinity of East Cape' being put forward repeatedly, the evidence presented was clearly that of a transition zone:

> '... a number of typical Aupourian endemics reaching their limits at various points along the coast to the north and other Aupourian dominants decreasing in abundance to the south.' (Knox 1963: 387)

The East Coast transition zone was illustrated by Knox (1963: fig. 5), as extending from East Cape to about Mahia Peninsula, and supported by distribution charts of several taxa (Knox 1975: fig. 3, crabs; fig. 4, echinoderms; fig. 7, dominant intertidal plants and animals). Pawson (1965) interpreted the ECR as a filter zone, with the pattern of coastal currents dictating the spread of species. South of East Cape, the echinoderm shelf fauna notably included the presence of some southern species, virtual absence of subtropical species, and an overlap of endemic species, with either a northern or southern distribution.

The transitional nature of the distributions of algae and invertebrates was recognised by Morton & Miller (1968: 336), who defined the East Coast from north to south as a shoreline of transitions, with no sharp biological threshold (boundary) at East Cape. Similarly, Waugh (1973: 258) plotted the distributions of 26 fishes along the East Coast and concluded that distributions overlap and provincial boundaries were not absolutely applicable to the fishes. Paulin & Roberts (1993) tabulated distributions of rockpool fishes, and showed that northern species extended southwards in a transitional pattern, with 18 northern species in the BOP, 12 extending past East Cape to Gisborne–Hawke Bay, and 9 extending further south. Francis (1996) recognised a boundary at East Cape for fishes, but stated that the reason for a distinct boundary was not obvious. He noted that, although the flow and direction of the East Auckland Current is offshore at East Cape, there is a significant southward flow (as the East Cape Current), and that sea surface temperatures (SST) did not decrease dramatically between East Cape and Hawke Bay.

The southern limits of northern fishes (and other taxa) extending along the East Coast probably vary over time depending upon a combination of adult breeding success, pelagic larval survival rate and prevailing hydrographic conditions. The relative strength and influence of the warm East Cape Current versus the cool Southland Current fluctuate seasonally, especially during alternating El Niño/La Niña periods in the ENSO cycle. Sufficient information is now available for East Coast algae, invertebrates and fishes to enable this dynamic relationship between biotic and hydrographic features to be tested, measured and defined.

5.3 FUTURE WORK

Additional sampling is needed at BOP inshore and offshore island groups, to obtain a better representation of species diversity present in these island reef habitats. Six to seven sample stations are inadequate, based upon the continued

steep gradient of the cumulative species curves, differences in species composition between coastal reefs and intuitively from the range of rich reef habitat present. It has been suggested that the fish fauna of White Island is most closely associated with those of the offshore islands and headlands of north-eastern New Zealand (e.g. Walls 1995: figs 1 and 2), which has some support from the present results and needs further investigation.

Although the present survey was carried out over the period 1992–1999, no account was taken of temporal variation in faunal diversity and biogeographic composition. It is almost certain that these will change between years, as weather and hydrographic conditions (especially ENSO events), influence the course and intensity of oceanic and coastal currents that impact on the ECR. Changes in environmental conditions of the ECR marine habitats and associated water bodies are likely to strongly influence both recruitment of larvae into the area, and the dispersal of larvae out of the area. Hence, in warm-water years, do more northern species appear along the East Coast; similarly, during cool periods do more southern species appear in northern areas? A series of stations at key locations around the ECR that are sampled, surveyed and monitored each year would help identify and understand this phenomenon. Such analysis would help elucidate the processes that cause the ECR to be an important biogeographic feature.

Future fieldwork to comprehensively survey reef fishes of the west coast of the North Island should reveal what similar biogeographic changes occur along the relatively straight western coastline at similar latitudes to the present survey. A west coast reef fish survey would help test the influence of geography, aspect, and current systems on biogeographic transition on both sides of the North Island.

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