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EXECUTIVE SUMMARY

Watson, T.; Hartill, B. (2005). Bayesian modelling of boat ramp traffic in SNA 1 since 1970.
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Changes in boat ramp traffic are modelled as a first step towards estimating the recreational harvest of snapper in SNA 1 since 1970. Unstandardised and standardised analyses of boat ramp traffic data collected from the SNA 1 fishery between 1991 and 2003 are presented. Results from these analyses were used to structure a hierarchical Bayesian model, which we used to consider boat ramp traffic per unit population (NPUE) as a proxy for fisher effort. Likely environmental and temporal effects thought to influence levels of fisher effort were also estimated as part of the inference procedure.

The Bayesian model produced plausible results within the limits of the dataset, with estimates of environment and temporal effects displaying relatively tight credibility intervals. Wind speed was shown to have the greatest influence on boat traffic rates. When the influence of prevailing environmental conditions was considered, there was evidence of a decline in the per capita tendency to go fishing in all three regions within SNA 1 – Bay of Plenty, Hauraki Gulf, and East Northland.

Bayesian model parameter samples were used to simulate boat ramp traffic from 1970 to 2003, using data on historical daily weather conditions for each of the three areas, given population growth. These simulations suggest that regional declines in the per capita tendency to go fishing have been offset by population growth, with an estimated increase in overall fishing effort in the Hauraki Gulf and East Northland, and a relatively constant trend in Bay of Plenty. Any projections substantially outside the dataset should be treated with caution, however, as the observational data on traffic rates used extends only as far back as 1991.

This report documents work undertaken in relation to the first objective of SNA200201:

"To determine a time series of recreational fishing effort indices for SNA 1 from 1970 to the present."

1. INTRODUCTION

Annual estimates of snapper removals from the SNA 1 stock are a fundamental requirement of any population model, but our current understanding of the recreational fishery is, at best, poor. Three methods have been used to estimate recreational harvests in SNA 1 to date: tagging programmes, which were conducted in 1984 and 1985; telephone diary surveys, conducted in 1994, 1996, 2000, and 2001; and an aerial overflight survey, which provided a partial estimate for the Hauraki Gulf only, in 1994.

The most widely accepted SNA 1 harvest estimates available are those derived from the 1984 (Bay of Plenty) and 1985 (Hauraki Gulf/East Northland) tagging programmes (Sullivan et al. 1988). Although some uncertainty surrounds aspects of these programmes (arising from issues such as misreporting, tag loss, tagging induced mortality, and assumed tag recapture rates for recreational fishery) there is no reason to suppose that the estimates are grossly biased, and they were used in the most recent SNA 1 stock assessment (Gilbert et al. 2000). Initially, estimates derived from telephone/diary surveys in the mid 1990s were considered reliable (Bradford 1998a), but pilot studies for a survey in 2000 (R. Boyd & J. Reilly, Kingett Mitchell and Associates, unpublished results) strongly suggested that fisher prevalence was underestimated due to soft refusals (when a telephone interviewee gives a misleading answer to politely avoid being interviewed further). However, correction for this bias resulted in implausibly high harvest estimates, focussing further attention on the shortcomings of this indirect method of estimating catch. A Recreational Technical Working Group was convened to review the telephone diary approach and recreational harvest estimates generally, and concluded that

> ".....the harvest estimates from the diary surveys should be used only with the following qualifications: 1) they may be very inaccurate; 2) the 1996 and earlier surveys contain a methodological error; and 3) the 2000 and 2001 estimates are implausibly high for many important fisheries."

The remaining estimate, derived from a combination of aerial overflight and boat ramp surveys in 1994 (Sylvester 1996), is thought to be more reliable given the direct measures of overall effort and catch per unit effort used. However, this estimate relates only to the western half of the Hauraki Gulf, over a five-month period, and has not been reviewed by the Snapper Working Group.

Modelling of recreational catch since 1970 in SNA 1 is therefore problematic, given the limited availability of reliable harvest estimates. Initially, a linear model was used to link the 1985 tagging programme estimate (1600 t) to the 1994 telephone/diary estimate (2850 t) given the intervening increase in the northern region's population (Annala & Sullivan 1997). When preliminary harvest estimates (2320 t) became available from the 1996 telephone/diary survey, Sylvester (1997) compared them with those from the previous survey and suggested that the difference was due to exceptionally good weather conditions in 1994. Bradford (1998b) conducted a more comprehensive analysis of data from the Hauraki Gulf, in which the catch and number of trips by diarists (scaled by the prevalence of fishers in each year) were regressed against wind strength, wind direction, data type, and month. Because of its reliance on only two years of telephone/diary data, and concerns arising from the magnitude of the more recent 1999–2000 estimates, the results of this model were not incorporated into the most recent SNA 1 stock assessment (Gilbert et al. 2000). Bradford concluded that

> "A definitive model of the recreational snapper harvest has not been derived."

and suggested that

> "Almost certainly, the recreational effort in any year depends on the wind strength and direction and these can be highly variable from year to year. The harvest is likely to be strongly correlated with effort, but changes in harvest rate will influence the total harvest. Changes in harvest rate as well as changes in effort must be considered in a model for recreational harvest which extends back into the past."

Previous modelling has therefore relied heavily on data recorded by individual diarists, which are subject to substantial, and potentially survey-specific, biases. In this study we use an alternative approach that makes use of boat ramp traffic data to derive inferences on changes in relative fishing effort (and ultimately catch rate). Boat ramp surveys conducted frequently since 1991 provide the most comprehensive and consistent time series of data available on recreational catch and effort in SNA 1. In these surveys, trained staff followed a standardised interview format, and directly gathered data from fishers returning to boat ramps. We explore the feasibility of using these data to model relative changes in a measure of fishing effort, i.e., boat ramp traffic rates, given environmental and population census data collected since 1970. The Bayesian approach used permits the further incorporation of data on trip durations and catch rates, which could be used to initially estimate a recreational catch history for snapper in SNA 1 if required.

2. DESCRIPTION OF DATA

2.1 Boat ramp survey descriptions

Boat ramp interviews have been the basis of most recreational research conducted in SNA 1 since 1990, although the purpose of these surveys has differed. New Zealand's first large-scale boat ramp survey was conducted in 1990–91, with the intention of collecting baseline information on harvest rates by recreational fishers throughout the Auckland Fisheries Management Area (AFMA) (Sylvester 1993). Most interviewing occurred on weekends between Boxing Day 1990 and June 1991. In 1994, boat ramp interviews conducted throughout the year were used to verify aspects of a concurrent telephone/diary survey. The length composition of recreational catches measured during boat ramp interviews was used to validate those reported by diarists. These boat ramp data were also used in conjunction with an aerial survey to estimate the snapper harvest from the Hauraki Gulf, which was compared with estimates derived from a telephone/diary survey (Sylvester 1996).

Throughout 1996, a nationwide boat ramp survey was carried out to estimate the mean weights of fish species caught by recreational fishers (Hartill et al. 1998). These mean fish weights were used in conjunction with estimates of annual average fisher catch derived from diarist data, and telephone survey estimates of fisher prevalence, to provide estimates of the national recreational harvest of key species (Bradford 1998a). A further small-scale survey conducted in 1998, focussed on fishing in three harbours, the Bay of Islands, Tauranga Harbour, and Ohiwa Harbour, although fishing parties returning to these harbours after fishing on the open coast were also interviewed (Hartill & Cryer 2001). Since 2001, annual boat ramp surveys have been used to collected information on the length and age composition of catches of kahawai landed between 1 January and 30 April (Hartill et al. 2004). Boat ramps were surveyed throughout SNA 1, with interviews taking place only on weekends and public holidays. Although recreational fishers were regarded as a kahawai population sampling tool, the approach used in interviews was the same as that used in previous surveys, which focused on recreational effort and catch per se.

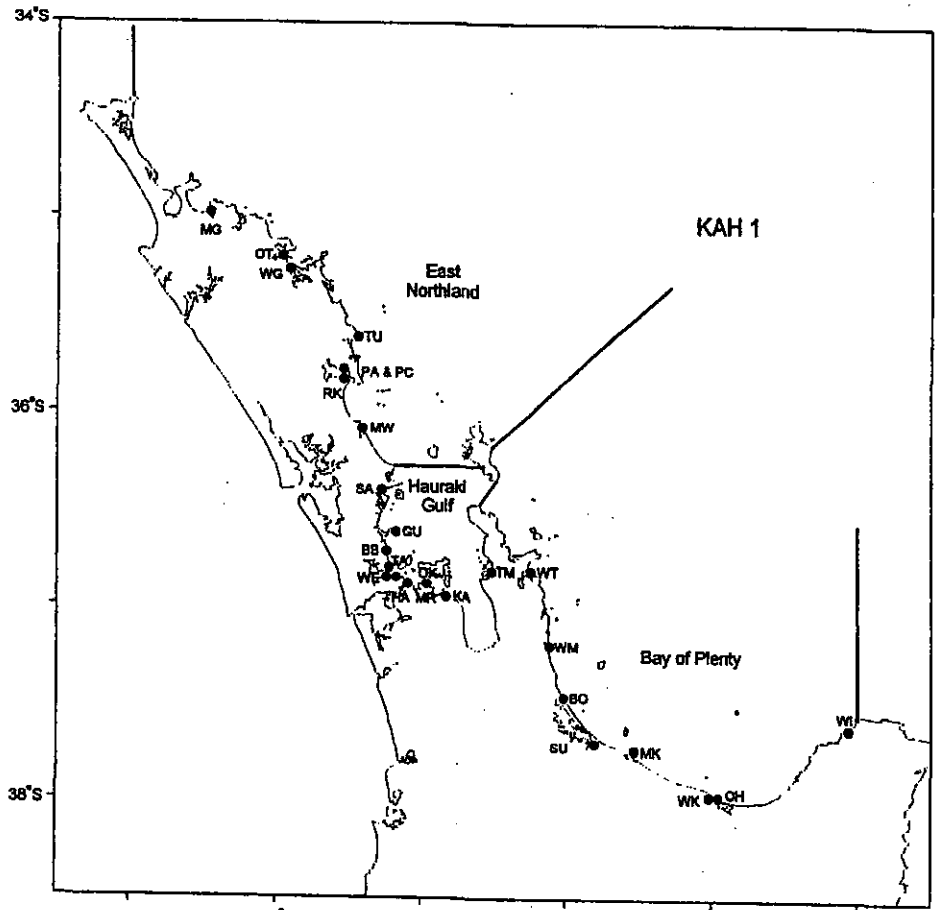
Regardless of the objective and design of these surveys (Table 1), the interview format and information collected in all interviews, and types of information used to define each interview session, remained unchanged. This standardisation has resulted in comparability of data across a range of temporal scales: days (midweek days vs weekend days) months and years.

All surveys, except that in 1998, covered the full geographic range fished by recreational fishers in SNA 1. For modelling, data were divided up into three regional data sets: East Northland, Hauraki Gulf and Bay of Plenty (Figure 1).

Table 1: Summary of recreational boat ramp surveys that have taken place in SNA 1 since 1991.

Survey	Time span	Interviewing duration (h)	Purpose
1991	17/11/90 – 28/07/91	4	Recreational fishery characterisation
1994	02/01/94 – 26/06/94	4	Telephone/diary validation
1996	30/12/95 – 02/01/97	2	Mean fish weight estimates
1998	01/12/97 – 19/12/98	2	Small three ramp characterisation
2001	03/01/01 – 29/04/01	4–6	Kahawai length & age composition
2002	02/01/02 – 09/05/02	4–6	Kahawai length & age composition
2003	01/01/03 – 27/04/03	4–6	Kahawai length & age composition

N.B. Another survey was conducted in 1999–2000, by Kingett Mitchell & Associates Ltd, but data from this survey are not currently available in an electronic format, and information on all types of boat ramp traffic was not collected.



East Northland

MG Mangonui
MW Mangawai
OT Opito Bay, Kerikeri
PA Parua Bay (public ramp)
PC Parua Bay (club ramp)
RK One Tree Point, Ruakaka
TU Tutukaka
WG Waitangi

Hauraki Gulf

BB Browns Bay
GU Gulf Harbour
HA Half Moon Bay
KA Kawakawa
MR Maretai
OK Okahu Bay
SA Sandspit
TA Takapuna
TM Te Kouma
WE Westhaven

Bay of Plenty

BO Bowentown
MK Maketu
OH Ohope
SU Sulphur Point, Tauranga
WI Waihau Bay
WK Whakatane
WM Whangamata
WT Whitianga

Figure 1: Location of key boat ramps in East Northland, Hauraki Gulf, and Bay of Plenty.

This regional approach was adopted, because environmental climatic conditions were considered unacceptably heterogeneous over larger spatial scales. Previous assessments of recreational fisheries have also divided SNA 1 up into these regions (e.g., Hartill et al. 1998, Boyd & Reilly unpublished results). The influence of different sample designs on the temporal and spatial distribution of data can be seen at a regional level in Tables 2a, 2b, and 2c, which describe the number of sessions and hours of interviewing conducted at key boat ramps in each region.

Table 2a: Number of boat ramp sessions and hours of interviewing at boat ramps in East Northland, by survey, month and ramp. Minor ramps are those that were sampled infrequently for short periods.

Year	Month	Mangonui N (h)	Opito Bay N (h)	Waitangi N (h)	Tutukaka N (h)	Parua (club) N (h)	Parua (public) N (h)	Ruakaka N (h)	Mangawai N (h)	Minor ramps N (h)	All ramps N (h)
	December	– –	– –	1 (4)	2 (7)	– –	3 (10)	– –	– –	6 (19)	12 (41)
1991	January	– –	– –	4 (10)	12 (48)	– –	12 (48)	– –	– –	12 (38)	40 (144)
	February	1 (4)	– –	– –	1 (4)	– –	– –	– –	– –	3 (12)	5 (20)
	March	7 (28)	– –	7 (33)	8 (31)	– –	11 (42)	– –	– –	20 (69)	53 (204)
	April	4 (13)	– –	5 (18)	8 (33)	– –	7 (17)	– –	– –	12 (44)	36 (125)
	May	4 (16)	– –	3 (13)	8 (32)	– –	4 (15)	– –	– –	4 (19)	23 (95)
	June	3 (14)	– –	2 (15)	3 (12)	– –	2 (5)	– –	– –	3 (12)	13 (58)
Survey total		19 (75)	– –	22 (93)	42 (167)	– –	39 (137)	– –	– –	60 (214)	182 (699)
1994	January	– –	– –	11 (39)	1 (4)	– –	7 (19)	– –	– –	10 (35)	29 (98)
	February	– –	– –	8 (28)	8 (27)	– –	3 (10)	– –	– –	8 (26)	27 (92)
	March	*6 (13)*	– –	9 (29)	4 (15)	– –	4 (13)	– –	– –	8 (29)	31 (99)
	April	2 (3)	– –	11 (32)	7 (25)	– –	7 (26)	– –	– –	9 (35)	36 (121)
	May	– –	– –	5 (10)	6 (18)	– –	5 (18)	– –	– –	2 (3)	18 (49)
	June	– –	– –	6 (12)	5 (16)	– –	8 (26)	– –	– –	– –	19 (54)
Survey total		8 (16)	– –	50 (150)	31 (105)	– –	34 (112)	– –	– –	37 (129)	160 (513)
1995	December	2 (4)	– –	1 (2)	1 (2)	– –	– –	– –	– –	– –	4 (8)
1996	January	10 (21)	– –	11 (22)	7 (14)	– –	6 (12)	– –	1 (2)	17 (32)	52 (103)
	February	7 (14)	– –	8 (16)	7 (14)	– –	11 (24)	– –	2 (2)	4 (8)	39 (79)
	March	15 (29)	– –	15 (30)	7 (14)	– –	11 (21)	– –	– –	4 (8)	52 (103)
	April	14 (29)	– –	12 (25)	14 (29)	– –	14 (28)	– –	2 (1)	12 (12)	68 (126)
	May	6 (12)	– –	8 (16)	4 (5)	– –	3 (6)	– –	– –	3 (6)	24 (46)
	June	3 (6)	– –	7 (14)	1 (2)	– –	– –	– –	– –	3 (6)	14 (28)
	July	3 (6)	– –	2 (4)	– –	– –	6 (12)	– –	– –	– –	11 (22)
	August	– –	– –	– –	– –	– –	6 (12)	– –	– –	– –	6 (12)
	September	– –	– –	– –	– –	– –	3 (6)	– –	– –	– –	3 (6)
	November	– –	– –	2 (4)	– –	– –	– –	– –	– –	– –	2 (4)
	December	– –	– –	2 (4)	– –	– –	– –	– –	– –	– –	2 (4)
1997	January	– –	– –	2 (4)	– –	– –	– –	– –	– –	– –	2 (4)
Survey total		60 (121)	– –	70 (141)	41 (84)	– –	60 (121)	– –	5 (5)	43 (72)	279 (424)
1997	December	– –	– –	11 (22)	– –	– –	– –	– –	– –	– –	11 (22)
1998	January	– –	– –	9 (18)	– –	– –	– –	– –	– –	– –	9 (18)
	February	– –	– –	7 (14)	– –	– –	– –	– –	– –	– –	7 (14)
	March	– –	– –	12 (24)	– –	– –	– –	– –	– –	– –	12 (24)
	April	– –	– –	13 (26)	– –	– –	– –	– –	– –	– –	13 (26)
	May	– –	– –	10 (20)	– –	– –	– –	– –	– –	– –	10 (20)
	June	– –	– –	9 (18)	– –	– –	– –	– –	– –	– –	9 (18)
	July	– –	– –	9 (18)	– –	– –	– –	– –	– –	– –	9 (18)
	August	– –	– –	9 (18)	– –	– –	– –	– –	– –	– –	9 (18)
	September	– –	– –	6 (12)	– –	– –	– –	– –	– –	– –	6 (12)
	October	– –	– –	10 (20)	– –	– –	– –	– –	– –	– –	10 (20)
	November	– –	– –	9 (18)	– –	– –	– –	– –	– –	– –	9 (18)
Survey total		– –	– –	103 (228)	– –	– –	– –	– –	– –	– –	103 (228)
2001	*January*	*6 (36)*	*7 (43)*	*6 (36)*	*6 (37)*	– –	*5 (31)*	*5 (30)*	8 (40)	7 (42)	*50 (296)*
	February	7 (36)	4 (24)	6 (36)	5 (30)	4 (25)	6 (37)	6 (33)	6 (35)	4 (24)	48 (282)
	March	6 (36)	6 (36)	6 (31)	5 (30)	8 (47)	8 (47)	2 (8)	5 (23)	– –	46 (260)
	April	7 (42)	7 (42)	8 (39)	8 (46)	8 (45)	8 (46)	– –	6 (27)	– –	52 (289)
Survey total		26 (150)	24 (145)	26 (144)	24 (144)	20 (118)	27 (162)	13 (72)	25 (126)	11 (66)	196 (1 129)
2002	January	4 (24)	10 (60)	8 (47)	8 (48)	9 (43)	9 (43)	8 (46)	8 (41)	– –	64 (355)
	February	6 (36)	4 (24)	5 (28)	6 (36)	7 (37)	7 (37)	5 (30)	8 (33)	– –	48 (262)
	March	5 (30)	5 (30)	7 (40)	6 (36)	6 (36)	6 (37)	8 (48)	6 (24)	– –	49 (282)
	April	8 (48)	4 (24)	4 (24)	4 (24)	5 (29)	5 (29)	3 (18)	5 (13)	– –	38 (210)
	May	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
Survey total		23 (138)	23 (138)	24 (141)	24 (145)	27 (146)	27 (146)	24 (142)	27 (113)	– –	199 (1 111)
2003	January	3 (19)	8 (48)	9 (47)	6 (32)	4 (27)	4 (28)	6 (36)	8 (42)	– –	48 (280)
	February	5 (29)	6 (36)	6 (35)	7 (42)	6 (35)	6 (35)	5 (29)	5 (30)	– –	46 (271)
	March	6 (34)	5 (30)	7 (41)	4 (18)	7 (41)	7 (41)	5 (28)	6 (23)	– –	47 (258)
	April	7 (42)	8 (48)	10 (51)	5 (24)	6 (29)	3 (13)	– –	6 (31)	– –	45 (238)
Survey total		21 (124)	27 (162)	32 (174)	22 (116)	23 (133)	20 (117)	16 (93)	25 (126)	– –	186 (1 048)
Grand total		157 (627)	74 (445)	338 (1073)	184 (760)	70 (397)	207 (799)	53 (309)	82 (372)	151 (482)	1 316 (5 268)

Table 2b: Number of boat ramp sessions and hours of interviewing at boat ramps in Hauraki Gulf, by survey, month and ramp. Minor ramps are those that were sampled infrequently for short periods.

Year	Month	Sandspit N (h)	Gulf Harbour N (h)	Browns Bay N (h)	Takapuna N (h)	Westhaven N (h)	Okahu Bay N (h)	Half Moon Bay N (h)	Maraetai N (h)	Kawakawa Bay N (h)	Te Kouma N (h)	Minor ramps N (h)	All ramps N (h)
1990	November	- -	- -	- -	1 (1)	- -	- -	- -	- -	- -	- -	- -	1 (1)
	December	- -	- -	- -	7 (13)	2 (7)	2 (7)	2 (7)	- -	2 (5)	- -	- -	15 (39)
1991	January	- -	- -	- -	6 (17)	8 (30)	9 (31)	8 (28)	- -	9 (31)	- -	- -	40 (138)
	February	2 (6)	1 (1)	- -	3 (9)	3 (8)	1 (4)	3 (8)	- -	- -	- -	7 (22)	20 (60)
	March	6 (24)	3 (13)	3 (12)	15 (58)	20 (69)	5 (17)	15 (54)	7 (28)	5 (18)	- -	32 (115)	111 (410)
	April	4 (16)	2 (8)	- -	8 (42)	14 (41)	4 (15)	7 (21)	3 (12)	4 (11)	- -	3 (18)	51 (184)
	May	4 (15)	4 (17)	- -	6 (21)	10 (28)	2 (9)	6 (19)	3 (12)	2 (5)	- -	5 (21)	42 (149)
	June	2 (8)	1 (2)	- -	- -	1 (3)	1 (3)	- -	- -	2 (5)	- -	1 (2)	8 (24)
Survey total		18 (70)	11 (41)	3 (12)	38 (161)	56 (188)	22 (87)	39 (138)	13 (52)	22 (77)	- -	50 (179)	372 (1 005)
1994	January	6 (18)	6 (20)	- -	6 (21)	8 (29)	- -	5 (15)	6 (21)	7 (24)	- -	- -	44 (150)
	February	5 (20)	5 (15)	- -	5 (15)	11 (32)	- -	11 (37)	5 (17)	8 (26)	- -	4 (12)	54 (176)
	March	10 (31)	16 (45)	- -	18 (60)	20 (59)	- -	28 (86)	16 (45)	14 (47)	- -	62 (201)	184 (578)
	April	5 (9)	6 (20)	- -	23 (75)	25 (86)	18 (53)	29 (85)	22 (61)	11 (41)	- -	76 (235)	215 (669)
	May	2 (8)	10 (34)	- -	19 (51)	17 (53)	7 (22)	17 (54)	13 (39)	14 (54)	- -	44 (126)	143 (446)
	June	4 (11)	9 (28)	- -	19 (53)	13 (37)	5 (17)	16 (55)	18 (61)	14 (47)	- -	41 (127)	139 (440)
Survey total		32 (118)	52 (185)	- -	90 (297)	94 (328)	30 (92)	106 (350)	80 (268)	68 (265)	- -	227 (703)	779 (2 612)
1996	January	- -	3 (6)	- -	1 (2)	3 (3)	- -	4 (8)	2 (4)	4 (8)	6 (11)	8 (17)	31 (61)
	February	- -	1 (2)	- -	2 (2)	1 (2)	- -	6 (12)	- -	9 (18)	6 (9)	6 (13)	31 (58)
	March	- -	2 (4)	- -	4 (5)	- -	- -	7 (14)	3 (6)	2 (4)	7 (7)	6 (13)	31 (54)
	April	- -	- -	- -	- -	- -	- -	16 (32)	8 (16)	7 (14)	3 (5)	8 (22)	42 (90)
	May	- -	- -	- -	9 (18)	- -	- -	8 (16)	2 (6)	7 (13)	7 (9)	3 (6)	37 (70)
	June	1 (1)	- -	- -	11 (20)	- -	- -	1 (2)	- -	3 (6)	3 (5)	3 (7)	22 (42)
	July	- -	- -	- -	5 (10)	- -	- -	2 (4)	- -	- -	4 (4)	- -	11 (19)
	August	- -	- -	- -	5 (7)	- -	- -	1 (2)	- -	- -	3 (4)	2 (4)	11 (18)
	September	- -	- -	- -	1 (3)	- -	- -	- -	- -	- -	4 (4)	2 (4)	7 (11)
	October	1 (1)	- -	- -	- -	- -	- -	- -	- -	- -	6 (7)	2 (3)	9 (11)
	November	- -	- -	- -	- -	- -	- -	2 (4)	- -	- -	2 (2)	- -	4 (6)
	December	- -	- -	- -	- -	- -	- -	- -	- -	1 (2)	- -	3 (8)	4 (10)
1997	January	- -	- -	- -	- -	- -	- -	- -	- -	2 (4)	- -	- -	2 (4)
Survey total		2 (2)	6 (12)	- -	38 (67)	4 (5)	- -	47 (94)	16 (32)	35 (69)	51 (67)	43 (96)	242 (444)
2001	January	- -	7 (32)	3 (18)	5 (29)	4 (24)	5 (21)	8 (40)	7 (36)	8 (36)	8 (36)	12 (70)	67 (345)
	February	- -	6 (29)	5 (30)	5 (28)	3 (23)	4 (19)	5 (29)	3 (14)	6 (36)	6 (27)	9 (50)	52 (287)
	March	- -	5 (32)	4 (23)	7 (42)	2 (14)	1 (6)	9 (55)	2 (12)	7 (24)	3 (15)	9 (54)	49 (279)
	April	- -	4 (26)	- -	3 (15)	6 (41)	- -	7 (47)	7 (35)	5 (24)	4 (24)	8 (48)	44 (261)
Survey total		- -	22 (120)	12 (72)	20 (114)	15 (103)	10 (47)	29 (173)	19 (97)	26 (120)	21 (102)	38 (223)	212 (1 173)
2002	January	4 (24)	1 (6)	3 (17)	8 (40)	2 (12)	5 (27)	12 (65)	6 (36)	9 (36)	6 (36)	- -	56 (300)
	February	4 (24)	7 (32)	2 (12)	6 (35)	5 (30)	5 (29)	11 (66)	5 (30)	7 (36)	2 (9)	- -	54 (304)
	March	6 (36)	7 (42)	2 (11)	4 (24)	5 (30)	5 (30)	9 (54)	3 (18)	3 (18)	6 (28)	- -	50 (291)
	April	1 (6)	3 (18)	- -	6 (38)	3 (18)	5 (27)	6 (33)	5 (30)	8 (30)	6 (34)	- -	43 (235)
	May												
Survey total		15 (90)	18 (98)	7 (40)	24 (138)	15 (90)	20 (114)	38 (218)	20 (120)	27 (120)	20 (107)	- -	204 (1 136)
2003	January	7 (42)	3 (18)	4 (24)	5 (29)	7 (42)	6 (36)	13 (72)	8 (48)	7 (36)	3 (18)	- -	63 (365)
	February	6 (36)	6 (36)	8 (48)	3 (18)	4 (24)	5 (30)	8 (47)	5 (30)	8 (30)	5 (30)	- -	58 (329)
	March	5 (30)	8 (48)	5 (28)	7 (30)	6 (36)	5 (30)	12 (66)	4 (24)	8 (30)	1 (4)	- -	61 (326)
	April	2 (12)	3 (18)	3 (16)	7 (39)	3 (18)	4 (24)	8 (45)	3 (18)	9 (48)	7 (40)	- -	49 (279)
Survey total		20 (120)	20 (120)	20 (116)	22 (116)	20 (120)	20 (120)	41 (231)	20 (120)	32 (144)	16 (92)	- -	231 (1 300)
Grand total		87 (382)	139 (558)	42 (240)	240 (879)	206 (806)	104 (460)	302 (1 192)	168 (668)	212 (773)	108 (374)	358 (1 204)	1 956(7541)

Data collected at Half Moon Bay in 2001 were not included in any analysis of boat ramp traffic, as the interviewer recorded only interviews with fishing parties who had landed kahawai. No information was therefore available on parties not interviewed, not fishing, or landing species other than kahawai. The Hauraki Gulf is the only region for which no data are available from the 1998 survey.

Table 2c: Number of boat ramp sessions and hours of interviewing at boat ramps in the Bay of Plenty, by survey, month and ramp. Minor ramps are those that were sampled infrequently for short periods.

		Whitianga		Whangamata		Bowentown		Sulphur Pt		Maketu		Ohope		Whakatane		Waihau Bay		Minor ramps		All ramps	
Year	Month	N	(h)	N	(h)	N	(h)	N	(h)	N	(h)	N	(h)	N	(h)	N	(h)	N	(h)	N	(h)
1990	December	3	(9)	2	(5)	–	–	3	(11)	–	–	3	(9)	2	(7)	–	–	4	(13)	17	(54)
1991	January	9	(27)	8	(24)	–	–	10	(37)	–	–	10	(30)	15	(48)	–	–	27	(88)	79	(255)
	February	–	–	–	–	4	(14)	3	(14)	–	–	1	(3)	1	(3)	–	–	2	(6)	11	(41)
	March	7	(21)	6	(23)	6	(23)	20	(63)	–	–	4	(13)	6	(24)	–	–	25	(83)	74	(251)
	April	9	(34)	5	(18)	4	(16)	7	(19)	–	–	5	(20)	8	(29)	–	–	26	(75)	64	(213)
	May	5	(17)	5	(16)	5	(16)	6	(21)	–	–	5	(17)	6	(20)	–	–	10	(36)	42	(145)
	June	2	(7)	1	(5)	1	(4)	1	(5)	–	–	1	(4)	2	(9)	–	–	8	(24)	16	(58)
	July	–	–	–	–	2	(8)	–	–	–	–	1	(2)	1	(4)	–	–	3	(6)	7	(20)
Survey total		35	(116)	27	(93)	22	(82)	50	(170)	–	–	30	(99)	41	(145)	–	–	105	(332)	310	(1 039)
1994	January	10	(35)	10	(35)	4	(16)	3	(11)	–	–	–	–	–	–	–	–	12	(38)	39	(136)
	February	6	(20)	8	(30)	3	(8)	1	(3)	–	–	–	–	–	–	–	–	13	(39)	31	(100)
	March	4	(14)	8	(26)	4	(16)	5	(10)	–	–	–	–	3	(6)	–	–	12	(44)	36	(117)
	April	7	(22)	10	(33)	3	(11)	11	(33)	–	–	–	–	7	(18)	–	–	12	(43)	50	(162)
	May	3	(11)	23	(86)	1	(4)	6	(21)	–	–	–	–	2	(5)	–	–	4	(13)	39	(141)
	June	4	(11)	14	(50)	6	(21)	14	(45)	–	–	–	–	4	(12)	–	–	3	(9)	45	(149)
Survey total		34	(114)	73	(261)	21	(76)	40	(124)	–	–	–	–	16	(42)	–	–	56	(188)	240	(807)
1996	January	6	(12)	2	(5)	12	(24)	7	(16)	–	–	–	–	6	(12)	6	(13)	14	(27)	53	(110)
	February	4	(8)	3	(6)	8	(16)	7	(14)	–	–	–	–	9	(18)	8	(16)	10	(20)	49	(98)
	March	7	(14)	2	(4)	5	(13)	13	(23)	–	–	4	(8)	7	(14)	13	(27)	11	(26)	62	(130)
	April	–	–	–	–	5	(10)	13	(23)	–	–	6	(15)	9	(12)	9	(20)	14	(32)	56	(113)
	May	–	–	–	–	–	–	12	(20)	–	–	4	(9)	5	(8)	10	(19)	6	(13)	37	(70)
	June	–	–	1	(2)	1	(2)	8	(16)	–	–	3	(6)	1	(2)	7	(13)	6	(12)	27	(53)
	July	–	–	3	(6)	2	(4)	7	(14)	–	–	–	–	1	(2)	6	(13)	2	(4)	21	(44)
	August	–	–	3	(6)	5	(10)	3	(5)	–	–	1	(2)	2	(4)	7	(14)	3	(5)	24	(46)
	September	–	–	2	(4)	–	–	4	(9)	–	–	1	(2)	1	(2)	2	(4)	2	(4)	12	(25)
	October	–	–	–	–	–	–	–	–	–	–	1	(2)	1	(2)	2	(4)	–	–	4	(8)
	November	–	–	–	–	–	–	–	–	–	–	1	(2)	1	(2)	1	(2)	–	–	3	(6)
	December	–	–	–	–	–	–	–	–	–	–	1	(2)	–	–	3	(4)	1	(2)	5	(8)
1997	January	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	(3)	1	(3)
Survey total		17	(34)	16	(33)	38	(79)	74	(126)	–	–	22	(48)	43	(78)	74	(149)	70	(148)	354	(695)
1997	December	–	–	–	–	4	(8)	4	(8)	–	–	–	–	–	–	–	–	–	–	8	(16)
1998	January	–	–	–	–	4	(7)	1	(2)	–	–	–	–	–	–	–	–	–	–	5	(9)
	February	–	–	–	–	1	(2)	–	–	–	–	–	–	–	–	–	–	–	–	1	(2)
	March	–	–	–	–	5	(10)	6	(12)	–	–	13	(26)	–	–	–	–	15	(30)	39	(78)
	April	–	–	–	–	3	(6)	6	(12)	–	–	17	(34)	–	–	–	–	9	(18)	35	(70)
	May	–	–	–	–	4	(8)	2	(4)	–	–	15	(30)	–	–	–	–	7	(14)	28	(56)
	June	–	–	–	–	2	(4)	7	(14)	–	–	–	–	–	–	–	–	–	–	9	(18)
	July	–	–	–	–	9	(18)	5	(10)	–	–	–	–	–	–	–	–	–	–	14	(28)
	August	–	–	–	–	6	(12)	6	(12)	–	–	–	–	–	–	–	–	–	–	12	(24)
	September	–	–	–	–	2	(4)	3	(6)	–	–	–	–	–	–	–	–	–	–	5	(10)
	October	–	–	–	–	4	(8)	7	(14)	–	–	–	–	–	–	–	–	–	–	11	(22)
	November	–	–	–	–	6	(12)	3	(6)	–	–	–	–	–	–	–	–	–	–	9	(18)
	December	–	–	–	–	1	(2)	5	(10)	–	–	–	–	–	–	–	–	–	–	6	(12)
Survey total		–	–	–	–	51	(102)	51	(110)	–	–	45	(90)	–	–	–	–	31	(62)	174	(364)
2001	January	3	(12)	–	–	2	(8)	2	(8)	2	(3)	2	(8)	1	(3)	6	(10)	9	(26)	27	(79)
	February	2	(7)	–	–	4	(16)	2	(8)	2	(4)	6	(24)	–	–	2	(2)	2	(10)	20	(73)
	March	2	(8)	–	–	3	(12)	2	(8)	2	(1)	3	(12)	2	(8)	7	(16)	3	(5)	24	(72)
	April	3	(12)	–	–	3	(12)	7	(28)	4	(4)	6	(23)	–	–	5	(12)	1	(2)	29	(94)
Survey total		10	(40)	–	–	12	(48)	13	(52)	10	(13)	17	(68)	3	(11)	20	(42)	15	(44)	100	(319)
2002	January	2	(8)	5	(16)	4	(16)	5	(16)	3	(7)	4	(12)	2	(8)	6	(15)	6	(9)	37	(110)
	February	2	(8)	3	(8)	3	(12)	3	(12)	3	(12)	5	(5)	1	(4)	3	(12)	5	(7)	28	(82)
	March	3	(12)	5	(18)	2	(8)	1	(4)	3	(12)	7	(19)	4	(16)	4	(16)	–	–	29	(106)
	April	6	(23)	4	(15)	5	(20)	7	(28)	4	(16)	4	(16)	9	(24)	7	(28)	–	–	46	(171)
	May	1	(3)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	(3)
Survey total		14	(55)	17	(58)	14	(56)	16	(60)	13	(47)	20	(53)	16	(53)	20	(71)	11	(17)	141	(473)
2003	January	4	(16)	–	–	2	(8)	4	(16)	2	(8)	4	(13)	2	(8)	3	(11)	2	(17)	23	(98)
	February	4	(16)	2	(4)	1	(4)	5	(20)	4	(16)	5	(18)	2	(8)	1	(4)	–	–	24	(90)
	March	4	(16)	5	(22)	4	(16)	3	(12)	4	(16)	4	(15)	2	(8)	3	(6)	2	(1)	31	(113)
	April	4	(16)	7	(28)	6	(24)	4	(16)	4	(16)	4	(17)	7	(32)	6	(11)	–	–	42	(160)
Survey total		16	(64)	14	(54)	13	(52)	16	(64)	14	(56)	17	(63)	13	(57)	13	(32)	4	(18)	120	(462)

Most boat ramp interviewing has taken place on weekends and public holidays, when the intensity of recreational fishing effort is generally greatest (Table 3). In 1996 and 1998, however, a significant proportion of interviews took place midweek. The 1998 survey was conducted at only four boat ramps, however, one in East Northland and three in the Bay of Plenty.

Table 3: Summary of the number of boat ramp interview sessions taking place on weekends/public holidays and weekdays during each of the surveys conducted in East Northland, Hauraki Gulf and the Bay of Plenty.

Area	Survey	Weekend/ pubic holiday	Weekday	All	Weekend proportion
East Northland	1991	102	20	122	0.84
	1994	113	10	123	0.92
	1996	151	85	236	0.64
	1998	40	74	114	0.35
	2001	182	3	185	0.98
	2002	194	5	199	0.97
	2003	180	6	186	0.97
	All	962	203	1 165	0.83
Hauraki Gulf	1991	194	44	238	0.82
	1994	338	214	552	0.61
	1996	136	63	199	0.68
	2001	166	8	174	0.95
	2002	192	12	204	0.94
	2003	221	10	231	0.96
	All	1 247	351	1 598	0.78
Bay of Plenty	1991	172	33	205	0.84
	1994	140	44	184	0.76
	1996	158	126	284	0.56
	1998	60	91	151	0.40
	2001	72	13	85	0.85
	2002	98	32	130	0.75
	2003	106	10	116	0.91
	All	805	349	1 155	0.70
Grand total		3 014	903	3 918	0.77

2.2 Boat ramp traffic rates

In this study we have used boat ramp traffic rates as a proxy for relative levels of fishing effort through time. During each boat ramp interview session, interviewers have recorded the time at which recreational fishing boats have returned to boat ramps, and classified types of interviews that have taken place. Interview classifications include: fishing related activity (I), non-fishing activity (O), not approached as the interviewer was already occupied (N), and fisher refusal (R). Refusals were comparatively uncommon, but at times on busy ramps, when interviewers were overwhelmed, fishing parties often went uninterviewed (Table 4). The probability that a boat party which was not interviewed but had been fishing (N or R) can be inferred from the activities of those parties which were interviewed (I or O). It was therefore possible to obtain estimates of the number of recreational fishing boats returning to each boat ramp per hour, as interviewers were instructed to note down the time at which each boat returned to the ramp.

Table 4: Summary of trip descriptor categories recorded by interviewers for boats returning to key boat ramps in East Northland, Hauraki Gulf, and the Bay of Plenty – all years combined.

Area	Ramp	Interviewed (I)	Not fishing (O)	Not interviewed (N)	Refused (R)
East Northland	Mangonui	1 137	550	309	4
	Opito Bay	1 063	377	66	41
	Waitangi	1 977	1 254	247	32
	Tutukaka	1 263	663	518	8
	Parua Bay (club)	1 190	209	454	3
	Parua Bay (public)	1 820	397	247	25
	Ruakaka	319	71	236	25
	Mangawai	699	364	96	28
Total		9 468	3 885	2 173	166
Hauraki Gulf	Sandspit	660	506	43	15
	Gulf Harbour	1 206	393	248	50
	Browns Bay	333	248	45	11
	Takapuna	2 724	964	881	52
	Westhaven	2 142	1 268	792	27
	Okahu Bay	870	523	116	50
	Maretai	1 431	457	354	30
	Half Moon Bay	4 247	1 508	2 445	147
	Kawakawa Bay	2 391	524	545	74
	Te Kouma	924	15	25	0
Total		16 928	6 406	5 494	456
Bay of Plenty	Whitianga	815	404	844	23
	Whangamata	1 244	556	844	27
	Bowentown	1 333	389	119	6
	Sulphur Point	2 181	1 403	1 250	12
	Maketu	120	2	59	1
	Whakatane	1 704	147	1 033	14
	Ohope	784	376	119	3
	Waihau Bay	620	4	72	14
Total		8 801	3 281	4 340	100
Grand total		35 197	13 572	12 007	722

2.3 Exploration of climate data

It is widely assumed that prevailing weather conditions influence levels of recreational fishing effort appreciably. The National Climate Database (CLIDB) was therefore used to identify weather stations with consistently collected datasets going back to 1970. Only a few stations have been maintained since 1970, however, and for the Bay of Plenty it was necessary to combine data from two sites to extend the available time series back as far as 1970 (Table 5). In the Hauraki Gulf, Auckland Airport data were used in preference to those from the Leigh Marine Laboratory station, as the latter is sheltered from the prevailing south/westerly winds. This was clearly evident when Leigh data were compared with those collected from other Hauraki Gulf sites. When environmental data were not available (e.g. Bay of Plenty wind speed data in the early 1970s), data from the Hauraki Gulf were used as a substitute.

Table 5: Data extracted from the National Climate Database that were used in an initial exploration of environmental variables likely to influence recreational fishing effort.

Environmental variable	Area	Location	Date range used
Daytime windspeed (0700 to 1900 hours)	East Northland	Whangarei Airport Whangarei Airport AWS*	01/01/70 to 31/12/91 01/01/92 to present
	Hauraki Gulf	Auckland Airport	01/01/70 to present
	Bay of Plenty	Whakatane Airport Tauranga Airport AWS*	30/11/74 to 30/05/90 31/05/90 to present
Daytime wind direction (0700 to 1900 hours)	East Northland	Whangarei Airport Whangarei Airport AWS*	01/01/70 to 31/12/91 01/01/92 to present
	Hauraki Gulf	Auckland Airport	01/01/70 to present
	Bay of Plenty	Whakatane Airport Tauranga Airport AWS*	30/11/74 to 30/05/90 31/05/90 to present
Daily air temperature	East Northland	Not examined	–
(Maximum degrees Celcius)	Hauraki Gulf	Auckland Airport	01/01/70 to present
	Bay of Plenty	Not examined	–
Daily rainfall	East Northland	Not examined	–
(mm per day)	Hauraki Gulf	Auckland Airport	01/01/70 to present
	Bay of Plenty	Not examined	–
Cloud cover	East Northland	Not examined	–
(1/8ths)	Hauraki Gulf	Leigh	01/01/70 to present
	Bay of Plenty	Not examined	–
Daily sushine hours	East Northland	Not examined	–
(hours per day)	Hauraki Gulf	Auckland Airport	01/01/70 to 01/07/94
	Bay of Plenty	Not examined	–

* Automatic Weather Station

Cloud cover was highly variable, even at the hourly level, and considered less explanatory than rainfall and was therefore excluded from any further analysis. Daily sunshine hour data were explored, but not used, as data were available only for some years, most of which did not coincide with available boat ramp session data.

All stochastic environmental variables (wind speed, wind direction, maximum air temperature, daily rainfall) were considered at the daily scale, with average values based on daylight hour (0700 to 2000) data only, where possible. This approach was adopted as the timing of a boat returning to a boat ramp was considered a crude and lagged descriptor of the timing of fishing effort. Tidal state was also considered to be a likely determinant of fishing effort, and hourly tidal predictions were therefore generated via the NIWA Tide Model (Walters 1988). These hourly tidal estimates were then categorised into four tidal state bins of equal length. Hourly tidal state estimates and daily environmental variables were then linked to hourly estimates of boat ramp traffic.

2.4 Population growth

Population growth is likely to be a key determinant of changes in fishing effort. National census data collected since 1970 by Statistics New Zealand were used to provide an index of population growth for each of the three regions considered in this model. As census data were collected on a five yearly basis, estimates in the intervening years were calculated by Statistics New Zealand, given annual statistics on births, deaths, and immigration. Main Urban Area classifications were used to describe population growth in each region, and these were: Northland for the East Northland fishery, Central Auckland for the Hauraki Gulf fishery, and South Auckland - Bay of Plenty for the Bay of Plenty fishery (MUAs, Figure 2). Annual population estimates for each region were then divided by the population in 1970, to provide an index of population growth (Figure 3). These regional indices of population growth were used for predictive purposes when deriving indices of fishing effort going back to 1970, as concurrent population abundance should be considered when modelling the tendency, and hence intensity, of fishing.

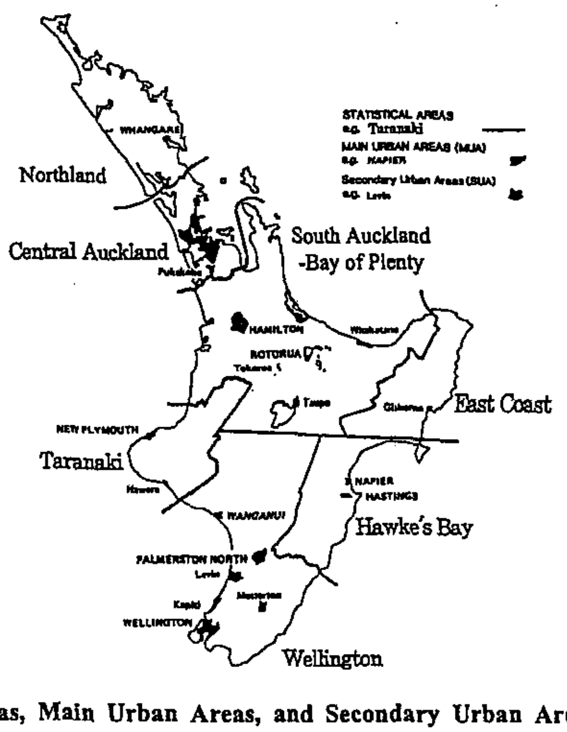


Figure 2: Statistical areas, Main Urban Areas, and Secondary Urban Areas used by Statistics New Zealand when summarising census data.

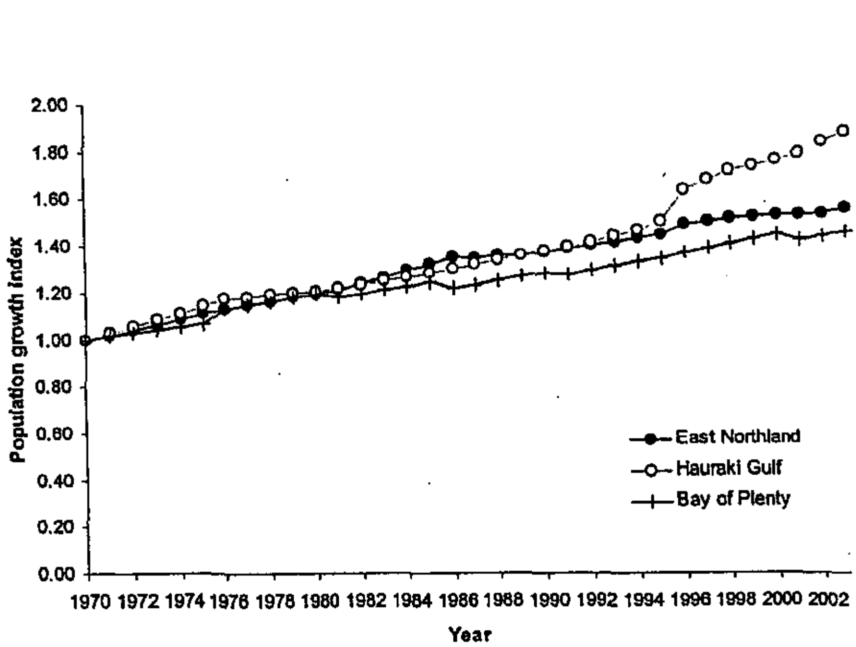


Figure 3: ***Indices of population growth in East Northland, the Hauraki Gulf, and the Bay of Plenty since 1970.***

3. METHODS AND RESULTS

3.1 Overview

The methods we have used to model changes in fishing effort in SNA 1 since 1970 are broadly based on those commonly used to generate standardised indices of catch per unit effort (CPUE) in which:

$$\mathrm{CPUE} = \exp[\mathrm{B} \bullet \mathrm{Z} + \mathrm{Y}_t] \qquad (1)$$

where Z is a matrix of time-independent indicator variables, either continuous or categorical, that represent environmental conditions that may influence the catch, B a vector of estimated coefficients, and Y_t a vector of estimated categorical coefficients that represent the catch rate for each year t. This is generally referred to as a log linear model.

In this study we use the above model to estimate annual boat ramp traffic per unit effort given concurrent environmental, temporal, spatial, and social conditions. In particular, we use direct observations of the number of recreational fishing boats returning to a given boat ramp per hour, N, to estimate the number of trips per hour (h) per unit population (P). We define this as NPUE ($\mathrm{N\,h^{-1}\,P^{-1}}$) which can be written:

$$\mathrm{NPUE} = \exp[\mathrm{B} \bullet \mathrm{Z} + \mathrm{Y}_t + \ln(\mathrm{P})_t] \qquad (2)$$

where B is as above, P_t the population, or population index, for each year t, and Y_t the recreational fishing effort (fishing trips) per unit population for each year t. We assume that NPUE can be described by a Poisson distribution, and that the estimated coefficients, B and Y, on the right hand side of the above equation are normally distributed. Unstandardised and standardised (Generalised Linear Models) explorations of the data were initially undertaken, and the results from these used to structure a hierarchical Bayesian model of the relative number of fishing parties returning to key boat ramps in SNA 1, through space and time.

3.2 Data

Observed boat ramp traffic data were used as described in Section 2. More data were available for some circumstances than others due to changes in survey design and daylight length throughout the year. For example, the 1996 survey ran for 12 months, and data were collected on all day types, in a randomly allocated manner. In 2001, 2002, and 2003, data on boat ramp traffic volumes were almost solely collected on weekends and public holidays, during the first four months of the calendar year. Further, more information is available for those days when environmental conditions permitted fishing activity, as boat ramp interviewing was often abandoned on days when the wind speed exceeded 20 knots, or excessive amounts of rain were encountered by boat ramp interviewers. We take account of the above problems in the Bayesian formulation (see Section 3.5).

Most environmental data were binned and treated as categorical variables (Table 6). In doing this, it is assumed that the relationship between fishing effort and the environmental variable within each bin is linear.

Table 6: ***Summary of temporal and environmental variables used in the generalised linear modelling of recreational boat ramp traffic.***

Variable	Type	Description
Year	cat 6	1991, 1994, 1996, 2001, 2002, 2003 (Dec. to Nov.)
Month	cat 12	Jan, Feb, etc.
Day type	cat 2	Weekday, Weekend/Public holiday
Hour	cat 24	Hour (NZSDT)
Wind speed	cat 4	0 to <11 knots, 11 to < 17 knots, 17 to < 22 knots, 22 knots plus
Wind direction	cat 2	*Onshore, Offshore*
Maximum air temperature	cont	°C (AK Airport)
Rain fall	cont	mm per day (Leigh Marine Laboratory)
Tidal state	cat 4	High, Outgoing (Out), Low, Incoming (In)

3.3 Unstandardised analysis

The influence of environmental and temporal variables on recreational fishing effort was initially investigated by comparing unstandardised observations of boat ramp traffic rates between 1991 and 2003. To facilitate the ready comparison of results between survey years, we have re-expressed these boat ramp traffic rates relative to a regional population abundance index. Trends in NPUE (number of fishing parties per hour per population) may therefore reflect the relative tendency of a population unit to go fishing, given the spatial, temporal, social or environmental states being compared.

Overall, and in all three regions, there was very little change in fishing effort since 1991 (Figure 4). Comparisons of NPUE across regions are potentially misleading, as boat ramp traffic rates within a region reflect the relative availability of facilities such as boat ramps and parking, and these will probably differ between regions. Individual ramp plots are given in Appendix 1.

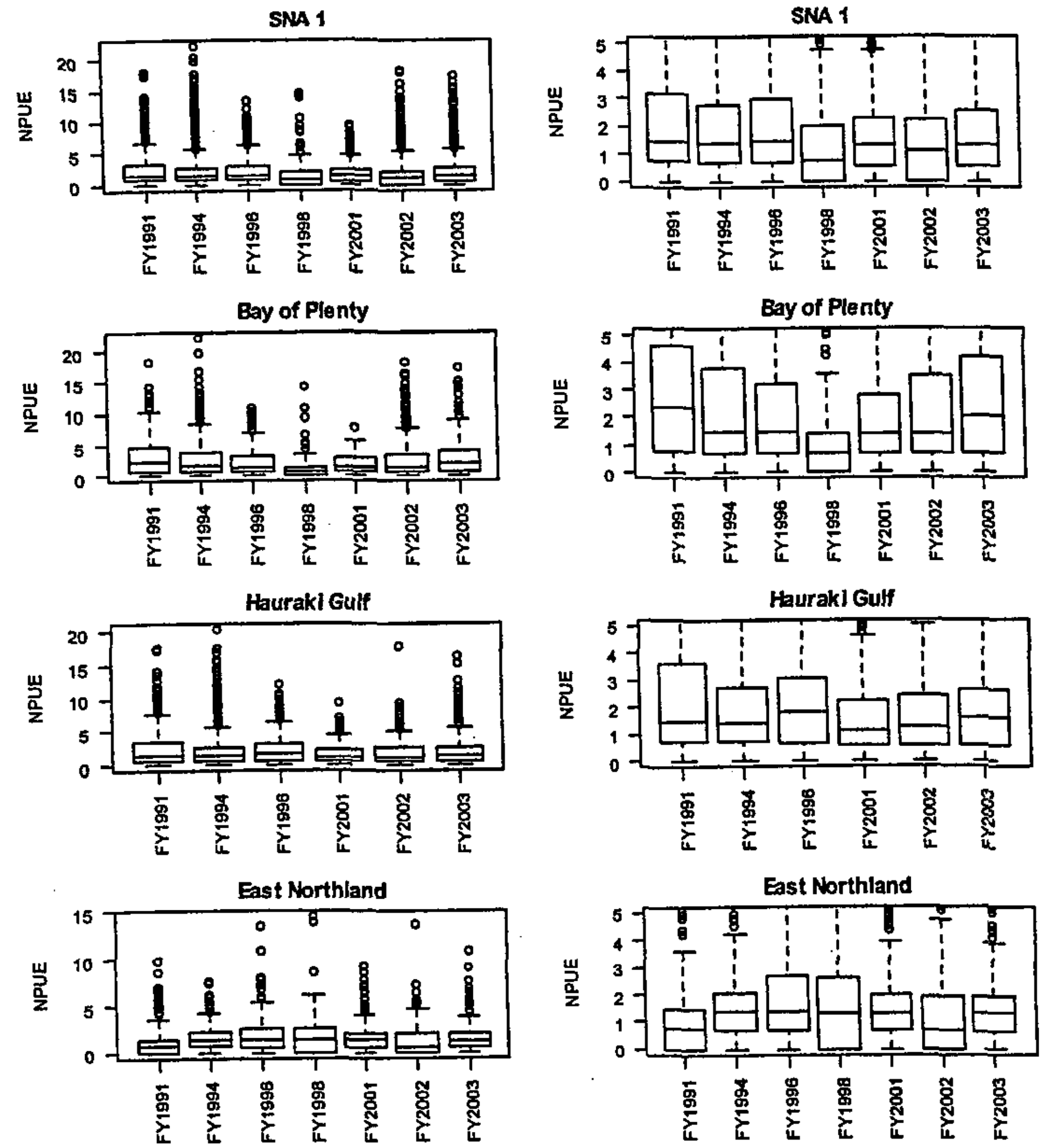


Figure 4: Boxplots of NPUE (boats per hour per unit population) for fishing years (1 October to 30 September) 1991-2003. The plots on the right hand side have a different y-axis scale. Each boxplot shows the median and inter quartile range, whiskers extending to the most extreme point which is no more than 1.5 times the length of the box away from the box, and extreme points outside the whisker range.

The influence of potentially explanatory variables is examined Figure 5. Traffic rates differ greatly at each ramp, probably due to a number of reasons including the size of the ramp, condition of the ramp, location, population density, and other factors. The effect of wind speed is also clearly shown with traffic decreasing as the speed increases. Both tide and wind direction (as inferred from a comparison of the bottom two rows of plots) appear to have little influence on the tendency to go fishing.

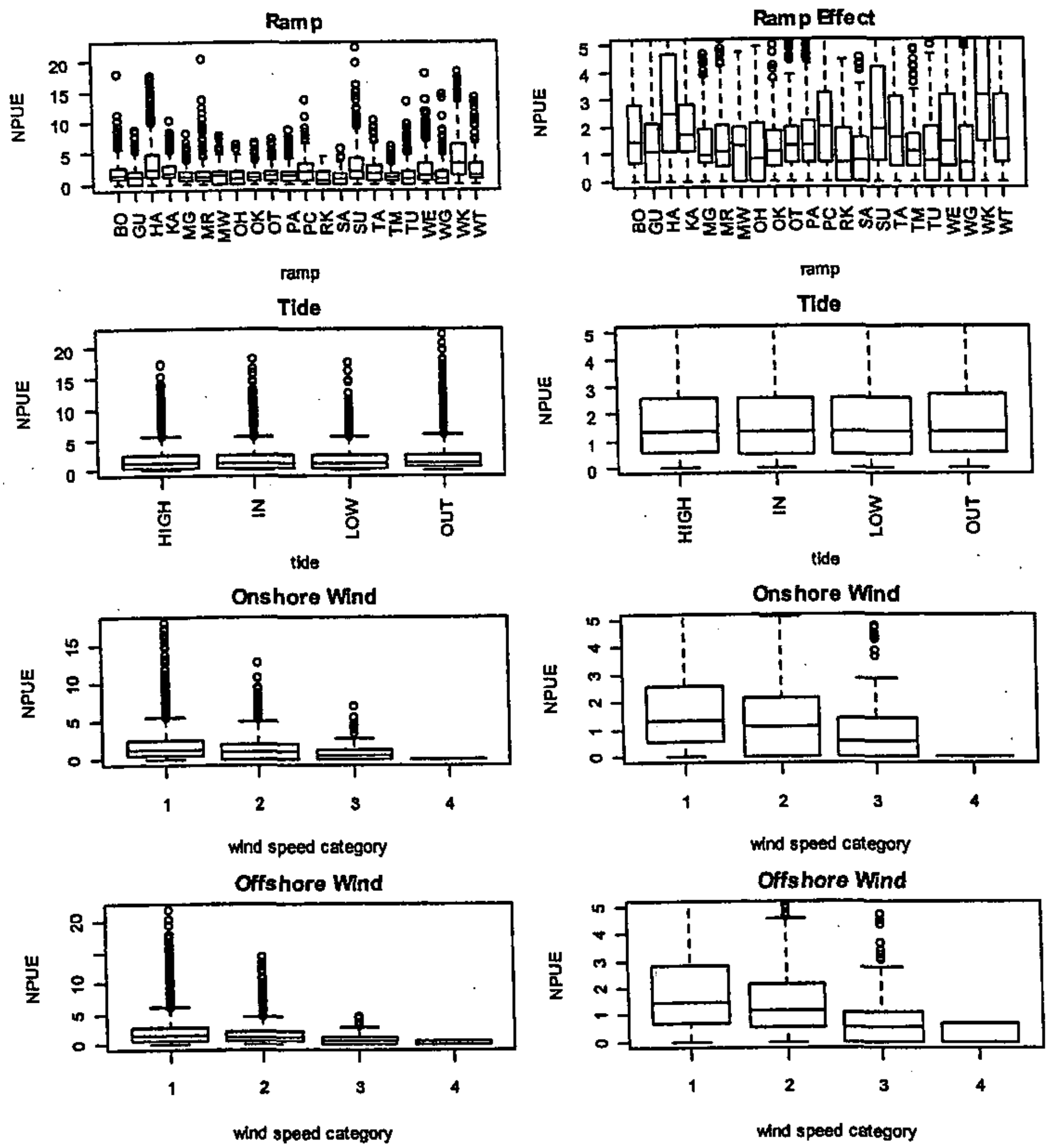


Figure 5: **Boxplots of NPUE for anticipated effects for all years combined. The right hand plots have a different y-axis scale. Wind speed category: 1 (0 to <11 knots), 2 (11 to < 17 knots), 3 (17 to < 22 knots), 4 (22 knots plus). Each boxplot shows the median and inter quartile range, whiskers extending to the most extreme point which is no more than 1.5 times the length of the box away from the box, and extreme points outside the whisker range. Ramp codes are given in Figure 1.**

Fisher behaviour is strongly influenced by time of day, type of day (whether or not it is a normal working day), and time of year (see Figure 6). More fishing parties are encountered at boat ramps during weekends and public holidays, and there is a greater tendency for them to return to the ramp between mid and late afternoon. The effect of decreasing daylight hours can also be seen by the profiles being compressed from April onwards. Few data are available in some months, particularly from June to December, when fishing effort is lowest.

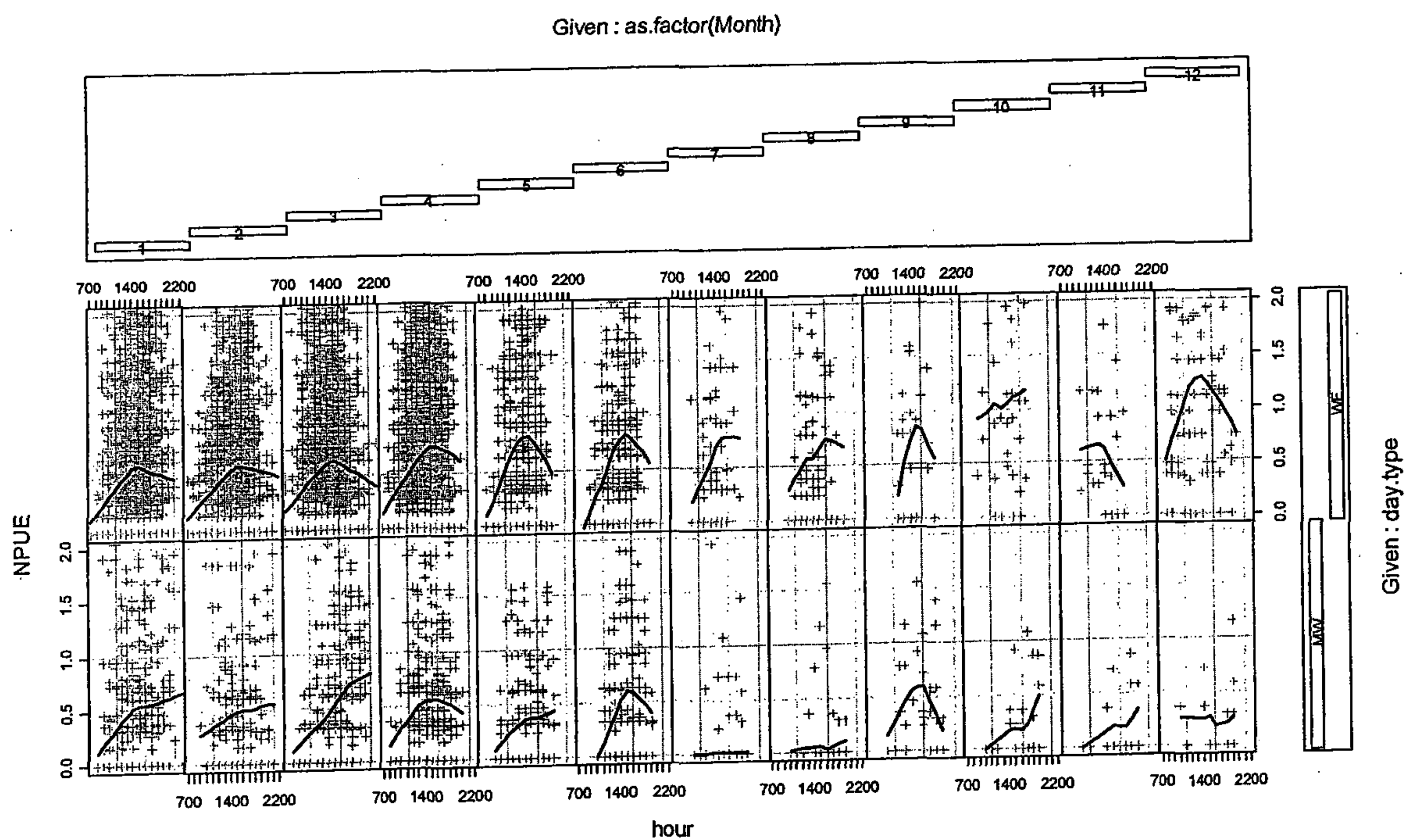


Figure 6: Number of recreational fishing boats returning to a given ramp per hour (NPUE) conditioned on day type and month for all years combined. January=1,...,December=12. Midweek=MW, Weekend=WE. Solid lines are lowess smoothed lines (f=0.2).

3.4 Standardised analysis

More data were available for some circumstances than others as explained in section 3.2. Generalised Linear Modelling (GLM) was used to further explore the relative influence of temporal and climatic variables on the hourly traffic of recreational fishing boats observed in boat ramp surveys. Relationships between fishing effort and most climatic variables are currently undescribed, but are unlikely to be linear.

In each model, both main effects and first order interaction terms (excluding those associated with a year effect) were selected via the automated stepwise fitting procedure stepAIC (R Statistical software). Effects were fitted in both directions (initially fitted in a forward direction, but subsequently dropped if a better fit resulting from other combinations of effects became apparent at a later iteration), and considered explanatory if their inclusion explained at least 0.5% of the remaining deviance.

Traffic rates were modelled according to the Poisson distribution, which accommodated the frequent occurrence of zero traffic rates, as well as high traffic rates at urban ramps during summer holidays. Canonical confidence intervals were not generated, as the purpose of this approach was solely to identify explanatory variables for a subsequent and more sophisticated Bayesian model, as discussed below.

The initial exploration of environmental influences on boat ramp traffic rates by GLM was restricted to data collected from the Hauraki Gulf. The reasons for this restriction were twofold; firstly the influence of prevailing climatic conditions on ramp traffic should be more apparent in the Hauraki Gulf, where traffic rates are generally higher, and secondly, the best descriptors of climatic conditions are generally found in this region. An initial attempt was made to model Hauraki Gulf traffic rates for all years in a single model, in which first order interaction terms were considered. This model exceeded the computational capacity of the statistical package used (R version 1.7.1) and only main effects were successfully modelled when all data were used (Table 7). All temporal effects explained an appreciable percentage of the deviance, as did ramp and wind speed effects. Tidal state and wind direction appear to have a lesser influence of boat ramp traffic rates, with daily rainfall and maximum temperatures having little explanatory power once other effects have been considered in the model.

Table 7: Selection of explanatory variables by a Generalised Linear Model of boat ramp traffic at key Hauraki Gulf ramps sampled during recreational surveys conducted since 1990. Interaction terms were not fitted in this model due to a lack of allocatable memory.

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	5835				
Ramp	8	2.20E-16	***	11.27	11.27
Hour	15	2.20E-16	***	16.78	5.51
Wind speed	3	2.20E-16	***	21.84	5.06
Day type	1	2.20E-16	***	25.78	3.94
Month	11	2.20E-16	***	27.76	1.99
Year	5	2.20E-16	***	29.91	2.15
Tide	3	2.20E-16	***	30.60	0.69
Wind direction	1	3.61E-04	***	30.67	0.07

* Daily rainfall and maximim temperature not selected by automated stepwise procedure

The significance of interactions between these main effects is, however, potentially informative, and it was computationally possible to model these interactions for individual survey years (1 December to 30

November; Appendix 2). The consistency with which main effects and first order interaction terms are selected by these models for each survey year individually was examined (Table 8).

The first term selected in all GLMs was the ramp effect. Hour, wind speed, and month effects also explained an appreciable percentage of the deviance in all models, though to a lesser extent in more recent years. Day type effects were only strongly evident in the first three surveys, which is not surprising given the low levels of midweek sampling which took place in the last three surveys (see Table 3). The most significant climatic effect after wind speed was tide, which was fitted in five of the survey models, but explained more than 0.5% of the deviance only in the first three years. Wind direction explained very little deviance in any of the models, and this was unexpected because there is a wide perception that onshore winds suppress fishing effort. The most significant interaction terms selected were those associated with the ramp effect, especially where temporal and wind effects were involved. Temporal interactions were also selected to a lesser degree.

Table 8: Percentage of deviance fitted in Generalised Linear Modelling of boat ramp traffic rates for each of the survey years. En-dashes denote instances where a term was not selected by a model. Some interaction terms were not selected by any of the models. The year effect was not considered, as models were year specific. Individual model results are given in Appendix 2.

Variable	1991	1994	1996	2001	2002	2003	used
Ramp	17.0	8.0	10.0	13.1	17.7	32.3	Y
Hour	13.0	8.3	9.3	3.0	5.9	3.9	Y
Wind speed	4.8	5.7	3.7	6.2	12.8	2.0	Y
Day type	1.5	8.4	7.3	–	0.3	0.4	Y
Month	6.0	8.1	8.7	4.4	0.8	0.8	Y
Ramp:Month	4.2	2.0	5.9	3.9	3.0	2.7	Y
Ramp:Hour	–	3.9	8.1	7.9	7.4	3.8	Y
Ramp:Wind speed	1.0	–	–	3.9	2.4	0.8	Y
Month:Wind speed	3.4	1.2	–	–	–	–	–
Tide	1.3	2.5	1.7	–	0.5	0.3	Y
Ramp:Day type	–	0.5	2.3	–	0.9	0.5	Y
Hour:Tide	5.5	2.6	–	–	–	1.8	–
Wind direction	–	–	0.3	0.9	0.1	0.3	Y
Day type:Hour	–	1.4	–	–	–	–	Y
Ramp:Wind direction	–	–	0.7	2.5	–	1.4	Y
Wind speed:Wind direction	–	–	0.4	0.6	0.4	–	Y
Temperature	1.5	–	–	0.2	0.1	0.6	–
Month:Tide	–	0.8	7.4	–	–	0.7	–
Month:Hour	–	–	–	3.6	–	–	Y
Wind speed:Temperature	0.7	–	–	–	0.2	0.4	–
Month:Temperature	2.3	–	–	0.5	0.3	1.5	–
Ramp:Tide	1.7	1.1	–	–	–	1.5	Y
Hour:Wind direction	–	–	3.1	1.4	–	–	–
Month:Wind direction	–	–	1.7	–	0.3	0.3	–
Rain	0.0	–	–	–	–	–	–
Hour:Temperature	1.5	–	–	1.6	0.7	–	–
Ramp:Temperature	–	–	–	–	0.7	1.3	–
Day type:Tide	–	0.2	–	–	0.2	–	–
Month:Day type	0.8	–	–	–	–	–	Y
Day type:Temperature	0.1	–	–	–	0.1	–	–
Wind direction:Temperature	–	–	–	–	0.1	0.3	–
Day type:Wind speed	–	0.1	–	–	–	–	–
Tide:Wind direction	–	–	0.5	–	–	–	–
Ramp:Rain	*0.6*	–	–	–	–	–	–
Month:Rain	0.3	–	–	–	–	–	–
Hour:Wind speed	–	–	–	–	–	0.6	–
Total deviance explained	67.3	54.8	71.1	53.6	54.9	58.3	

3.5 The Bayesian model approach

A hierarchical Bayesian model was constructed in WinBUGS[1] version 1.4 (Windows Bayesian Inference using Gibbs Sampling), the structure of which was based on the results of the GLMs described above. WinBUGS, and the Bayesian approach in general, is well suited to mixed effects models and has several potential advantages over GLM methods. We outline the most relevant of these below.

The main limiting factor of a GLM approach is its inability to interpret relatively sparse and unbalanced data sets, such as those used here, in a statistically robust manner. This is particularly a problem when estimating second (or even higher) order interactions and nested effects. An example of this can be seen in Figure 6, where very little, if any, data are available for some month/day-type combinations. The hierarchical structure of the Bayesian model overcomes this limitation by pooling data across similar anticipated effects, thereby improving the precision of the estimates. The amount and strength of this pooling effect is formally determined by the prior specifications and the amount of available data. When few data exist therefore, the pooling effect is stronger, and vice versa for when large amounts of data exist. One key assumption of this approach is that the data are in some way exchangeable and therefore some care has to be taken in determining sensible hierarchies.

Another potential benefit of a Bayesian model is the formal inclusion of ancillary information which may provide insight into changes in fishing effort. A description of associated data sources which were considered is given in Appendix 4. Unfortunately, it appears that there are no reliable ancillary data available for the specification of priors on a trend in fishing effort since 1970. In the absence of any such data, uninformed priors were used and we let the data speak for itself.

The *initial structure* for the Bayesian model was based primarily on the results of the GLM analysis (see Table 8). However, we have also included some structure and effects in the model that we believe add intuitive nicety to the model. We outline these below.

Although wind direction explained very little deviance in any of the GLM models, we included this effect in the Bayesian model (in conjunction with wind speed) as there is a wide perception that onshore winds suppress fishing effort.

From our unstandardised analysis, it was apparent the average number of fishing parties encountered at a given time of day was dependent on the month and type of day during which the survey took place. This is due to some extent on the length of daylight in different months. In the GLM analysis we did not look at any third order interaction between these variables due mainly to the lack of data that such a stratification would result in because of computational limitations. However, in the Bayesian model we nested hours within day types and months, as we believed that fishing effort changes across each hour, day type, and month.

In the Bayesian model we include random effects at a ramp level and at an individual observational level (although strictly speaking all effects in the Bayesian model are random). The random effect at the ramp level is used to model differences between ramps based on environmental, physical, and other possible factors that we have not explicitly included in the model. These factors may include the size of the ramp, location, available parking, and others that may influence ramp patronage. The random effect at the observational level is included to model Poisson overdispersion that exists in the model. Overdispersion exists when the variation in hourly boat counts can not be accounted for by the specified Poisson model and related distribution. The observational random effect therefore accounts for any effects that are not included in the rest of the model. This is comparable to normally distributed model error in a standard GLM.

[1] © WinBUGS 1996-2003: Imperial College & MRC, UK

Another feature of the model is the inclusion of a fitted rate of increase parameter, 'Rate', to yearly effort across each area, a (i.e., Rate[a]). This is essential to enable a projection of the model outside our observed data set, i.e., forward or in this case backwards in time. The model was also run without this parameter to enable estimates of the fishing effort per unit population. NPUE can now be expressed as:

$$NPUE = exp[Rate[a] + B \bullet Z + Y_t + ln(P)_t] \qquad (3)$$

The final model structure and WinBUGS code is given in Appendix 5. A summary of the modelled effects is given in Table 9.

Table 9: Summary of temporal, environmental, and physical effects estimated in the hierarchical Bayesian model (N, number of estimable parameters).

Estimated effect	N	Description
Year[y,r]	154	Year effort effect y for each ramp r. Linked across each year category.
Rate[a]	3	Rate of increase in yearly effort for each region a. Linked across all regions.
Tide[t,r]	88	Tide effect t for each ramp r. Linked across each tide category.
Ramp[r]	22	*Ramp effect r. Linked across each tide category.*
Wind[w,s]	8	Wind effect for direction w and speed s. Linked across each wind speed category.
Hour[h,d,m]	110	Hour effect h given day type d and month m. Linked across day and hour.
R.E.[i]	13 470	Random observed hourly effect. Linked across all observations.

The data set used for the Bayesian model was identical to that of the GLM analysis. However, further binning of the data was undertaken to sensibly reduce the number of effects where there were clearly insufficient data available to allow meaningful modelling. The final model data set used in the Bayesian model in given in Table 10.

Table 10: Summary of temporal and environmental data used in the hierarchical Bayesian model of recreational boat ramp traffic.

Variable	Type	Description
Year	Cat 7	Fishing year - 1991, 1994, 1996, 1998, 2001, 2002, 2003 (Dec. to Nov.)
Month	Cat 5	Calender month – Jan, Feb, Mar, Apr, May-Dec
Day Type	Cat 2	Weekend/holiday, Weekday
Hour	Cat 11	0700–0900, 1000, ..., 1800, 1900–2200
Ramp	Cat 22	Individual ramps
Region	Cat 3	Bay of Plenty, Hauraki Gulf, East Northland
Tide	Cat 4	High, out, low, in
Wind speed	Cat 4	0 to <11 knots, 11 to < 17 knots, 17 to < 22 knots, 22 knots plus
Wind direction	Cat 2	Inshore, offshore
Population	Scalar	Population effect for each region per year

3.6 Estimated environmental effects (per capita)

The relationship between boat ramp traffic rates and the temporal and environmental variables given in Table 10 was examined in a Bayesian model run resulting in a Markov chain of 1 000 000 samples with every 10th one saved for further examination. Statistical and convergence diagnostics were performed which resulted in the samples being further thinned to every 20th sample. This resulted in a posterior sample of 5000. Full diagnostics and results are given in Appendices 6, 7, and 8. A summary of the main results of interest are given below. It should be noted that we present the canonical indices for each effect (not the absolute effect).

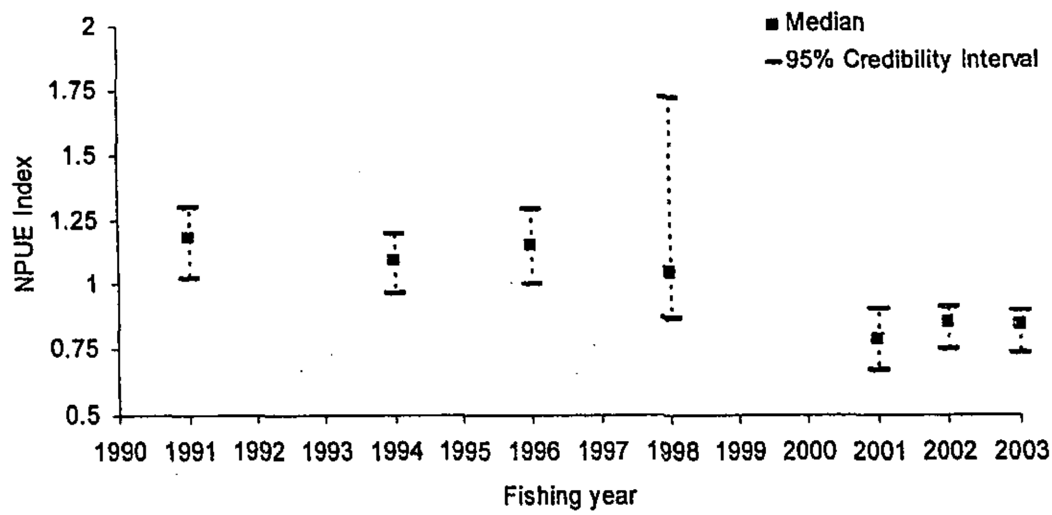


Figure 7: Plot of estimated annual canonical NPUE Index for SNA 1 showing the median and 95% credibility intervals. Full results for each ramp are given in Appendix 3.

There appears to have been a gradual decline in the per capita tendency to go fishing (relative number of trips per person) since 1991, when all other environmental effects, including population size, are taken into account (Figure 7). The credibility intervals in most survey years appear acceptable, with the exception of 1998, when data were collected from only one ramp in the Bay of Islands and two in the Bay of Plenty. As the sole objective of this study was to estimate indices of recreational fishing effort since 1970, is was necessary to fit canonical rates of fishing intensity change to all available data, which can then be used to extrapolate any indices outside the period for which data are available, i.e., between 1970 and 1990. The fitted rate for each region is shown in Figure 8, which suggests that effort declined in all three regions.

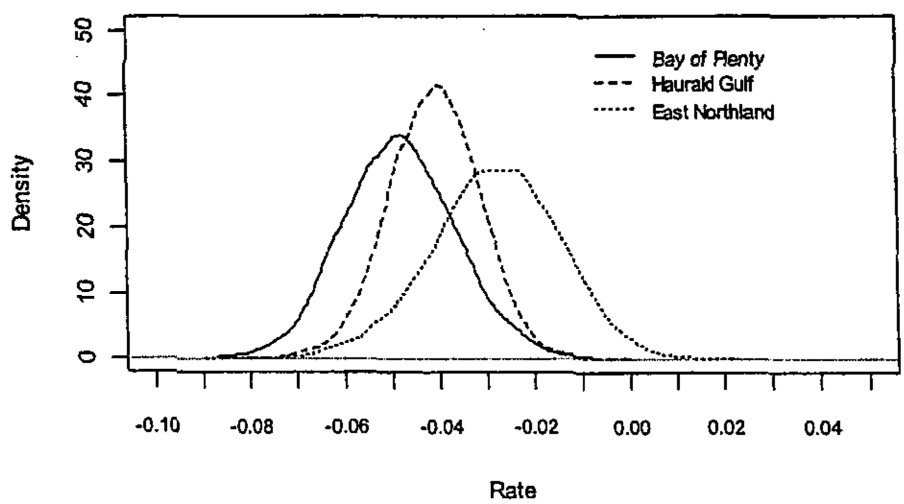


Figure 8: Estimated rate of effort increase in each region.

Initially two parametric functions were considered when projecting the fitted rate backwards to 1970: a linear function (1+rt) and an exponential function (e^{rt}), where r is the fitted estimated rate of effort increase (Rate[a]). In this report we present only the results of the linear back projection, as we believe that this gives a better representation of past levels of effort, and is more appropriate for projecting backwards in time. The alternative exponential function exhibits an unrealistic slope due to the length of the projection and the compounding nature of the exponential function.

Estimated individual hour effects (nested within day-type and month) were used to calculate the daily profiles of fisher party return times for the two day types, weekday and weekend/holiday. The profiles are shown in Figure 9 and can be compared to the unstandardised monthly day type profiles given in Figure 6. The main difference between the two day types is that boat ramp traffic peaks at 1500 hours during weekends and public holidays, but the mid-week traffic rates are fairly steady between 1300 and 1800.

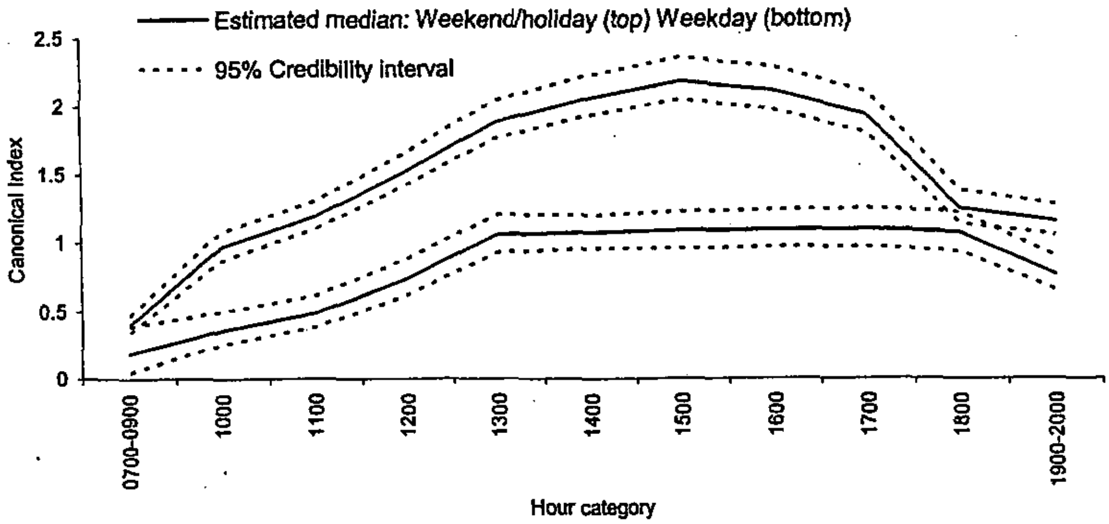


Figure 9: Plot of estimated canonical index for hourly effort given day type.

The estimated canonical influence of month and day type effects on boat ramp traffic rates suggests that these temporal variables are key determinants of fishing effort (Figure 10). As expected, effort peaks over the summer months of January to April and then declines during the winter. Also, the effort in the weekend/holiday is about twice that for mid-week. This is comparable to Figure 6.

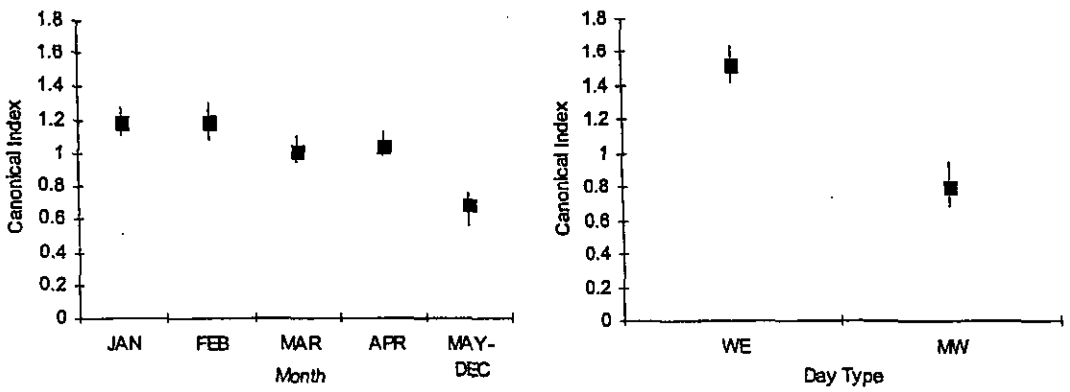


Figure 10: Estimated month and day type effects showing median (squares) and 95% credibility intervals (vertical lines).

Environmental and random ramp effects are shown in Figure 11. Both tide and wind direction appear to have little influence on the effort. As expected, the wind speed effect displays a steep decline with increasing wind strength, with effort in the 0 to <11 knot category close to 10 times that for the 22 knot plus category. The large credibility interval for the 22 knot plus wind category represents uncertainty due to the limited amount of data available. The random ramp effect displays the effort variation between ramps, and therefore highlights the busy ramps, e.g., Half Moon Bay (HA) and Whakatane (WK). Also of interest are the relatively large credibility intervals for each boat ramp. This suggests that traffic rates are still highly variable at individual ramps when all other modelled effects are held constant.

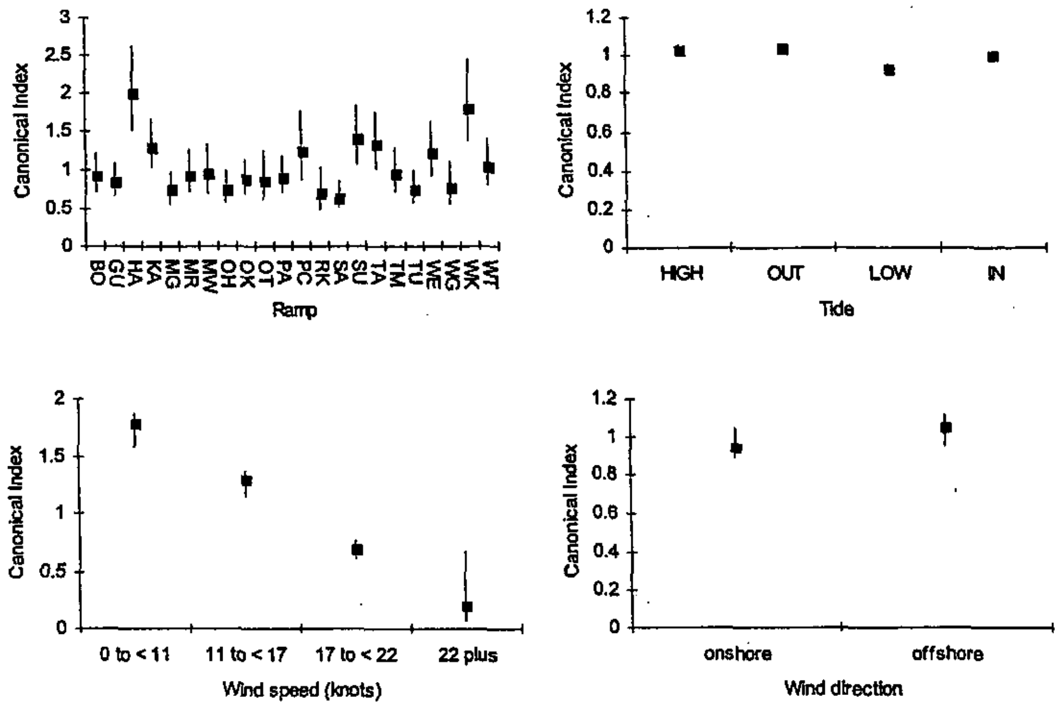


Figure 11: Estimated effects showing median (squares) and 95% credibility intervals (vertical lines). Ramp codes are given in Figure 1.

The influence of tidal state on traffic rates at each boat ramp is explored further in Figure 12. At some ramps the number of boats returning from fishing is lower during outgoing and especially low tides. This may reflect reduced accessibility at the ramps when the lower part of the ramp is exposed.

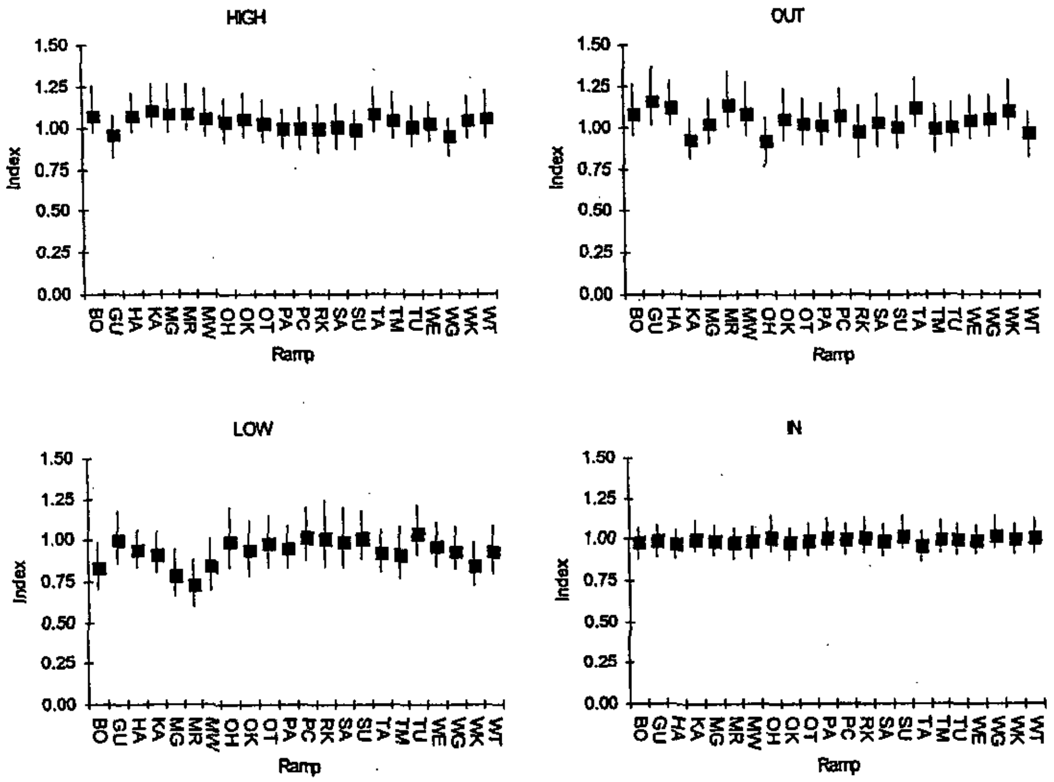


Figure 12: Estimated effects showing median (squares) and 95% credibility intervals (vertical lines). Ramp codes can be found in Figure 1.

3.7 Historical prediction (including population)

An object oriented C++ simulation model was developed to further utilise the results of the hierarchical Bayesian approach outlined above. This model combines daily regional historical weather data, as described in Table 5, and population indices (back as far as 1970), as shown in Figure 3, with the estimated effect of each of these conditions on boat ramp traffic, as derived from the Bayesian model. The distribution of these effects being determined from the thinned Markov Chain of 5000 samples (see Section 3.6). This permits the prediction of the number of boats at any given ramp or region (based on our sample of ramps), at any given time interval, for any given historical weather pattern. It should be noted that this prediction is for the total number of boats, N, in a given time interval and includes the effect of any population increase or decrease, and the estimated per capita change in the tendency to go fishing. Any regional projections are based on our sample of ramps, which we assume to be representative of the population of ramps within each area.

The predicted total number of boats per year for each region projected from 1970 to 2003 is given in Figure 13. There appears to have been little change in the intensity of fishing effort in the Bay of Plenty since 1970, compared to a gradual increase in the Hauraki Gulf and East Northland (Figure 13). Individual ramp plots are given in Appendix 7.

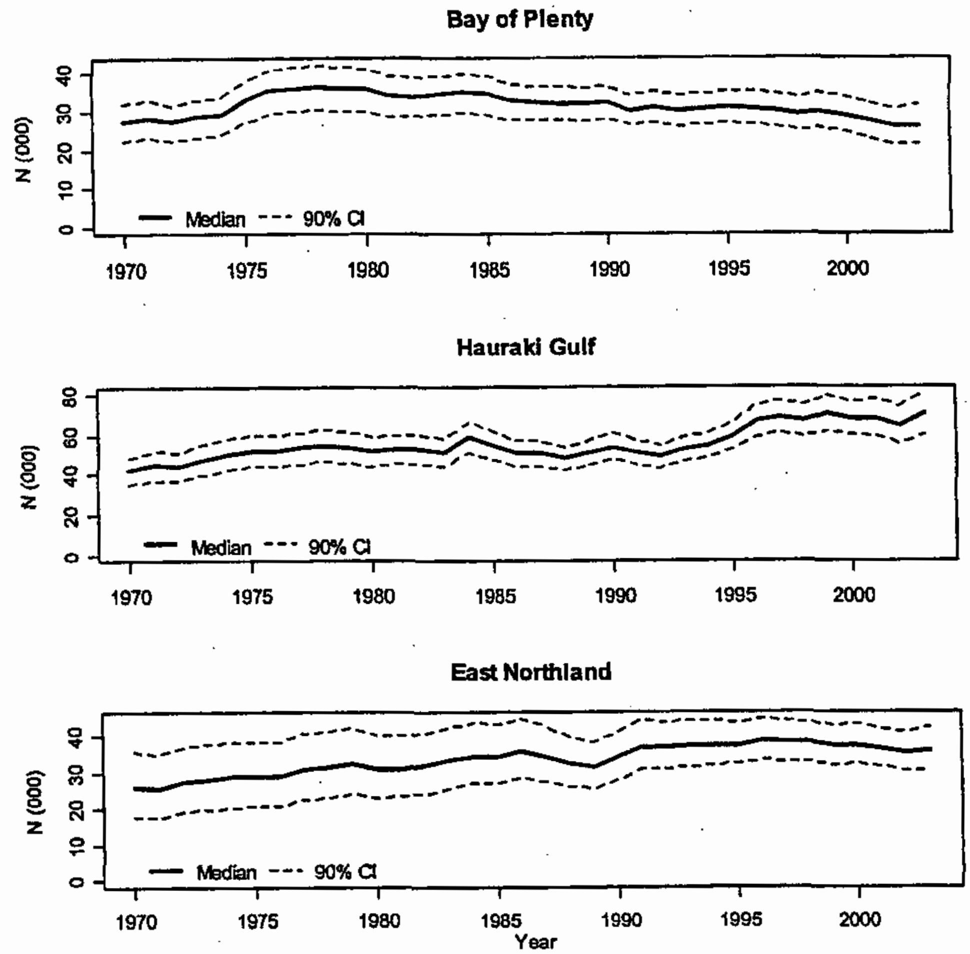


Figure 13: Annual total boats for each region.

As a further comparison we plotted the posterior distributions for 2003 and 1970 for each region (Figure 14). This plot shows the uncertainty that exists in our predictions and emphasises the magnitude of the estimated change in regional levels of fishing effort. The overlap in the East Northland posteriors indicates that there is a small probability that the total number of boats in 2003 has remained relatively constant compared to 1970. In contrast, the Bay of Plenty posterior seems to suggest that little has changed between 1970 and 2003.

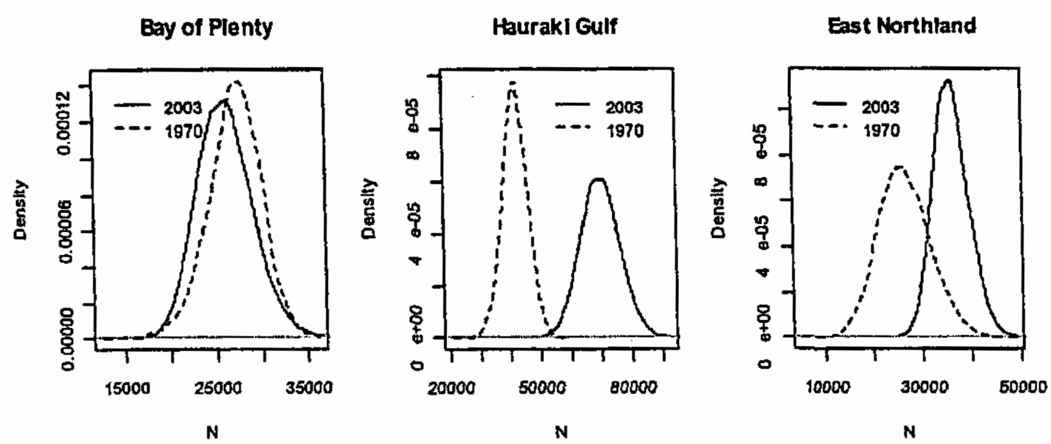


Figure 14: Predicted total number of boats in each region in 1970 compared to 2003.

The seasonality of fishing effort is clearly evident in all three regions (Figure 15). As expected, recreational fishing effort peaks over the summer months, but drops sharply after April, usually following the Easter break.

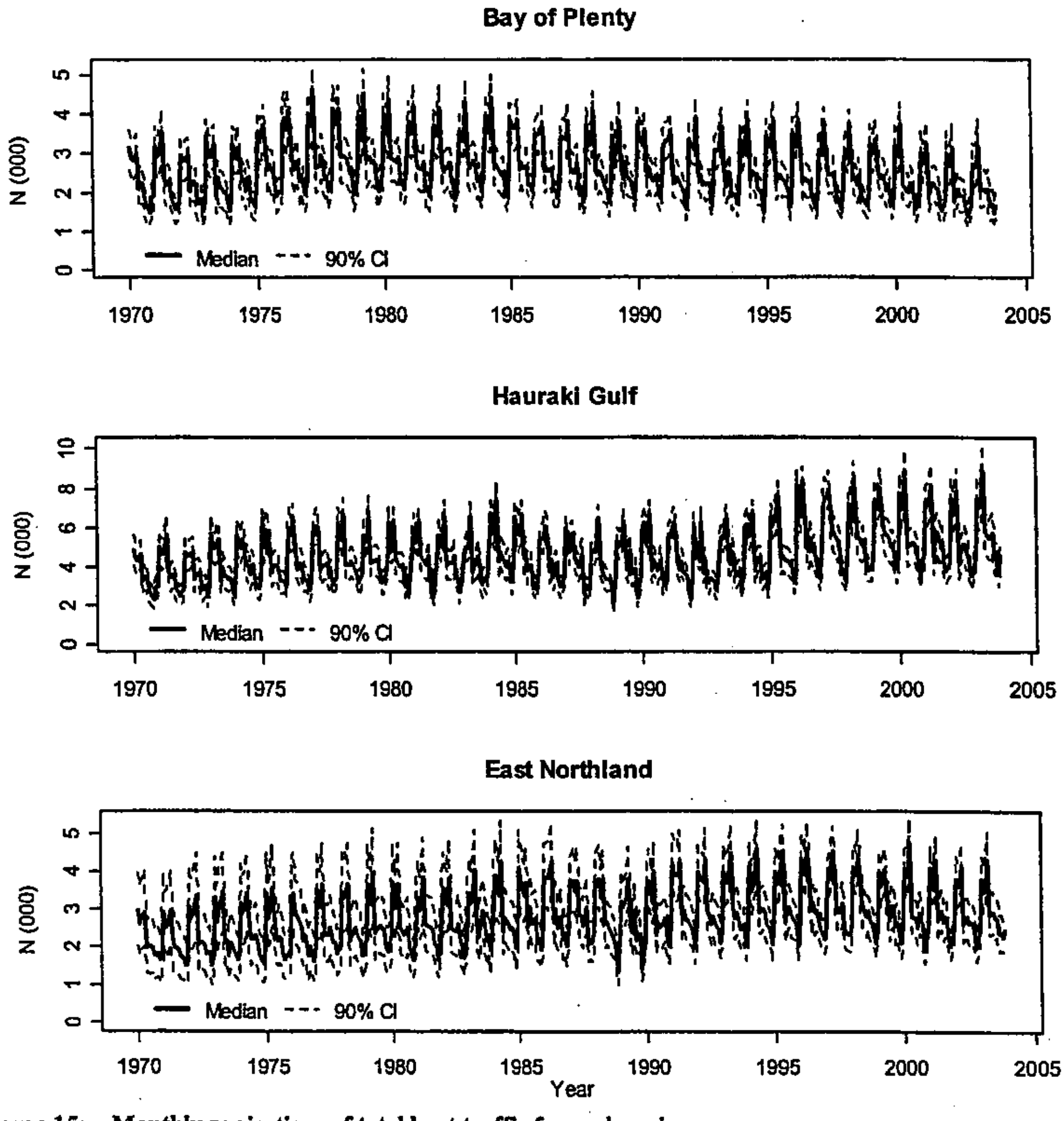


Figure 15: Monthly projections of total boat traffic for each region.

Predictions for an individual boat ramp (Takapuna) for a weekend and a mid-week day are given in Figure 16. The day type effect can clearly be seen with the mid-week day showing fewer boats. More importantly, this plot can be used to compare and test our model predictions with actual observed data obtained from boat ramp interviews, web cams, and over-flight surveys.

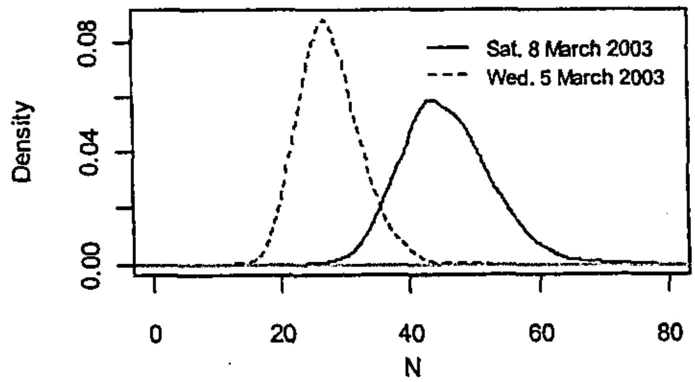


Figure 16: Predicted total number of boats for the public ramp at Takapuna on Saturday, 8 March 2003 (weekend, onshore, < 12 kts) and Wednesday, 5 March 2003 (mid-week, offshore, <12 kts).

4. DISCUSSION

Our understanding of current and historical levels of snapper harvesting by recreational fishers is currently inadequate for both stock assessment modelling and management. The model described in this report represents the most sophisticated attempt to date towards understanding the nature and extent of the SNA 1 recreational fishery. Previous attempts to estimate recreational catch histories have been based on harvest estimates of dubious accuracy and limited extent, and little progress has been made in this region.

We have used the most extensive and consistent source of information available on recreational fisheries in SNA 1 that is independent of voluntary information provided by recreational fishers, collected from boat ramps since 1991, to construct a history of relative fishing effort. The number of fishing trips undertaken by recreational fishers is likely to be the main determinant of relative harvest levels, followed by catch rates and trip durations which are not considered here, but are unlikely to change dramatically through time. It should be seen that the number of fishing trips is largely driven by population growth.

The Bayesian approach we have adopted appears to sensibly estimate investigated environmental and temporal effects, with all estimates displaying reasonably tight credibility intervals. This precision is partially due to the hierarchical nature of the model used, which facilitates the pooling of information to overcome uncertainty surrounding under-sampled conditions. Intuitively obvious seasonal, diurnal, and environmental trends in predicted fishing effort were generated by the model which seems to indicate that the model performs satisfactoraly. We believe that the estimated decline in fishing effort across all three areas may have some validity, particularly within the data set (i.e., since data were first collected in 1991). The projection of these trends back as far as 1970 is, however, far more questionable, as discussed below.

The results of the Bayesian model suggest that per capita fishing effort has declined over the intermittently observed time period, from 1991 to 2003. This suggested decline may be in part due to the increasing range of recreational activities which have become available over the last two decades (Simon Chamberlain, Sport and Recreation New Zealand, pers. comm.) When the daily occurrence of environmental conditions and the rate of population increase since 1970 is considered however, it appears that the number of fishing trips by trailer boats has increased gradually through time in East Northland and the Hauraki Gulf, but has decreased in the Bay of Plenty. These results should be regarded with some caution, for the following reasons.

In the model we have assumed increase in population is uniform across each region. However, this may not be true and population may have varied substantially within each region.

For example, in the Bay of Plenty region, the population of Tauranga has increased at a far higher rate than elsewhere, which may have resulted in an atypically high increase in traffic rates at associated ramps. Applying a standard population growth across all ramps within a region may not therefore be representative of the actual growth in fishing effort. As population is a multiplicative scalar in the model, the effect of underestimating (or possibly overestimating) the population growth will directly affect the effort index and, ultimately, the number of observed boats. We believe that this problem is reasonably isolated to the Bay of Plenty region as the population catchment represents a large and diverse region (see Figure 2).

Any increase in the population index will result in a further decrease of the estimated fishing effort, as the net effect on observed boats must remain the same, i.e., the estimated 'Rate' parameter will compensate. However, the observed boats may not be representative of the true effort as some of the decline may be due to new ramps being installed close to our sample ramps. This will obviously dilute the effort from our sample ramps. Information on boat ramp developments (resource consent applications since 1992) was obtained from Environment Waikato and Environment Bay of Plenty. These data suggest that although some minor improvements have been made to several of the ramps we have surveyed, the only ramps built in recent years have been modest structures, and their influence would be minor. This is also thought to be the case in East Northland and the Hauraki Gulf. No information is available on ramp development before the early 1990s, however, and any extrapolation before this should be treated with extreme caution. Ramps may also suffer from deterioration (or be upgraded), thereby modifying fishers' preference and effort between ramps, either surveyed or not surveyed. We assume that over time this effect averages out to zero.

Some ramps may have increased use over the holiday periods. The annual global regional population scalar effect may therefore be inappropriate in these months. This may be accounted for by the inclusion of a month:ramp interaction effect or by the explicit inclusion of a monthly population index. However, with limited data, both of these remain difficult to implement. For example, a month:ramp interaction would result in a further 110 parameters being estimated in the model, for which little information exists, particularly when monthly, subregional, and population growth is considered.

It should also be noted that due to the observed boat ramp data being given per hour, it is already a rate. In the raw form this is not the case, and the observation period consists of several hours in a row. We have assumed each hour is an independent observation and ignored any possible auto-correlation. This may result in slight bias of the data, although we believe it most likely that this would average out to zero.

In the simulation we made several assumptions to predict outside the dataset. The most significant is that we chose a parametric model to project the estimated rate of effort increase (in this case negative) back to 1970. Further, we did not include a relationship between fishing effort and stock size. For our observed data set, the stock size has remained relatively constant. However, this is unlikely to be the case for our projection period – estimates of SNA 1 stock size have significantly decreased since 1970 (Gilbert et al.2000). Taking these two main points into consideration and projecting this far out of the bounds of the observed data set, any results, and particularly those more than a few years outside our observed data, must be treated with caution.

5. CONCLUSIONS AND FURTHER DEVELOPMENT

5.1 *Conclusions*

This report outlined the development of hierarchical Bayesian model used to estimate boat ramp traffic. The following conclusions are made.

- Weather effects and other factors influencing boat traffic have been estimated and shown to have a clear effect in determining fishing effort.
- Per capita fishing effort has decreased over time in all three regions.
- The decrease in effort has largely been offset by an overall population increase.
- The level of estimated fishing activity has increased in Hauraki Gulf and East Northland, and remained relatively constant in Bay of Plenty.
- Results obtained from projecting the model significantly outside the observed data set should be treated with caution.
- Further development, testing, and inclusion of more data are needed to improve the existing model for final use.

5.2 Further development and use

There are many potential uses for this model, and several regions in which further development could/should proceed. We provide a brief summary of these below.

- Inclusion of further data, including that from the most recent ramp surveys.
- Further refinement and model testing.
- Testing with independent data sources – e.g., overflight surveys and boat ramp web cam data.
- Use as simulation tool for survey design.
- Identification of any new ramps that have been built within each region and any significant deterioration or improvements in existing ramps.
- Development of recreational catch history model for SNA 1 using existing snapper catch survey data and a stock assessment model.

Ultimately, the model should be integrated within a SNA 1 fisheries stock assessment model and a relationship between the stock size and fishing effort established. Integration into another model would require development of the model outside of WinBUGS (possibilities include the recently released ADMB-RE[2] or a custom built model using C++). This is seen as an advantage as it has other benefits associated with it, namely, an increase in computational speed and ability to deal with models of greater complexity. The main use of the model as it stands in WinBUGS is that it should be used as a framework and testing comparison to further development.

6. ACKNOWLEDGMENTS

Thanks to Murray Smith and Renate Meyer for providing useful suggestions, help regarding the Bayesian approach, and particularly the BUGS model development. We also thank David Fisher, boat ramp interviewers, and providers of ancillary information on recreational fishing. We also appreciated Mike Beardsell's editorial comments on this document. Funding for this project (SNA200201) was provided by the Ministry of Fisheries.

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[2] ©AD Model Builder – Random Effects, August 2004, Otter Research Ltd., Canada.

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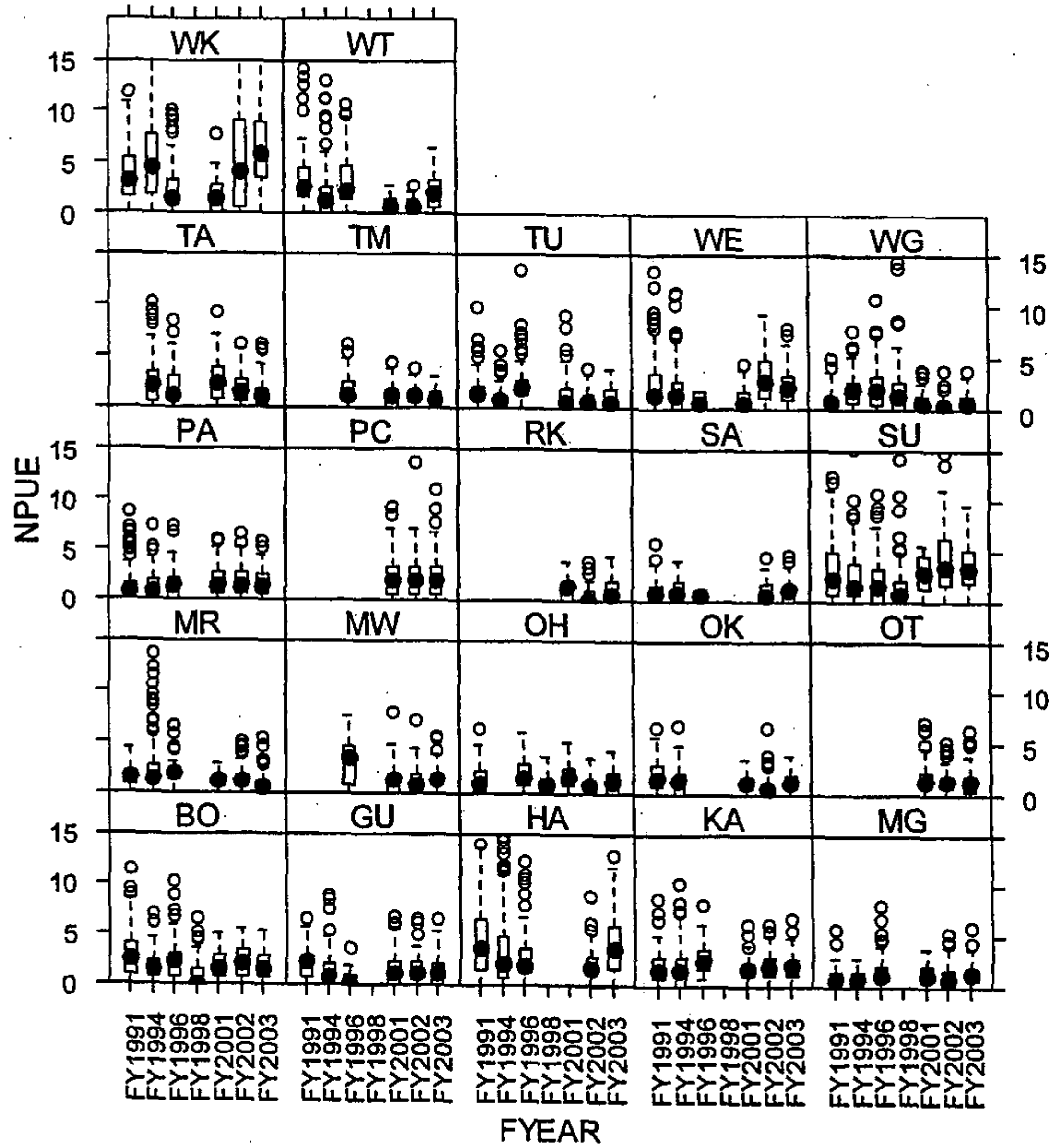
Appendix 1: Unstandardised individual ramp results



Appendix 2: Selection of explanatory variables by a Generalised Linear Model of boat ramp traffic at key Hauraki Gulf ramps sampled during each of the recreational surveys conducted since 1990. Interaction terms are denoted by a colon, and the predictors used the final Bayesian model are denoted with an asterisk

1 December 1990 to 30 November 1991

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	647				2419.82
*Ramp	6	2.20E-16	***	16.95	16.95
*Hour	14	2.20E-16	***	29.94	12.98
*Month	6	2.20E-16	***	35.91	5.97
*Wind speed	3	2.20E-16	***	40.75	4.84
Month:Wind speed	7	3.29E-15	***	44.18	3.43
*Ramp:Month	26	6.36E-11	***	48.39	4.21
*Tide	3	4.97E-07	***	49.72	1.33
*Day type	1	2.44E-09	***	51.19	1.47
Hour:Tide	39	4.18E-12	***	56.66	5.47
Temperature	1	1.03E-09	***	58.20	1.54
Wind speed:Temperature	1	3.13E-05	***	58.92	0.72
Month:Temperature	4	2.05E-11	***	61.23	2.31
Rain	1	9.88E-01		61.23	0.00
Hour:Temperature	13	6.45E-04	***	62.71	1.48
*Month:Day type	3	1.31E-04	***	63.56	0.85
*Ramp:Wind speed	9	3.53E-03	**	64.57	1.01
Ramp:Rain	5	1.21E-02	*	65.18	0.60
*Ramp:Tide	18	1.02E-03	**	66.92	1.75
Month:Rain	1	1.20E-02	*	67.19	0.26
Day type:Temperature	1	8.27E-02	.	67.31	0.12

1 December 1993 to 30 November 1994

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	1637				5910.60
*Ramp	7	2.20E-16	***	8.02	8.02
*Day type	1	2.20E-16	***	16.41	8.38
*Hour	15	2.20E-16	***	24.66	8.26
*Month	5	2.20E-16	***	32.74	8.07
*Wind speed	2	2.20E-16	***	38.46	5.73
*Tide	3	2.20E-16	***	40.93	2.47
Hour:Tide	39	1.22E-15	***	43.54	2.61
*Day type:Hour	13	1.03E-12	***	44.99	1.45
Month:Wind speed	7	1.19E-12	***	46.18	1.19
*Ramp:Hour	88	2.50E-14	***	50.03	3.85
*Ramp:Month	32	1.04E-11	***	52.02	1.99
*Ramp:Tide	21	1.34E-06	***	53.14	1.12
Month:Tide	15	3.30E-05	***	53.94	0.80
*Ramp:Day type	7	8.11E-05	***	54.46	0.51
Day type:Tide	3	7.60E-03	**	54.66	0.20
Day type:Wind speed	1	1.16E-02	*	54.77	0.11

1 December 1995 to 30 November 1996

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	444				1213.01
*Ramp	7	2.20E-16	***	9.99	9.99
*Day type	1	2.20E-16	***	17.25	7.26
*Month	10	2.20E-16	***	25.98	8.73
*Hour	14	2.20E-16	***	35.28	9.30
*Wind speed	3	7.74E-10	***	39.02	3.74
*Ramp:Month	27	5.57E-06	***	44.97	5.95
*Ramp:Day type	5	4.45E-05	***	47.24	2.27
*Ramp:Hour	43	3.11E-06	***	55.35	8.12
*Tide	3	1.35E-04	***	57.04	1.69
Month:Tide	29	4.66E-08	***	64.40	7.36
*Wind direction	1	6.63E-02	.	64.68	0.28
Hour:Wind direction	12	1.97E-04	***	67.76	3.08
Month:Wind direction	7	3.63E-03	**	69.50	1.74
*Wind speed:Wind direction	2	9.71E-02	.	69.88	0.38
*Ramp:Wind direction	4	8.59E-02	.	70.55	0.67
Tide:Wind direction	3	8.95E-02	.	71.09	0.54

1 December 2000 to 30 November 2001

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	716				1836.73
*Ramp	6	2.20E-16	***	13.07	13.07
*Wind speed	2	2.20E-16	***	19.22	6.15
*Month	3	2.20E-16	***	23.64	4.42
*Ramp:Month	17	1.17E-08	***	27.54	3.90
*Ramp:Wind speed	12	1.99E-10	***	31.41	3.87
*Hour	11	9.69E-08	***	34.38	2.97
*Ramp:Hour	44	8.32E-13	***	42.30	7.93
*Wind direction	1	5.08E-05	***	43.20	0.89
*Ramp:Wind direction	5	1.25E-08	***	45.67	2.47
*Month:Hour	30	1.54E-04	***	49.27	3.60
*Wind speed:Wind direction	2	4.25E-03	**	49.86	0.59
Hour:Wind direction	9	2.50E-03	**	51.25	1.39
Temperature	1	7.07E-02	.	51.43	0.18
Hour:Temperature	11	1.81E-03	**	53.04	1.61
Month:Temperature	3	2.25E-02	*	53.56	0.52

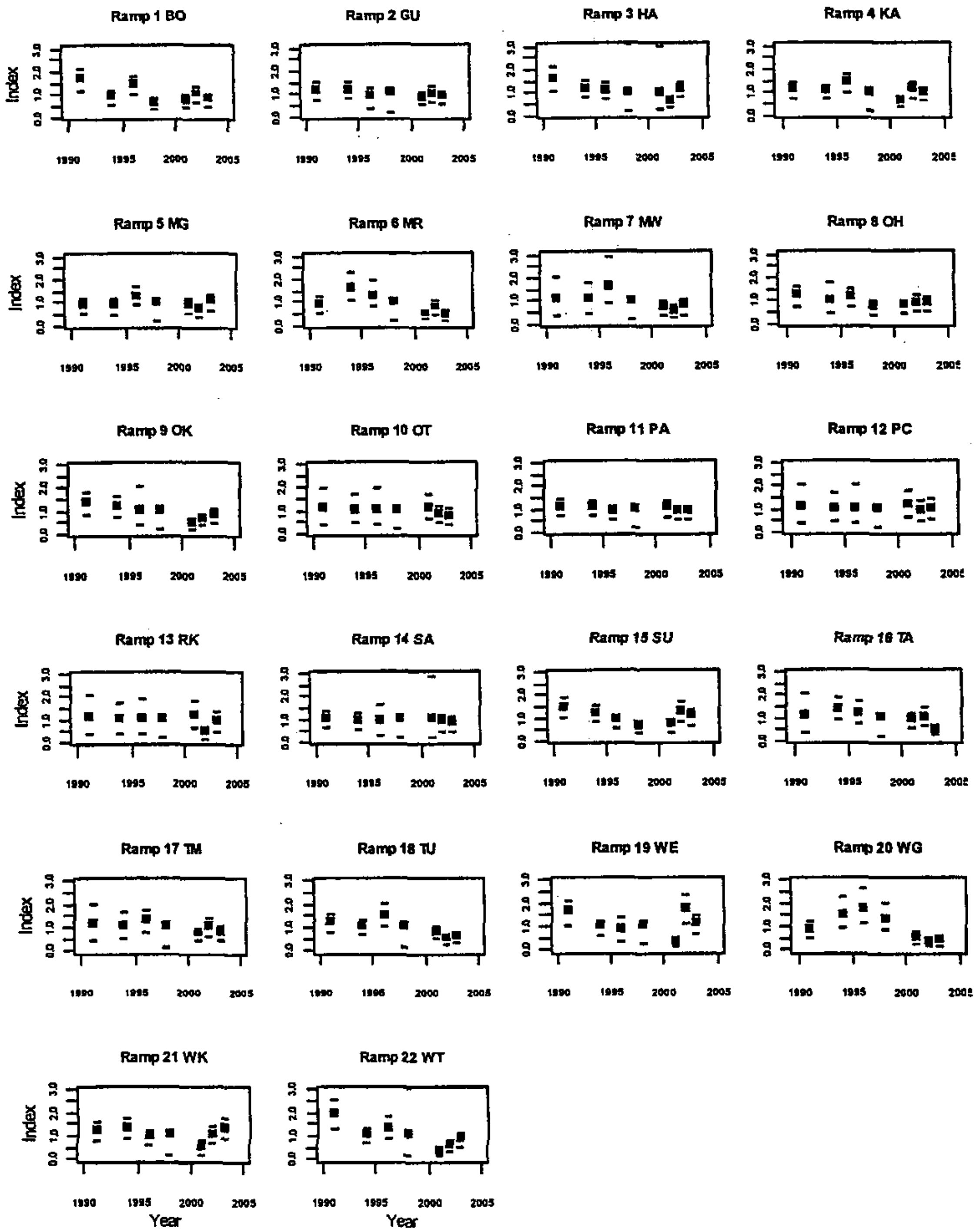
1 December 2001 to 30 November 2002

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	1177				3153.44
*Ramp	8	2.20E-16	***	17.73	17.73
*Wind speed	2	2.20E-16	***	30.50	12.76
*Hour	11	2.20E-16	***	36.37	5.88
*Ramp:Hour	62	2.20E-16	***	43.81	7.44
*Ramp:Wind speed	15	2.86E-10	***	46.24	2.43
*Month	4	8.63E-05	***	47.00	0.76
*Ramp:Month	24	2.34E-10	***	50.00	3.00
*Wind direction	1	5.71E-02	.	50.12	0.11
*Wind speed:Wind direction	2	2.36E-03	**	50.50	0.38
*Day type	1	1.66E-03	**	50.81	0.31
*Ramp:Day type	3	2.30E-06	***	51.73	0.92
Temperature	1	4.49E-02	*	51.86	0.13
Month:Temperature	3	2.12E-02	*	52.17	0.31
Wind speed:Temperature	2	3.45E-02	*	52.38	0.21
Hour:Temperature	9	1.22E-02	*	53.05	0.67
Day type:Temperature	1	6.75E-02	.	53.16	0.11
Month:Wind direction	3	4.71E-02	*	53.41	0.25
*Tide	3	2.13E-03	**	53.87	0.46
Day type:Tide	3	7.34E-02	.	54.09	0.22
Ramp:Temperature	8	3.01E-03	**	54.83	0.74
Wind direction:Temperature	1	1.14E-01		54.91	0.08

1 December 2002 to 30 November 2003

Predictor	Dof	F	Pr(>F)	Percentage deviance explained	Additional % deviance explained
Null model	1209				4404.40
*Ramp	8	2.20E-16	***	32.26	32.26
*Hour	11	2.20E-16	***	36.18	3.92
*Wind speed	2	2.20E-16	***	38.21	2.03
*Ramp:Hour	57	9.21E-13	***	42.01	3.80
*Month	3	5.78E-08	***	42.84	0.83
*Ramp:Month	24	3.01E-14	***	45.50	2.66
*Ramp:Wind speed	11	1.32E-04	***	46.33	0.83
*Wind direction	1	2.12E-04	***	46.64	0.31
*Ramp:Wind direction	8	5.19E-10	***	48.00	1.36
*Day type	1	5.34E-05	***	48.37	0.37
*Ramp:Day type	4	7.92E-05	***	48.92	0.54
Temperature	1	2.64E-07	***	49.52	0.60
Month:Temperature	3	1.36E-14	***	51.06	1.54
Ramp:Temperature	8	1.22E-09	***	52.37	1.31
Month:Wind direction	2	3.07E-03	**	52.63	0.26
Wind direction:Temperature	1	2.78E-04	***	52.93	0.30
*Tide	3	6.99E-03	**	53.21	0.27
Month:Tide	9	3.31E-04	***	53.91	0.70
*Ramp:Tide	24	4.44E-06	***	55.45	1.54
Wind speed:Temperature	1	8.26E-05	***	55.80	0.35
Hour:Wind speed	17	3.82E-02	*	56.45	0.65
Hour:Tide	29	1.48E-06	***	58.25	1.80

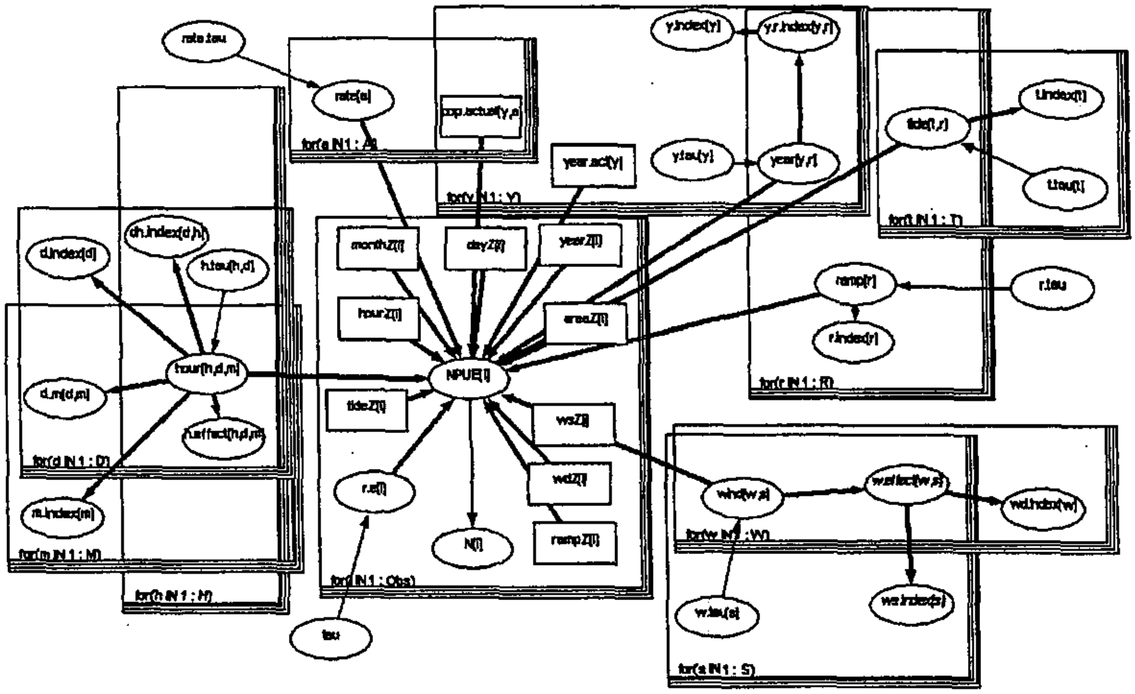
Appendix 3: Standardised individual ramp effort showing median (■) and 95% credibility intervals (-)



Appendix 4: Ancillary information of changes in fishing effort

- For almost 20 years there has been a large fishing competition in the Hauraki Gulf, commonly known as "the Furuno". Participation in this competition is capped at 3000 entrants, and is therefore of little use as an index of effort. Catch is also very atypical of the recreational fishery, as the competition attracts the more proficient fishers, and their fish retention behaviour is highly influenced by the prize categories recognised by the organisers. For example, in 2004, the average length of snapper measured by officials was several centimetres more than that usually observed in the Hauraki Gulf.
- Consumer expenditure and disposable income estimates can give some insight into recreational spending generally. Statistics New Zealand generate estimates from a National Accounts Measure. These national estimates of expenditure are then divided by census estimates to take population growth into account, which can then be scaled by an "All groups CPI index" to take inflation into account. These are average estimates, however, and don't readily account for an increasingly skewed distribution of wealth in recent years. Average disposable income has remained reasonably static over the last 30 years. Median expenditure estimates are obtainable, but we have been told that this is not a trivial task.
- Since 1984, Statistics New Zealand has also conducted a Household Economic Survey, which tracks boat usage and spending on recreational goods generally. This survey is based on face-to-face interviews and a two week diary. Although diarists are asked if they spent money on leisure and recreational goods and boats specifically, they are not asked how much was spent. Regardless, reported levels expenditure on boats over the preceding two weeks fell from around 2% in the mid 1980s, to around 1% in recent years. It was suggested that this may reflect a redistribution of wealth over the past 20 years, with fewer people having a greater share of overall disposable income. Given the low percentage of diarists recording expenditure on boats, the likelihood of measurement bias, and the two week sample frame, it is unlikely that these data will be of much use.
- The Coastguard were asked whether VHF traffic (such as trip reports) and Coastguard call outs were a likely index of fishing effort. In the opinion of the Director of Operations, there has been too much change in reporting practice and an increase in the proportion of boats carrying VHF radios for this to be of any use.
- The Auckland Regional Council Harbourmaster was approached, but was not aware of any historical data that may be of any use. He suggested using data on boat ramp parking ticket sales at Westhaven Marina, but no data appear to be available from this source.
- Water Safety New Zealand Inc. provided NIWA with data on drownings, but there have been very few marine, boating-related drownings over the last 30 years.
- Department of Conservation staff (John Gibbs and Glen MacLean) were asked to comment on the feasibility of using sales of Taupo trout fishery licences as an index of participation. In their opinion, trout licence sales (of which there are several types) are a poor measure of fishing effort. Licence sales have remained broadly static since 1990, but both fishing effort and catch, as estimated by aerial overflight surveys, have increased by over 40%. It appears that individuals currently fish more frequently within a season, possibly in response to increased catch rates, and hence chance of success, and a localised increase of people retiring in the region, who have more time available for recreational activity.
- Kearney (2002) used data on expenditure on fishing reels, hooks, rods, and outboard motors imported between 1989 and 2002 (supplied by the Ministry of Trade and Industry) to examine how fishing effort may have changed. Kearney concluded that when these data were adjusted for inflation and population growth, there appeared to be, at most, marginal growth in fishing activity.
- Both Sport Auckland New Zealand, and SPARC (formerly known as the Hillary Commission) were approached for data on sporting activity. A survey has been conducted since 1996 in which respondents are asked about which recreational activities they have participated in the last week. Data from this survey have been requested, but were not available at the time that this report was written.

Appendix 5: Hierarchical Bayesian model structure and code




```
model;
{
  for( i in 1 : Obs ) {
    N[i] ~ dpois(NPUE[i])
  }
  for( i in 1 : Obs ) {
    log(NPUE[i]) <- year[yearZ[i] , rampZ[i]] + wind[wdZ[i] , wsZ[i]] + hour[hourZ[i] , dayZ[i] , monthZ[i]] + log(pop.actual[yearZ[i] ,
areaZ[i]]) + ramp[rampZ[i]] + rate[areaZ[i]] * (year.act[yearZ[i]] - 2003) + tide[tideZ[i] , rampZ[i]] + r.e[i]
  }
  for( y in 1 : Y ) {
    for( r in 1 : R ) {
      year[y , r] ~ dnorm(0,y.tau[y])
    }
  }
  for( w in 1 : W ) {
    for( s in 1 : S ) {
      wind[w , s] ~ dnorm( 0.0,w.tau[s])I(-100,)
    }
  }
  for( w in 1 : W ) {
    for( s in 1 : S ) {
      log(w.effect[w , s]) <- wind[w , s]
    }
  }
  for( d in 1 : D ) {
    for( m in 1 : M ) {
      for( h in 1 : H ) {
        hour[h , d , m] ~ dnorm( 0.0,h.tau[h , d])I(-100,)
      }
    }
  }
  for( y in 1 : Y ) {
    y.tau[y] ~ dgamma(0.001,0.001)
  }
  for( y in 1 : Y ) {
    for( r in 1 : R ) {
      log(y.r.index[y , r]) <- year[y , r] - mean(year[ , ])
    }
  }
  for( y in 1 : Y ) {
    y.index[y] <- mean(y.r.index[y , ]) / mean(y.r.index[ , ])
  }
```

```
for( r in 1 : R ) {
  ramp[r] ~ dnorm( 0.0,r.tau)
}
r.tau ~ dgamma(0.001,0.001)
for( r in 1 : R ) {
  log(r.index[r]) <- ramp[r] - mean(ramp[])
}
for( d in 1 : D ) {
  for( h in 1 : H ) {
    h.tau[h , d] ~ dgamma(0.001,0.001)
  }
}
for( d in 1 : D ) {
  for( m in 1 : M ) {
    for( h in 1 : H ) {
      log(h.effect[h , d , m]) <- hour[h , d , m] - mean(hour[ , , ])
    }
  }
}
for( m in 1 : M ) {
  log(m.index[m]) <- mean(hour[ , , m]) - mean(hour[ , , ])
}
for( s in 1 : S ) {
  w.tau[s] ~ dgamma(0.001,0.001)
}
for( s in 1 : S ) {
  ws.index[s] <- mean(w.effect[ , s]) / mean(w.effect[ , ])
}
for( w in 1 : W ) {
  wd.index[w] <- mean(w.effect[w , ]) / mean(w.effect[ , ])
}
for( a in 1 : A ) {
  rate[a] ~ dnorm( 0.0,rate.tau)
}
for( d in 1 : D ) {
  log(d.index[d]) <- mean(hour[ , d , ]) - mean(hour[ , , ])
}
for( d in 1 : D ) {
  for( m in 1 : M ) {
    d.m[d , m] <- mean(hour[ , d , m])
  }
}
for( t in 1 : T ) {
  for( r in 1 : R ) {
    tide[t , r] ~ dnorm( 0.0,t.tau[t])
  }
}
for( t in 1 : T ) {
  t.tau[t] ~ dgamma(0.001,0.001)
}
for( t in 1 : T ) {
  log(t.index[t]) <- mean(tide[t , ]) - mean(tide[ , ])
}
rate.tau ~ dgamma(0.001,0.001)
for( i in 1 : Obs ) {
  r.e[i] ~ dnorm( 0.0,tau)
}
tau ~ dgamma(0.001,0.001)
for( d in 1 : D ) {
  for( h in 1 : H ) {
    log(dh.index[d , h]) <- mean(hour[h , d , ]) - mean(hour[ , , ])
  }
}
}
```

Appendix 6: Model fit and observational random effects

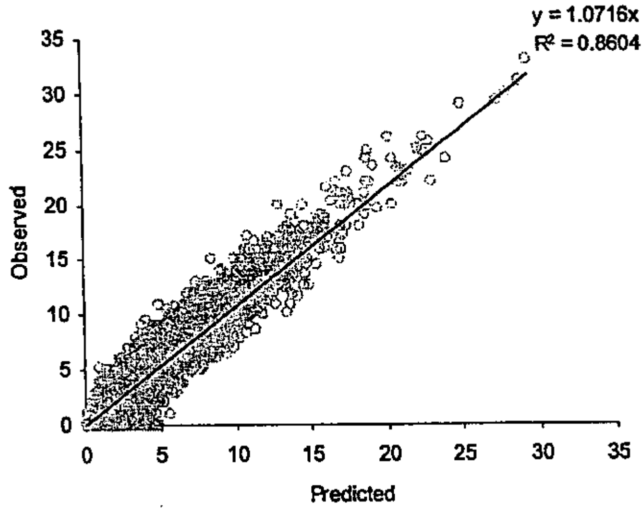


Figure A6.1: Plot of model fit showing predicted versus observed boat ramp traffic.

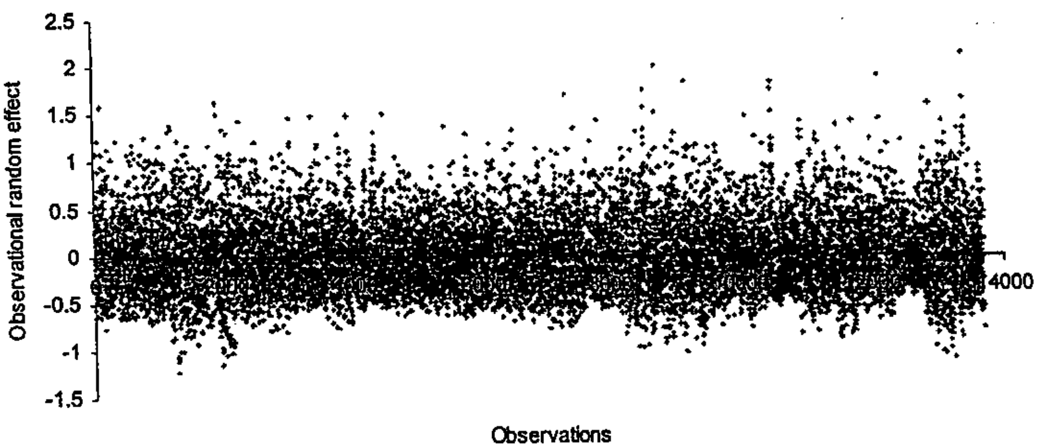
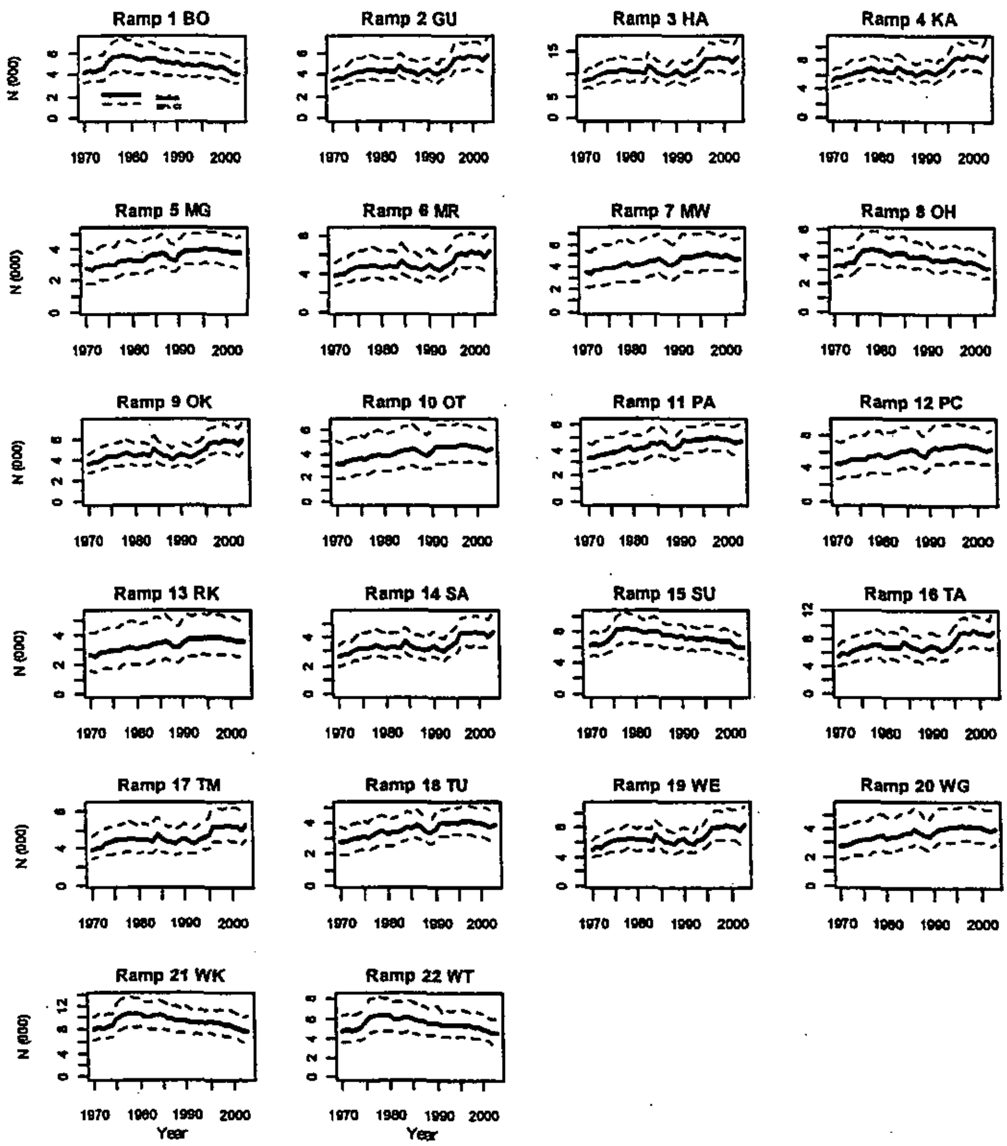


Figure A6.2: Observational random effects – displaying good random scatter centred around zero.

Appendix 7: Simulated individual ramps showing total number of estimated boat traffic



Appendix 8: Bayesian diagnostics for final estimated effects

MCMC Autocorrelation Statistics

Parameter	Lag	Lag	Lag 1	Lag 5
d.m[1,1]	-0.009	0.019	0.004	0.000
d.m[1,2]	0.009	-0.008	0.014	-0.002
d.m[1,3]	0.000	0.009	-0.009	0.023
d.m[1,4]	-0.011	0.010	-0.004	0.000
d.m[1,5]	0.004	0.000	-0.007	0.010
d.m[2,1]	-0.010	-0.004	0.010	0.002
d.m[2,2]	-0.001	0.006	0.007	-0.001
d.m[2,3]	0.016	0.007	0.000	0.003
d.m[2,4]	-0.000	-0.010	0.004	0.001
d.m[2,5]	0.007	-0.020	-0.006	0.015
hour[1,1,1]	-0.001	0.032	-0.001	-0.008
hour[1,1,2]	0.008	-0.004	-0.009	0.009
hour[1,1,3]	-0.000	0.019	0.004	-0.002
hour[1,1,4]	0.016	0.014	-0.001	-0.003
hour[1,1,5]	0.009	-0.020	-0.027	0.004
hour[1,2,1]	0.005	-0.032	-0.009	-0.004
hour[1,2,2]	-0.007	0.008	0.001	-0.004
hour[1,2,3]	0.017	-0.007	-0.007	-0.004
hour[1,2,4]	0.004	-0.021	0.008	-0.010
hour[1,2,5]	0.004	-0.027	-0.011	0.009
hour[10,1,1]	-0.010	0.001	0.022	-0.017
hour[10,1,2]	0.026	-0.007	-0.018	-0.006
hour[10,1,3]	0.005	-0.010	-0.011	0.003
hour[10,1,4]	-0.027	-0.033	0.014	-0.006
hour[10,1,5]	-0.009	0.032	0.015	-0.012
hour[10,2,1]	0.002	-0.002	-0.005	0.011
hour[10,2,2]	-0.010	0.011	0.003	0.010
hour[10,2,3]	0.001	-0.009	0.009	-0.003
hour[10,2,4]	-0.014	-0.012	0.016	-0.006
hour[10,2,5]	-0.003	0.011	0.015	-0.018
hour[11,1,1]	-0.011	-0.002	-0.009	0.007
hour[11,1,2]	0.036	0.009	-0.009	0.013
hour[11,1,3]	0.021	-0.011	0.019	0.013
hour[11,1,4]	-0.007	0.012	0.001	-0.011
hour[11,1,5]	0.004	0.013	0.026	-0.026
hour[11,2,1]	-0.029	0.002	0.001	-0.015
hour[11,2,2]	-0.013	0.004	0.005	-0.005
hour[11,2,3]	-0.027	-0.026	0.001	0.016
hour[11,2,4]	-0.011	0.013	-0.001	0.025
hour[11,2,5]	-0.038	0.010	0.013	0.002
hour[2,1,1]	-0.015	0.009	0.003	-0.002
hour[2,1,2]	-0.016	-0.004	0.005	-0.005
hour[2,1,3]	-0.017	0.015	-0.013	0.024
hour[2,1,4]	-0.018	0.013	-0.018	-0.007
hour[2,1,5]	-0.011	-0.003	0.001	-0.017
hour[2,2,1]	-0.011	-0.019	0.015	-0.002
hour[2,2,2]	-0.004	0.027	-0.026	0.020
hour[2,2,3]	-0.006	0.011	0.025	0.006
hour[2,2,4]	0.012	0.011	0.012	-0.017

hour[2,2,5]	-0.024	-0.023	0.005	0.009
hour[3,1,1]	-0.027	0.003	0.002	-0.007
hour[3,1,2]	0.005	-0.006	0.024	0.013
hour[3,1,3]	-0.003	0.005	0.014	0.016
hour[3,1,4]	0.000	-0.009	0.022	0.031
hour[3,1,5]	0.019	0.035	-0.021	-0.001
hour[3,2,1]	-0.005	-0.020	-0.019	-0.002
hour[3,2,2]	-0.010	-0.003	0.004	0.010
hour[3,2,3]	-0.008	-0.000	-0.012	-0.003
hour[3,2,4]	0.024	-0.001	0.007	-0.005
hour[3,2,5]	0.006	0.017	0.007	0.001
hour[4,1,1]	-0.014	0.009	-0.010	0.001
hour[4,1,2]	-0.006	0.006	0.030	-0.002
hour[4,1,3]	0.000	-0.007	-0.014	0.009
hour[4,1,4]	-0.017	0.000	-0.014	-0.000
hour[4,1,5]	0.015	0.001	0.002	0.006
hour[4,2,1]	-0.007	-0.002	-0.004	-0.009
hour[4,2,2]	-0.007	0.005	0.001	-0.017
hour[4,2,3]	0.009	0.000	0.002	0.018
hour[4,2,4]	-0.013	0.004	0.015	-0.011
hour[4,2,5]	0.008	-0.014	-0.001	-0.014
hour[5,1,1]	-0.010	0.004	0.010	0.004
hour[5,1,2]	0.014	-0.006	0.018	0.011
hour[5,1,3]	0.006	0.004	-0.014	0.000
hour[5,1,4]	-0.006	0.024	0.015	0.002
hour[5,1,5]	-0.016	0.013	0.005	0.003
hour[5,2,1]	-0.008	0.000	-0.000	0.007
hour[5,2,2]	-0.020	-0.010	-0.017	-0.005
hour[5,2,3]	-0.006	-0.008	0.000	0.003
hour[5,2,4]	0.002	-0.023	0.018	0.009
hour[5,2,5]	-0.003	0.015	0.013	-0.017
hour[6,1,1]	0.021	0.008	-0.002	-0.000
hour[6,1,2]	0.011	0.007	0.019	-0.015
hour[6,1,3]	0.023	-0.003	0.009	-0.002
hour[6,1,4]	0.015	0.023	0.006	0.008
hour[6,1,5]	0.018	-0.026	-0.002	0.013
hour[6,2,1]	-0.031	-0.004	0.030	0.026
hour[6,2,2]	-0.015	-0.026	-0.011	0.001
hour[6,2,3]	0.003	-0.012	0.013	-0.018
hour[6,2,4]	0.018	-0.000	0.028	0.004
hour[6,2,5]	0.007	0.000	-0.004	-0.008
hour[7,1,1]	-0.014	-0.005	-0.030	0.001
hour[7,1,2]	-0.004	0.004	0.017	0.003
hour[7,1,3]	-0.016	0.004	-0.015	0.019
hour[7,1,4]	-0.019	-0.003	0.024	-0.007
hour[7,1,5]	0.031	-0.002	0.002	0.011
hour[7,2,1]	-0.006	-0.016	0.004	-0.010
hour[7,2,2]	0.009	-0.015	0.017	0.002
hour[7,2,3]	0.039	0.029	-0.006	0.031
hour[7,2,4]	0.008	-0.000	0.001	0.025
hour[7,2,5]	0.013	-0.007	-0.002	0.017
hour[8,1,1]	0.007	-0.013	0.004	0.023
hour[8,1,2]	0.010	0.008	-0.009	0.020
hour[8,1,3]	0.002	-0.001	-0.005	0.043

hour[8,1,4]	0.026	-0.014	-0.009	-0.016
hour[8,1,5]	0.008	0.026	-0.004	-0.009
hour[8,2,1]	-0.013	0.009	-0.013	-0.007
hour[8,2,2]	-0.025	-0.008	0.026	0.034
hour[8,2,3]	0.010	-0.019	-0.003	-0.016
hour[8,2,4]	0.010	-0.022	0.010	0.012
hour[8,2,5]	0.010	-0.005	0.024	0.010
hour[9,1,1]	0.007	-0.023	-0.003	0.029
hour[9,1,2]	-0.000	0.004	0.003	-0.003
hour[9,1,3]	-0.002	0.000	0.004	0.008
hour[9,1,4]	-0.017	0.014	0.010	0.004
hour[9,1,5]	-0.002	-0.018	-0.011	-0.012
hour[9,2,1]	-0.007	-0.011	0.018	-0.018
hour[9,2,2]	0.000	0.004	-0.004	-0.020
hour[9,2,3]	-0.010	-0.018	-0.009	-0.032
hour[9,2,4]	-0.005	0.015	0.020	-0.016
hour[9,2,5]	-0.004	-0.003	0.004	-0.011
ramp[1]	0.077	0.014	-0.019	-0.010
ramp[10]	0.072	-0.000	-0.001	0.007
ramp[11]	0.099	0.024	0.005	-0.008
ramp[12]	0.047	0.005	-0.018	0.002
ramp[13]	0.072	-0.005	0.011	0.007
ramp[14]	0.079	-0.009	0.002	-0.004
ramp[15]	0.124	-0.006	0.004	0.011
ramp[16]	0.108	0.012	-0.001	-0.007
ramp[17]	0.024	0.013	0.004	-0.004
ramp[18]	0.110	0.017	0.006	0.009
ramp[19]	0.200	0.005	0.003	0.003
ramp[2]	0.089	0.013	0.008	-0.020
ramp[20]	0.203	0.009	0.003	0.022
ramp[21]	0.117	0.006	-0.010	-0.054
ramp[22]	0.094	-0.012	-0.000	-0.015
ramp[3]	0.215	0.017	-0.024	-0.015
ramp[4]	0.100	0.016	0.002	0.026
ramp[5]	0.047	-0.004	-0.006	0.005
ramp[6]	0.111	0.013	-0.011	-0.021
ramp[7]	0.028	0.017	-0.004	-0.009
ramp[8]	0.072	-0.010	-0.000	-0.010
ramp[9]	0.072	0.010	0.001	-0.000
rate[1]	0.134	0.006	-0.012	-0.000
rate[2]	0.142	0.003	0.020	0.010
rate[3]	0.051	-0.009	0.011	-0.011
tide[1,1]	0.018	-0.007	0.025	-0.016
tide[1,10]	-0.003	-0.021	0.004	-0.006
tide[1,11]	-0.002	0.008	-0.010	0.001
tide[1,12]	-0.003	-0.002	-0.009	0.004
tide[1,13]	0.003	0.002	0.001	0.027
tide[1,14]	-0.018	0.023	0.024	-0.013
tide[1,15]	-0.007	0.007	0.001	0.007
tide[1,16]	0.006	-0.008	-0.010	-0.006
tide[1,17]	0.009	-0.005	0.002	0.013
tide[1,18]	-0.012	-0.001	0.010	-0.009
tide[1,19]	-0.003	0.011	-0.001	-0.011
tide[1,2]	0.011	0.002	0.009	0.010

tide[1,20]	0.022	0.013	-0.014	0.012
tide[1,21]	0.006	0.001	-0.011	-0.012
tide[1,22]	0.000	-0.005	0.012	0.000
tide[1,3]	0.009	0.008	0.019	0.001
tide[1,4]	-0.008	0.004	-0.006	-0.012
tide[1,5]	0.010	0.004	0.015	0.024
tide[1,6]	0.015	0.024	-0.026	-0.000
tide[1,7]	-0.005	0.003	-0.010	0.007
tide[1,8]	-0.011	-0.009	0.009	0.001
tide[1,9]	-0.012	-0.007	0.021	0.004
tide[2,1]	0.014	0.001	-0.008	0.010
tide[2,10]	0.011	-0.005	-0.000	0.004
tide[2,11]	-0.002	-0.016	-0.023	0.002
tide[2,12]	-0.001	-0.006	0.002	-0.001
tide[2,13]	0.009	-0.003	0.001	0.000
tide[2,14]	0.024	0.023	-0.001	0.002
tide[2,15]	0.023	0.003	0.009	0.025
tide[2,16]	-0.012	0.025	-0.010	-0.009
tide[2,17]	-0.024	-0.000	-0.007	-0.006
tide[2,18]	0.007	0.002	-0.009	-0.009
tide[2,19]	0.011	0.003	-0.018	-0.000
tide[2,2]	-0.015	0.018	0.005	-0.009
tide[2,20]	0.006	0.018	-0.006	-0.013
tide[2,21]	-0.011	-0.020	0.010	-0.026
tide[2,22]	0.008	0.003	0.001	-0.040
tide[2,3]	-0.007	0.024	0.035	-0.017
tide[2,4]	-0.004	-0.008	-0.005	-0.000
tide[2,5]	-0.027	0.004	-0.007	0.004
tide[2,6]	-0.001	0.032	-0.019	-0.023
tide[2,7]	-0.013	-0.013	0.026	-0.017
tide[2,8]	-0.004	-0.001	-0.013	0.004
tide[2,9]	-0.004	0.010	-0.002	-0.002
tide[3,1]	0.019	-0.006	0.009	0.008
tide[3,10]	-0.029	0.013	0.001	-0.003
tide[3,11]	-0.005	0.002	0.012	-0.027
tide[3,12]	0.004	0.005	-0.008	0.035
tide[3,13]	0.023	0.002	0.021	0.021
tide[3,14]	0.013	0.022	-0.002	0.026
tide[3,15]	0.008	-0.010	0.002	0.007
tide[3,16]	0.019	0.024	-0.017	-0.013
tide[3,17]	0.008	-0.007	-0.034	-0.007
tide[3,18]	0.012	0.041	0.001	-0.003
tide[3,19]	0.001	0.000	-0.000	0.000
tide[3,2]	0.015	-0.011	0.016	-0.026
tide[3,20]	0.004	0.000	-0.019	-0.003
tide[3,21]	-0.006	-0.015	-0.014	-0.005
tide[3,22]	0.005	-0.018	0.001	-0.001
tide[3,3]	-0.003	-0.033	0.011	-0.018
tide[3,4]	-0.017	0.000	-0.009	-0.016
tide[3,5]	-0.002	0.005	-0.020	-0.015
tide[3,6]	-0.001	0.013	-0.022	-0.004
tide[3,7]	-0.012	0.007	0.005	-0.018
tide[3,8]	-0.004	-0.001	-0.022	0.007
tide[3,9]	0.003	-0.025	-0.011	0.002

tide[4,1]	0.028	0.009	0.013	0.009
tide[4,10]	0.001	-0.006	0.025	-0.004
tide[4,11]	0.004	-0.008	0.009	-0.001
tide[4,12]	0.005	-0.010	0.006	0.001
tide[4,13]	0.006	-0.006	-0.017	0.002
tide[4,14]	-0.005	-0.022	0.010	-0.004
tide[4,15]	0.017	-0.012	0.023	-0.007
tide[4,16]	-0.014	0.003	-0.015	-0.006
tide[4,17]	0.007	0.008	-0.001	0.002
tide[4,18]	0.015	0.023	0.019	-0.007
tide[4,19]	-0.028	0.002	-0.006	0.016
tide[4,2]	-0.002	0.005	-0.008	-0.004
tide[4,20]	0.017	-0.001	0.005	0.027
tide[4,21]	-0.006	-0.005	-0.016	-0.021
tide[4,22]	-0.008	0.013	-0.005	-0.009
tide[4,3]	0.010	-0.013	-0.014	0.005
tide[4,4]	-0.012	-0.010	-0.023	0.004
tide[4,5]	-0.003	0.004	-0.017	0.021
tide[4,6]	-0.001	-0.000	0.003	-0.018
tide[4,7]	-0.033	-0.008	-0.008	-0.018
tide[4,8]	0.005	0.028	-0.030	-0.005
tide[4,9]	0.014	0.014	-0.003	-0.000
wind[1,1]	0.364	0.003	-0.009	0.008
wind[1,2]	0.317	0.001	-0.004	-0.000
wind[1,3]	0.170	0.025	-0.008	0.001
wind[1,4]	-0.009	0.018	-0.002	0.019
wind[2,1]	0.364	0.012	-0.009	0.009
wind[2,2]	0.334	0.014	-0.004	0.017
wind[2,3]	0.198	-0.000	0.001	0.003
wind[2,4]	0.009	0.002	0.018	-0.008

Raftery and Lewis Convergence Diagnostic

RAFTERY AND LEWIS CONVERGENCE DIAGNOSTIC:
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Quantile = 0.025
Accuracy = +/- 0.01
Probability = 0.95

Chain: snaprec

Parameter	Thi	Burn-i	Tot:	Lower Boun	Dependence Factc
d.m[1,1]			92	93	0.9
d.m[1,2]			93	93	1.0
d.m[1,3]			93	93	1.0
d.m[1,4]			95	93	1.0
d.m[1,5]			98	93	1.0
d.m[2,1]			93	93	1.0
d.m[2,2]			96	93	1.0
d.m[2,3]			92	93	0.9
d.m[2,4]			98	93	1.0
d.m[2,5]			96	93	1.0
hour[1,1,1]			95	93	1.0
hour[1,1,2]			93	93	1.0
hour[1,1,3]			90	93	0.9
hour[1,1,4]			92	93	0.9
hour[1,1,5]			100	93	1.0
hour[1,2,1]			91	93	0.9
hour[1,2,2]			93	93	1.0
hour[1,2,3]			95	93	1.0
hour[1,2,4]			95	93	1.0
hour[1,2,5]			96	93	1.0
hour[10,1,1]			92	93	0.9
hour[10,1,2]			100	93	1.0
hour[10,1,3]			94	93	1.0
hour[10,1,4]			90	93	0.9
hour[10,1,5]			92	93	0.9
hour[10,2,1]			93	93	1.0
hour[10,2,2]			95	93	1.0
hour[10,2,3]			92	93	0.9
hour[10,2,4]			90	93	0.9
hour[10,2,5]			95	93	1.0
hour[11,1,1]			89	93	0.9
hour[11,1,2]			92	93	0.9
hour[11,1,3]			92	93	0.9
hour[11,1,4]			96	93	1.0
hour[11,1,5]			100	93	1.0
hour[11,2,1]			90	93	0.9
hour[11,2,2]			89	93	0.9
hour[11,2,3]			90	93	0.9
hour[11,2,4]			90	93	0.9
hour[11,2,5]			90	93	0.9
hour[2,1,1]			90	93	0.9
hour[2,1,2]			92	93	0.9

hour[2,1,3]	95	93	1.0
hour[2,1,4]	95	93	1.0
hour[2,1,5]	95	93	1.0
hour[2,2,1]	98	93	1.0
hour[2,2,2]	95	93	1.0
hour[2,2,3]	92	93	0.9
hour[2,2,4]	95	93	1.0
hour[2,2,5]	98	93	1.0
hour[3,1,1]	92	93	0.9
hour[3,1,2]	90	93	0.9
hour[3,1,3]	90	93	0.9
hour[3,1,4]	92	93	0.9
hour[3,1,5]	95	93	1.0
hour[3,2,1]	92	93	0.9
hour[3,2,2]	98	93	1.0
hour[3,2,3]	92	93	0.9
hour[3,2,4]	93	93	1.0
hour[3,2,5]	103	93	1.1
hour[4,1,1]	92	93	0.9
hour[4,1,2]	92	93	0.9
hour[4,1,3]	92	93	0.9
hour[4,1,4]	95	93	1.0
hour[4,1,5]	100	93	1.0
hour[4,2,1]	95	93	1.0
hour[4,2,2]	90	93	0.9
hour[4,2,3]	96	93	1.0
hour[4,2,4]	93	93	1.0
hour[4,2,5]	90	93	0.9
hour[5,1,1]	98	93	1.0
hour[5,1,2]	95	93	1.0
hour[5,1,3]	100	93	1.0
hour[5,1,4]	90	93	0.9
hour[5,1,5]	96	93	1.0
hour[5,2,1]	93	93	1.0
hour[5,2,2]	90	93	0.9
hour[5,2,3]	90	93	0.9
hour[5,2,4]	90	93	0.9
hour[5,2,5]	93	93	1.0
hour[6,1,1]	92	93	0.9
hour[6,1,2]	98	93	1.0
hour[6,1,3]	95	93	1.0
hour[6,1,4]	95	93	1.0
hour[6,1,5]	93	93	1.0
hour[6,2,1]	90	93	0.9
hour[6,2,2]	89	93	0.9
hour[6,2,3]	98	93	1.0
hour[6,2,4]	92	93	0.9
hour[6,2,5]	95	93	1.0
hour[7,1,1]	95	93	1.0
hour[7,1,2]	95	93	1.0
hour[7,1,3]	94	93	1.0
hour[7,1,4]	93	93	1.0
hour[7,1,5]	94	93	1.0
hour[7,2,1]	93	93	1.0

hour[7,2,2]	93	93	1.0
hour[7,2,3]	90	93	0.9
hour[7,2,4]	93	93	1.0
hour[7,2,5]	95	93	1.0
hour[8,1,1]	93	93	1.0
hour[8,1,2]	95	93	1.0
hour[8,1,3]	92	93	0.9
hour[8,1,4]	89	93	0.9
hour[8,1,5]	100	93	1.0
hour[8,2,1]	90	93	0.9
hour[8,2,2]	95	93	1.0
hour[8,2,3]	93	93	1.0
hour[8,2,4]	95	93	1.0
hour[8,2,5]	90	93	0.9
hour[9,1,1]	95	93	1.0
hour[9,1,2]	95	93	1.0
hour[9,1,3]	91	93	0.9
hour[9,1,4]	92	93	0.9
hour[9,1,5]	92	93	0.9
hour[9,2,1]	92	93	0.9
hour[9,2,2]	101	93	1.0
hour[9,2,3]	90	93	0.9
hour[9,2,4]	93	93	1.0
hour[9,2,5]	95	93	1.0
ramp[1]	98	93	1.0
ramp[10]	96	93	1.0
ramp[11]	105	93	1.1
ramp[12]	95	93	1.0
ramp[13]	92	93	0.9
ramp[14]	96	93	1.0
ramp[15]	100	93	1.0
ramp[16]	105	93	1.1
ramp[17]	95	93	1.0
ramp[18]	101	93	1.0
ramp[19]	101	93	1.0
ramp[2]	101	93	1.0
ramp[20]	101	93	1.0
ramp[21]	100	93	1.0
ramp[22]	99	93	1.0
ramp[3]	102	93	1.0
ramp[4]	105	93	1.1
ramp[5]	98	93	1.0
ramp[6]	100	93	1.0
ramp[7]	98	93	1.0
ramp[8]	100	93	1.0
ramp[9]	95	93	1.0
rate[1]	92	93	0.9
rate[2]	102	93	1.0
rate[3]	96	93	1.0
tide[1,1]	98	93	1.0
tide[1,10]	98	93	1.0
tide[1,11]	92	93	0.9
tide[1,12]	95	93	1.0
tide[1,13]	90	93	0.9

tide[1,14]	95	93	1.0
tide[1,15]	100	93	1.0
tide[1,16]	92	93	0.9
tide[1,17]	95	93	1.0
tide[1,18]	94	93	1.0
tide[1,19]	98	93	1.0
tide[1,2]	90	93	0.9
tide[1,20]	90	93	0.9
tide[1,21]	93	93	1.0
tide[1,22]	90	93	0.9
tide[1,3]	90	93	0.9
tide[1,4]	90	93	0.9
tide[1,5]	89	93	0.9
tide[1,6]	90	93	0.9
tide[1,7]	96	93	1.0
tide[1,8]	93	93	1.0
tide[1,9]	100	93	1.0
tide[2,1]	93	93	1.0
tide[2,10]	96	93	1.0
tide[2,11]	94	93	1.0
tide[2,12]	92	93	0.9
tide[2,13]	93	93	1.0
tide[2,14]	100	93	1.0
tide[2,15]	93	93	1.0
tide[2,16]	93	93	1.0
tide[2,17]	92	93	0.9
tide[2,18]	90	93	0.9
tide[2,19]	90	93	0.9
tide[2,2]	92	93	0.9
tide[2,20]	98	93	1.0
tide[2,21]	92	93	0.9
tide[2,22]	95	93	1.0
tide[2,3]	95	93	1.0
tide[2,4]	92	93	0.9
tide[2,5]	93	93	1.0
tide[2,6]	93	93	1.0
tide[2,7]	96	93	1.0
tide[2,8]	92	93	0.9
tide[2,9]	92	93	0.9
tide[3,1]	98	93	1.0
tide[3,10]	94	93	1.0
tide[3,11]	90	93	0.9
tide[3,12]	100	93	1.0
tide[3,13]	89	93	0.9
tide[3,14]	92	93	0.9
tide[3,15]	95	93	1.0
tide[3,16]	99	93	1.0
tide[3,17]	89	93	0.9
tide[3,18]	100	93	1.0
tide[3,19]	98	93	1.0
tide[3,2]	92	93	0.9
tide[3,20]	93	93	1.0
tide[3,21]	92	93	0.9
tide[3,22]	95	93	1.0

tide[3,3]	92	93	0.9
tide[3,4]	95	93	1.0
tide[3,5]	98	93	1.0
tide[3,6]	93	93	1.0
tide[3,7]	95	93	1.0
tide[3,8]	93	93	1.0
tide[3,9]	93	93	1.0
tide[4,1]	90	93	0.9
tide[4,10]	95	93	1.0
tide[4,11]	95	93	1.0
tide[4,12]	95	93	1.0
tide[4,13]	93	93	1.0
tide[4,14]	93	93	1.0
tide[4,15]	95	93	1.0
tide[4,16]	96	93	1.0
tide[4,17]	95	93	1.0
tide[4,18]	90	93	0.9
tide[4,19]	93	93	1.0
tide[4,2]	95	93	1.0
tide[4,20]	90	93	0.9
tide[4,21]	92	93	0.9
tide[4,22]	96	93	1.0
tide[4,3]	89	93	0.9
tide[4,4]	98	93	1.0
tide[4,5]	96	93	1.0
tide[4,6]	95	93	1.0
tide[4,7]	95	93	1.0
tide[4,8]	100	93	1.0
tide[4,9]	93	93	1.0
wind[1,1]	228	93	2.4
wind[1,2]	216	93	2.3
wind[1,3]	209	93	2.2
wind[1,4]	89	93	0.9
wind[2,1]	309	93	3.3
wind[2,2]	320	93	3.4
wind[2,3]	214	93	2.2
wind[2,4]	90	93	0.9