

Estimation of Hector's dolphin bycatch from inshore fisheries, 1997/98 fishing year

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ABSTRACT

Information on the bycatch of Hector's dolphins (*Cephalorhynchus hectori*) in inshore setnet and trawl fisheries off the east coast of South Island, New Zealand, was collected by observers during the 1997/98 fishing year. Shark species and elephant fish were the main target species for the 214 observed setnets; five observed setnets accounted for the eight Hector's dolphins reported caught (two were released alive). Analysis of the bycatch of Hector's dolphins in Statistical Areas 020 and 022 resulted in high variance in the bycatch rates and estimated numbers. Estimates were most precise for Statistical Area 022, where the mean bycatch rate was 0.064 dolphins per setnet (coefficient of variation, c.v. = 43%) and a total of 16 Hector's dolphins were estimated caught. The total estimated number caught in Statistical Areas 020 and 022 was 18 (c.v. = 38%). To achieve a 20% coefficient of variation, at least 74% of setnets would need to be observed in Statistical Area 022 and 92% in Statistical Area 020. A total of 434 trawls targeting primarily red cod, flatfish, and tarakihi were observed, and one Hector's dolphin was observed caught in shallow water. The single capture, and the lack of depth or position information from the majority of the commercial data collection forms, prevented any analysis of the bycatch from the observed trawls. The above estimates are of numbers captured, and not necessarily of mortalities.

Keywords: Hector's dolphins, *Cephalorhynchus hectori*, bycatch rate, statistical method, setnet fisheries, inshore trawl fisheries.

1. Introduction

The bycatch of Hector's dolphins (*Cephalorhynchus hectori*) in inshore fisheries off the east coast of the South Island during the fishing year from 1 October 1997 to 30 September 1998 was monitored by an observer programme. This programme was designed to sample the setnet effort for the main shark species and elephant fish (*Callorhynchus milii*) and the inshore trawl effort primarily for red cod (*Pseudophycis bachus*), flatfish, and tarakihi (*Nemadactylus macropterus*) (Starr & Langley 2000). That report should be consulted for details of the observer programme.

Vessels were observed in the Statistical Areas 018, 020, and 022 (Figure 1). A total of 25 were observed, of which 7 carried out setnetting and 22 carried out trawling, with some vessels operating setnets and trawls. Coverage of both types of vessels increased the potential amount of effort available for sampling, given that the problem of bycatch of Hector's dolphin is considered to be related to area rather than fishery type (Starr & Langley 2000). Statistical Areas 020 and 022 were of primary interest, but because of the patterns of fishing, some of the observed effort extended into Statistical Area 018. The observed part of the fishery in these areas was limited to the inshore waters out to the 200 m contour.

The monitoring of effort close inshore, in shallow depths, was necessary because Hector's dolphins prefer shallow waters and are generally found close inshore, especially in summer months (Dawson & Slooten 1988). Their preferred diet includes species such as yellow-eyed mullet (*Aldrichetta forsteri*), red cod, and squid (*Nototodarus* spp.) which are targeted by inshore

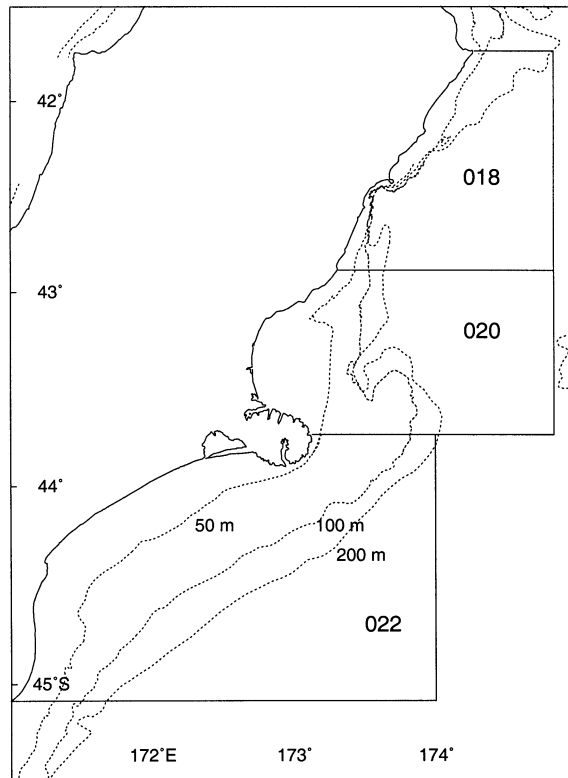


Figure 1. Fishing statistical areas 018, 020, and 022 off the east coast of the South Island, New Zealand.

Depth contours at 50 m, 100 m, and 200 m are shown.

trawlers and setnet fishers. The Banks Peninsula Marine Mammal Sanctuary was established in late 1988 (Anon. 1994) and restricts commercial setnetting to outside a 4 n. mile zone. Voluntary actions by fishers (Anon. 1994) to mitigate the capture of Hector's dolphins include: using weights to increase the rate at which the net sinks when set; ensuring the net is tight to deflect dolphins; refraining from setnetting when water is discoloured or when dolphins are present; and reducing soak times to 2-4 hours if close inshore.

This report extends the work presented in Starr & Langley (2000) and provides:

- details of the observer coverage as a proportion of the total fishing effort,
- estimates (and associated coefficients of variation) of the numbers of Hector's dolphins caught (not necessarily mortalities), and
- estimates of the observer coverage required to achieve coefficients of variation of the total Hector's dolphin bycatch of 10%, 20%, and 30%.

2. Estimation methods

For simplicity, the estimator of mean observed bycatch rate of Hector's dolphins in a fishery can be written as the total number of Hector's dolphins observed caught, b , divided by the total number of fishing operations observed, n . The estimator currently used in estimation of total bycatch uses the individual catches per fishing operation (*see below*). The above estimator is simpler for explaining the process involved. The total bycatch of Hector's dolphin, H , in the fishery of N operations that the observed sample represents is given by:

$$H = \frac{b}{n} N = \frac{b}{f}$$

where f is the fraction of observed operations.

We need to ask several questions about the data before making an estimate of total bycatch.

- What was the total number of fishing operations, N , in the observed part of the fishery? In this case, the observed fishery consisted of the inshore parts of Statistical Areas 020 and 022 and part of Statistical Area 018. However, we have no depth or fine scale positional information for most of the commercial data. Thus, if all fishing operations in these statistical areas were used to define N , we would obtain a gross overestimate of H .
- Does f remain roughly constant throughout the observed fishery in space and time? Biases could be introduced if the observed sample was not representative of the fishery.
- Are the data adequate to make an estimate of H (once N has been determined)? We cannot make estimates of total bycatch that have any reliability when b/n is very small: essentially the variance is too ill-defined to be useful. When b/n is small, we can also expect problems in estimation if $f = n/N$ is small.

3. Commercial and observed fishing effort

Commercial fishing effort data for Statistical Areas 018, 020, and 022 were extracted from the Ministry of Fisheries Catch and Effort database for the fishing year 1 October 1997 to 30 September 1998. Setnet fishers record data on Catch Effort Landing Returns (CELR). Trawl fishers record data either on CELR (generally filled in by skippers of smaller vessels operating inshore) or Trawl Catch Effort Processing Returns (TCEPR) (filled in by larger trawl vessels). All data were checked for obvious errors and amended where possible.

The observed fishing effort was obtained from the database provided by the Seafood Industry Council (SeaFIC) as used in Starr & Langley (2000).

3.1 SETNET DATA

Setnet effort in Statistical Area 018 targeted a variety of species, whereas in Statistical Areas 020 and 022, most effort was targeted at flatfish, yellow-eyed mullet, and shark species (Table 1). Different mesh sizes and net setting procedures are used depending upon the target species. Hector's dolphins are comparable in size to the shark species being targeted and are thus most likely to be entangled in setnets targeting shark species and elephant fish.

The monthly setnet effort data for sharks and all other species grouped together are given in Table 2. Of the 945 setnets that targeted elephant fish and the shark species, 53% were in Statistical Area 018 (mainly during October to March), 21% in Statistical Area 020 (throughout the year depending on the species), and 26% in Statistical Area 022 (during October to March). Setnets targeting these species represented about 30% of the total setnet effort for 1997/98.

The observed setnet data used in Starr & Langley (2000) relate to shark species and elephant fish. A total of 214 setnets were observed: 13% in Statistical Area 018, 42% in Statistical Area 020, and 45% in Statistical Area 022 (Table 3).

3.2 TRAWL DATA

Data collected from CELR forms have no data on depth or actual position, only a statistical area. Therefore, to include data comparable with the observed trawl data (*see* Starr & Langley 2000), the target species data recorded on the TCEPR forms were used as a guide to those species which were targeted in waters less than 200 m deep. Tows with target species generally fished in deeper waters, such as orange roughy, oreos, ling, and rattails, were deleted from the dataset used here, as were daily CELR records for which there were more than 10 tows reported (Tables 4 & 5). These latter records were considered spurious.

TABLE 1. NUMBER OF SETNETS IN STATISTICAL AREAS 018, 020, AND 022 AS RECORDED ON CELR FORMS DURING 1997/98, BY TARGET SPECIES.

TARGET SPECIES CODES*	STATISTICAL AREA			TOTAL
	018	020	022	
BAR	1			1
BCO		1		1
BFL			9	9
BNS	168			168
BSH	1	2		3
BUT	62			62
BYX	1			1
ELE	5	12	37	54
ESO			1	1
FLA		3	58	61
GMU		1		1
GSH	2			2
GUR	1	2	1	4
HOK	7			7
HPB	212	10	3	225
KAH	7			7
LIN	742	34		776
MOK	18	9	3	30
SCH	53	90	44	187
SFL			5	5
SNA			1	1
SPD	190	26	13	229
SPO	251	68	156	475
TAR	721	1		722
TRU	1			1
WAR	9	1		10
YBF			9	9
YEM			93	93
Total	2452	260	433	3145

* Target species codes are defined in Appendix 1.

Of the available trawl data for these statistical areas, about 83% of the tows were recorded on CELR forms, and 56% of the total commercial trawl effort included in this assessment was in Statistical Area 022, 34% in Statistical Area 020, and 10% Statistical Area 018 (Table 6).

The data were collated into groups of target species which equate to those reported in Starr & Langley (2000): barracouta (*Thyrsites atun*), flatfish, red cod, tarakihi, and a mixture of other species given in Table 6. Over 50% of the commercial trawl effort targeted red cod in 1997/98, and 58% of this effort was in Statistical Area 022. Flatfish accounted for about 25% of the total tows.

Depth data from the TCEPR records show that red cod trawls were primarily towed with the groundrope at depths of less than 90 m in Statistical Area 018, 20-60 m in Statistical Area 020, and spread throughout the range 20-200 m in

TABLE 2. NUMBER OF SETNETS IN STATISTICAL AREAS 018, 020, AND 022 AS ON CELR FORMS DURING 1997/98, BY MONTH AND TARGET SPECIES*.

MONTH	TARGET SPECIES					TOTAL
	ELE	SCH	SPD	SPO	OTH	
<i>Statistical Area 018</i>						
Oct			44	62	92	198
Nov	1	15	30	98	157	301
Dec	1	2	29	62	232	326
Jan	2	1	27	2	223	255
Feb		14	25	7	214	260
Mar		5	22	10	129	166
Apr		13	9	4	173	199
May		2	2	2	222	228
Jun					239	239
Jul		1			145	146
Aug	1		1		79	81
Sep			1	4	48	53
Total	5	53	190	251	1953	2452
<i>Statistical Area 020</i>						
Oct			2	9	7	18
Nov		1		17	2	20
Dec	1	2	3	19	2	27
Jan		15		1	2	18
Feb	1	13	1	8	2	25
Mar	1	13	1	9	3	27
Apr	1	10	1	3		15
May		13	7		3	23
Jun	1	11	2	2	6	22
Jul	6	3	2		16	27
Aug	1	4	5		8	18
Sep		5	2		13	20
Total	12	90	26	68	64	260
<i>Statistical Area 022</i>						
Oct		1	1	8	22	32
Nov	11	3	1	29	15	59
Dec	17	5		33	6	61
Jan	6	14	7	34	12	73
Feb	3	18	2	31	1	55
Mar		3		20		23
Apr						
May			1		15	16
Jun			1		34	35
Jul				1	20	21
Aug					24	24
Sep					34	34
Total	37	44	13	156	183	433
Total all areas	54	187	229	475	2200	3145

* Target species codes are defined in Appendix 1. OTH refers to all species given in Table 1, other than ELE, SCH, SPD, and SPO.

TABLE 3. NUMBER OF SETNETS IN STATISTICAL AREAS 018, 020, AND 022 AS RECORDED BY OBSERVERS DURING 1997/98, BY TARGET SPECIES*.

MONTH	TARGET SPECIES						TOTAL
	ELE	MIX	SCH	SHA	SPO	UNK	
Statistical Area 018							
Oct				12			12
Feb				6			6
Mar				4			4
Jun			2				2
Jul			3				3
Total			5	22			27
Statistical Area 020							
Oct				4			4
Nov				3			3
Jan		2		6			8
Feb				11			11
Mar				3			3
Apr				21			21
Jun			7		16		23
Jul			17				17
Total		2	24	48	16		90
Statistical Area 022							
Oct	2						2
Nov	2			5	4	1	12
Dec	1			3	4		8
Jan			6	9	14		29
Feb			6		4		10
Mar				14			14
Apr				10			10
May				3			3
Jun			3				3
Jul			6				6
Total	5		21	44	26	1	97
Total	5	2	50	114	42	1	214

* Target species codes are defined in Appendix 1. MIX refers to a mixture of shark species and/or elephant fish. UNK is target species unknown.

Statistical Area 022. Most groundrope depths for tows that targeted barracouta were primarily in waters 40-100 m in Statistical Area 018, 80-130 m in Statistical Area 020, and 20-120 m in Statistical Area 022. Of the few tows that targeted tarakihi for which there are depth data (mainly in Statistical Area 018), most groundrope depths were between 40 and 70 m. Bottom trawl nets were used in 99% of all the tows targeting these species. This suggests that trawls targeting these species and recorded on CELR forms will have been inshore of 200 m depth and mainly inshore of 100 m depth.

TABLE 4. NUMBER OF TOWS IN STATISTICAL AREAS 018, 020, AND 022 AS RECORDED ON CELR FORMS (WHERE THE NUMBER OF TOWS PER DAY <10) DURING 1997/98, BY TARGET SPECIES.

TARGET SPECIES CODES*	STATISTICAL AREA			TOTAL
	018	020	022	
BAR	300	42	351	693
BCO	37	6	14	57
ELE	6	7	16	29
FLA	102	2330	2948	5380
GSH	3			3
GUR		23	27	50
HAP			1	1
HOK	61	14	5	80
MOK	8			8
RCO	709	3149	5541	9399
SCH	5			5
SKI	5			5
SPD	1	13		14
SPE	347		53	400
SPO	4		4	8
SQU	1		43	44
STA	49	48	28	125
TAR	74	152	61	287
TRE	1			1
WAR	47	7	8	62
Total	1760	5791	9100	16651

* Target species codes are defined in Appendix 1. FLA refers to flatfish BRI, ESO, FLA, FLO, LSO, SFL, and YBF.

In Statistical Area 020, fishing effort for red cod peaked in January and again in March to June, whereas effort for flatfish was similar throughout the year (Table 7). In Statistical Area 022, red cod effort was greatest during January-June and there was a small peak in the effort for flatfish in July and August.

A summary of the observer data and the commercial trawl data is given in Table 8. A total of 32 of the 434 observed tows had either a mixture of target species or the target species was unknown. More than 98% of observed tows were in Statistical Area 020 and Statistical Area 022, the areas of primary interest. In these two areas, less than 3% of flatfish and red cod tows were observed and about 4.5% tarakihi tows were observed. However, these two data sets are not strictly comparable because the observed trawl effort was in shallow water (e.g. observed red cod trawls were generally in waters 20-50 m deep) (Starr & Langley 2000), whereas the commercial trawls extended out to 200 m. (Depths are not provided on CELR forms, so depth stratification is not possible.)

The monthly observed trawl data are given in Table 9. Observed red cod effort peaked during January and February and observed tows targeting flatfish were mainly in May-July.

TABLE 5. NUMBER OF TOWS IN STATISTICAL AREAS 018, 020, AND 022 AS RECORDED ON TCEPR FORMS DURING 1997/98, BY TARGET SPECIES.

TARGET SPECIES CODES*	STATISTICAL AREA			TOTAL
	018	020	022	
BAR	35	180	548	763
BCO	1		22	23
BYX	1			1
HOK	138	48	18	204
JMA	22	64	285	371
RCO	76	608	786	1470
SPD		7	7	14
SPE	3	37	1	41
SQU		95	462	557
SWA		4	2	6
TAR	12	3		15
Total	288	1046	2131	3465

* Target species codes are defined in Appendix 1.

TABLE 6. TOTAL NUMBER OF TOWS IN STATISTICAL AREAS 018, 020, AND 022 AS RECORDED ON CELR AND TCEPR FORMS DURING 1997/98, BY TARGET SPECIES.

TARGET SPECIES CODES*	STATISTICAL AREA			TOTAL
	018	020	022	
BAR	335	222	899	1456
BCO	38	6	36	80
BYX	1			1
ELE	6	7	16	29
FLA	102	2330	2948	5380
GSH	3			3
GUR		23	27	50
HAP			1	1
HOK	199	62	23	284
JMA	22	64	285	371
MOK	8			8
RCO	785	3757	6327	10869
SCH	5			5
SKI	5			5
SPD	1	20	7	28
SPE	350	37	54	441
SPO	4		4	8
SQU	1	95	505	601
STA	49	48	28	125
SWA		4	2	6
TAR	86	155	61	302
TRE	1			1
WAR	47	7	8	62
Total	2048	6837	11231	20116

* Target species codes are defined in Appendix 1. FLA refers to flatfish BRI, ESO, FLA, FLO, LSO, SFL, and YBF.

TABLE 7. NUMBER OF TOWS FOR CELR AND TCEPR DATA IN TABLE 6, BY MONTH AND TARGET SPECIES GROUPS*.

MONTH	BAR	FLA	OTH	RCO	TAR	TOTAL
<i>Statistical Area 018</i>						
Oct	57	8	48	44	16	173
Nov	63		39	90	10	202
Dec	41	42	47	64	14	208
Jan	19	30	97	59	22	227
Feb	1	12	24	93	3	133
Mar	28		55	108	4	194
Apr	48	4	90	73	8	224
May	32		78	136		246
Jun	18		69	51	7	145
Jul	5		95	7	1	108
Aug	2	1	68	5		76
Sep	21	5	31	55		112
Total	335	102	741	785	85	2048
<i>Statistical Area 020</i>						
Oct	26	172	24	203	40	465
Nov	34	286	25	200		545
Dec	113	139	47	256		555
Jan	2	173	26	610		811
Feb		237	16	280	6	539
Mar	11	222	24	347	27	631
Apr	19	142	49	351	14	575
May	9	270	68	445	8	800
Jun	4	249	40	410	5	708
Jul	4	132	15	232	8	391
Aug		121	19	184	17	341
Sep		187	20	239	30	476
Total	222	2330	373	3757	155	6837
<i>Statistical Area 022</i>						
Oct	116	213	30	376	12	747
Nov	254	283	21	360	11	929
Dec	173	239	21	307		740
Jan	47	161	144	785		1137
Feb	11	187	93	765		1056
Mar	32	162	205	890	14	1303
Apr	105	205	280	796	16	1402
May	26	165	121	713		1025
Jun	69	283	40	591		983
Jul	30	442	3	285	3	763
Aug	19	342	24	218	5	608
Sep	17	266	14	241		538
Total	899	2948	996	6327	61	11231
Grand total	1456	5380	2110	10869	301	20116

* Target species codes are defined in Appendix 1.

FLA refers to flatfish BRI, ESO, FLA, FLO, LSO, SFL, YBF.

OTH includes all target species given in Table 6 other than the flatfish, BAR, RCO, and TAR.

TABLE 8. TOTAL NUMBER OF TOWS AS RECORDED ON CELR AND TCEPR FORMS AND OBSERVED TOWS DURING 1997/98 IN STATISTICAL AREAS 018, 020, AND 022, BY TARGET SPECIES GROUPS*.

TARGET SPECIES CODES	STATISTICAL AREA							
	018		020		022		TOTAL	
	Total	Observed	Total	Observed	Total	Observed	Total	Observed
BAR	335		222		899		1456	
FLA	102		2330	102	2948	47	5380	149
OTH	740		373		996		2109	
RCO	785	5	3757	125	6327	113	10869	243
TAR	86		155	10	61		302	10
MIX/UNK		2		9		21		32

* Target species codes are defined in Appendix 1. FLA refers to flatfish BRI, ESO, FLA, FLO, LSO, SFL, YBF. OTH includes all target species given in Table 6 other than the flatfish, BAR, RCO, and TAR.

Original data provided by SeaFIC also reported a total of 14 tows as mixed species and 18 as target species unknown (MIX/UNK)

TABLE 9. NUMBER OF OBSERVED TOWS FOR EACH TARGET SPECIES*, BY MONTH AND STATISTICAL AREAS.

MONTH	TARGET SPECIES*					TOTAL
	FLA	MIX	RCO	TAR	UNK	
Statistical Area 018						
Nov			1			1
Dec		2				2
Mar			4			4
Total		2	5			7
Statistical Area 020						
Oct	2		6	4		12
Nov	2		15			17
Dec		1	20			21
Jan			30			30
Feb		3	32			35
Mar			15			15
May	32		4		0	36
Jun	27		3		3	33
Jul	39			6	2	47
Total	102	4	125	10	5	246
Statistical Area 022						
Oct	4	6	6			16
Nov	13		5			18
Dec		2	11		5	18
Jan			28			28
Feb			32			32
Apr			3		0	3
May			13			13
Jun	18		14		0	32
Jul	12		1		8	21
Total	47	8	113		13	181
* Target species codes are defined in Appendix 1.						

* Data are from SeaFIC. FLA is flatfish, MIX is mixed species, RCO is red cod, TAR is tarakihi, and UNK is target species unknown.

4. Results

4.1 BYCATCH OF HECTOR'S DOLPHIN IN SETNET FISHERIES

A total of 8 Hector's dolphins were observed caught in setnets during the 1997/98 year; details on these captures are given in Starr & Langley (2000). One dolphin was caught during March in Statistical Area 018 and another in November in Statistical Area 020. Six dolphins were observed caught in Statistical Area 022: two in a school shark setnet and two in a shark setnet in January, and two in a shark setnet in March. The latter two dolphins were caught in one incident and were released alive. All 8 Hector's dolphin captures in setnets are included in this analysis.

The commercial setnet data and observed data were pooled across months and target species to increase the sample size available for analysis. The aim of the observer programme was to only target shark species and elephant fish and therefore, to further increase the observed dataset, all the "MIX" and "UNK" data were combined with the shark species and elephant fish data. Commercial setnet data used for the estimation of Hector's dolphin bycatch included only those sets where the target species were specified as elephant fish, rig, spiny dogfish, school shark.

4.1.1 Data analysis

All setnet data were then stratified by statistical area to estimate the bycatch rate of Hector's dolphins (mean number caught per setnet). It was assumed that the chance of catching two Hector's dolphins is the same as catching one dolphin. The mean bycatch rate and the standard error were estimated by a bootstrap resampling procedure (Efron & Tibshirani 1993) in which the observed bycatch rates per fishing operation were resampled 1000 times for each stratum.

The estimated standard error for each statistical area is:

$$\hat{\sigma}_{Ai} = \sigma_i \sqrt{(1 - f_i)}$$

where f_i is the fraction of the observed number of setnets (n_i) to the total number of setnets (N_i) for a statistical area and σ_i is the standard error derived from the bootstrap procedure.

The mean bycatch rate for each area was then scaled by the total commercial fishing effort in each area to provide a total estimate (H_i) of the number of Hector's dolphins caught.

Therefore,

$$\hat{H}_i = \bar{h}_i N_i$$

where \bar{h}_i is the mean of the individual bycatch rates per observed fishing operation in statistical area i , with the variance given by:

$$\text{var}(\hat{H}_i) = (N_i)^2 \hat{\sigma}_{Ai}^2$$

The estimated standard deviation is then used to calculate the coefficient of variation (c.v.) of the total estimate:

$$\text{c.v.}(\hat{H}_i) = \frac{\sqrt{\text{var}(\hat{H}_i)}}{\hat{H}_i}$$

For the total number of Hector's dolphins caught, when different areas contribute to the numbers estimated caught for a given year,

$$\hat{H}_T = \sum \hat{H}_i$$

with the variance given by:

$$\text{var}(\hat{H}_T) = \sum \text{var}(\hat{H}_i)$$

and the c.v. equal to:

$$\text{c.v.}(\hat{H}_T) = \frac{\sqrt{\text{var}(\hat{H}_T)}}{\hat{H}_T}$$

To estimate the sample size of observed data required for a target c.v. (e.g. c.v. = 10%, 20%, and 30%), the standard deviation of the population (σ_{Ni}) will be used:

$$\sigma_{Ni} = \frac{\sigma_i}{\sqrt{n_i}}$$

such that the estimated sample size is given as (after substitution and re-arrangement of the above formula):

$$\hat{n}_i = \frac{\sigma_i^2 / n_i}{\text{c.v.}^2 \bar{h}_i^2 + \sigma_i^2 / n_i N_i}$$

4.1.2 Estimated number of Hector's dolphins caught

Less than 6% of setnets targeting elephant fish and shark species in Statistical Area 018 were observed, and therefore it is considered unwise to attempt any analysis based on these data, though one Hector's dolphin was observed caught. The observer coverage for the setnet fishery in the remaining two areas was 46% for Statistical Area 020 and 39% for Statistical Area 022. The mean bycatch rates calculated for these areas are given in Table 10. Estimates of the total numbers caught are given where the data can be considered to be reasonably meaningful.

The highest bycatch rate was from Statistical Area 022, where an estimated 16 Hector's dolphins (c.v. = 43%) were caught. A lower c.v. was obtained when all the areas were combined, but this result is misleading because of the poor coverage in Statistical Area 018. A more viable combination is Statistical Areas 020 and 022. When these data are combined for bootstrapping to achieve a mean bycatch rate, the estimated total catch is the same as that for Statistical Area 022, because of the influence of the 6 captures in this area. To account for any difference in the bycatch rates for these two areas, the separate estimates for Statistical Areas 020 and 022 were summed to produce a total estimated catch of 18 Hector's dolphins (c.v. = 38%).

4.1.3 Estimated sample size required for a certain c.v.

The c.v.s resulting from the estimation of total numbers caught were high. For setnets in Statistical Area 020 at least 83% of the setnets made in the areas would need to be observed to achieve a c.v. of 30%, and almost 100% observer coverage would be required for a c.v. of less than 20% (Table 10). For setnets in Statistical Area 022, the observed sample size would need to be 56% of the total effort for a c.v. of 30%, 74% for a c.v. of 20%, and 92% for a c.v. of 10%.

TABLE 10. ESTIMATED NUMBER OF HECTOR'S DOLPHINS (HEC) CAPTURED IN SETNETS IN STATISTICAL AREAS 018, 020, AND 022 FROM 1 OCTOBER 1997 TO 30 SEPTEMBER 1998.

Stat. Area	Total no. of setnets	No. of obs. setnets	Percent setnets observed	No. HEC obs. caught	Mean bycatch rate	S.E.	Est. no. HEC caught	Obs. c.v. (%)	No. setnets needed to be observed for c.v.		
									10%	20%	30%
018	499	27	5.4	1	0.037	0.035					
020	196	90	45.9	1	0.011	0.008	2	71	192	179	162
022	250	97	38.8	6	0.064	0.027	16	43	230	186	140
Total	945	214	22.6	8	0.037	0.015					
020 & 022	446	187	41.9	7	0.037	0.014	16	39	408	326	244

4.2 BYCATCH OF HECTOR'S DOLPHIN IN TRAWL FISHERIES

One Hector's dolphin was observed caught in a red cod trawl net during February in Statistical Area 022 (Starr & Langley 2000). The lack of information on the total commercial effort in terms of depth and position (and therefore poor comparability with the observer data), and the low percentage of observer coverage, preclude any estimation of the total numbers of Hector's dolphins caught in trawl nets in these areas.

5. Discussion

There was good observer coverage of the setnet operations in Statistical Areas 020 and 022 where the target species was elephant fish or shark species. This enabled more reliable estimation of the total numbers of Hector's dolphins caught in these fisheries. However, the low bycatch rate in Statistical Area 020 resulted in a large variance. Setnet fishers tend to fish close inshore and, because a large proportion of the setnets in Statistical Areas 020 and 022 were observed, the lack of depth data was not so critical in this analysis. However, it does preclude any further breakdown of the bycatch data, and certainly depth and position data would provide more reliable estimates of the bycatch of

Hector's dolphins in setnets. With this added data, there would also be a better understanding of the percentage of setnets that needed to be observed.

Extrapolation of any observed trawl data to the total trawl data in any of these areas will not be viable until position and depth data are recorded to a finer scale than statistical area. In this study, the lack of such data placed severe limitations on any analysis, as predicted by Starr & Langley (2000).

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Appendix 1

TARGET SPECIES RECORDED, WITH CODES

Target species recorded on CELR and TCEPR forms for trawl and setnet operations in Statistical Areas 018, 020, and 022 during 1997/98.

TARGET SPECIES CODES	COMMON NAME	SCIENTIFIC NAME
BAR	barracouta	<i>Thyrsites atun</i>
BCO	blue cod	<i>Parapercis colias</i>
BFL	black flounder	<i>Rhombosolea retiaria</i>
BNS	bluenose	<i>Hyperoglypbe antarctica</i>
BSH	seal shark	<i>Dalatius licha</i>
BUT	butterfish	<i>Odax pullus</i>
BYX	beryx species	<i>Beryx</i> spp.
ELE	elephant fish	<i>Callorhynchus milii</i>
ESO	NZ sole	<i>Pellorobambus novaezeelandiae</i>
FLA	flatfish	
FLO	flounder	
GMU	grey mullet	<i>Mugil cephalus</i>
GSH	dark ghost shark	<i>Hydrolagus novaezeelandiae</i>
GUR	red gurnard	<i>Chelidonichthys kumu</i>
HOK	hoki	<i>Macruronus novaezeelandiae</i>
HPB	hapuka & bass	<i>Polyprion oxygeneios, P. americanus</i>
JMA	jack mackerels	<i>Trachurus</i> spp.
KAH	kahawai	<i>Arripis trutta</i>
LIN	ling	<i>Genypterus blacodes</i>
LSO	lemon sole	<i>Pelotretis flavilatus</i>
MOK	moki	<i>Latridopsis ciliaris</i>
RCO	red cod	<i>Pseudophycis bachus</i>
SCH	school shark	<i>Galeorhinus galeus</i>
SFL	sand flounder	<i>Rhombosolea plebeia</i>
SHA	shark species	
SKI	gemfish	<i>Rexea solandri</i>
SNA	snapper	<i>Pagrus auratus</i>
SPD	spiny dogfish	<i>Squalus acantbias</i>
SPE	sea perch	<i>Helicolenus</i> spp.
SPO	rig	<i>Mustelus lenticulatus</i>
SQU	arrow squid	<i>Nototodarus sloanii, N. gouldi</i>
STA	giant stargazer	<i>Kathetostoma giganteum</i>
SWA	silver warehou	<i>Seriotelella punctata</i>
TAR	tarakihi	<i>Nemadactylus macropterus</i>
TRE	trevally	<i>Pseudocaranx dentex</i>
TRU	trumpeter	<i>Latris lineata</i>
WAR	common warehou	<i>Seriotelella brama</i>
YBF	yellow-belly flounder	<i>Rhombosolea leporina</i>
YEM	yellow-eyed mullet	<i>Aldrichetta forsteri</i>