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EXECUTIVE SUMMARY

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The aim of this work was to determine those factors, other than abundance, that have influenced the volumes and sizes of fish taken in several specified fisheries, and to initiate an understanding of the mechanisms by which they exert this influence. While a qualitative summary of the factors is useful in understanding these fisheries, the benefit of developing a set of quantitative variables was recognised during the course of the work and the study broadened to include an interpretation of relevant factors as a preliminary to producing a set of quantitative values.

A list of possible factors was drawn up based on previous knowledge, and these were discussed with fishing company staff members who either direct the targeting or have access to relevant information for most of the fishing companies operating or contracting vessels in the domestic purse-seine or TCEPR (vessels recording catch on *Trawl Catch Effort and Processing Returns*) charter-boat jack mackerel fishery. The information, which included both general comments (e.g., the range of factors resulting in start/end of fishing season) and data specific to the years of interest (e.g., species interactions leading to the end of season in a particular year) was summarised and expanded into a textual record by fishery/fishing gear and species.

Information was summarised for the five main species of the purse-seine fishery (kahawai, blue mackerel, trevally, jack mackerel, and skipjack tuna) and for salient aspects of the TCEPR charter-boat fishery that targets jack mackerel and also takes an appreciable bycatch of blue mackerel.

A number of factors were identified as having the potential to influence landing volumes and fish size. These included market variables, but, because not all were directly related to the marketing of fish and, because their point of impact within the fishing operation is in influencing the choice of target, they were categorised as "target-choice variables".

The most influential target-choice variables were concerned with the preferential targeting of higher valued species and a combination of mixed-species schooling behaviour and the inhibitory influence of bycatch when quota is limited in some way. Market value proved to be important in the TCEPR fishery where the trade-off between recent market prices for jack mackerel had resulted in some fishers choosing this species in preference to paying what were considered high quota costs to gain access to the hoki fishery. Within the purse-seine fishery it was concluded that the preferred-species hierarchy, based on the persistent relativity in market values of (in order from highest to least valued) skipjack tuna, blue mackerel, and jack mackerel, would remain the most important consideration in dictating target choice at any time unless there are further changes to catch limits or the market price of a species becomes so low that it is uneconomical to be landed.

1. INTRODUCTION

1.1 Overview

The aim of the work documented here was to determine those factors, other than abundance, that have influenced the volumes and sizes of fish taken in several specified fisheries, and to initiate an understanding of the mechanisms by which they exert this influence. A summary of these factors has been requested by MFish to aid in the interpretation of catch data. While qualitative interpretation is useful in understanding these fisheries, the benefit to be gained from developing a set of quantitative variables was recognised during the course of this work.

The approach taken has been to provide both a qualitative description of relevant factors and an interpretation of them as a preliminary to developing a set of values that can be used in a quantitative sense. It is likely, however, that production of something useful will take some debate and several iterations of this work. No references were available from the literature where similar factors had been investigated apart from documentation of market variables by Manning et al. (2007) under MFish Project EMA2003/01.

This work was completed under the Ministry of Fisheries Research Projects JMA2004/01, "Monitoring the species composition of the commercial catch of jack mackerel" and EMA2004/01, "Stock monitoring of blue mackerel". Although relevant specific objectives in each of these projects focused on documenting "market variables", it became clear as the work proceeded that not all relevant factors were directly related to the marketing of fish. The approach was expanded accordingly, to include all the factors that had been identified. Consequently, this report summarises work defining those factors that have influence on fish size and landed volumes in the domestic purse-seine and TCEPR (i.e., vessels recording catch on *Trawl Catch Effort and Processing Returns*) charter-boat fisheries.

1.2 Background

1.2.1 Defining the variables of interest

Standardising fisheries data to produce indices of relative abundance requires the inclusion of those factors that influence the *apparent* abundance of a species, but which are independent of the *true* abundance. For example, wind influences the schooling behaviour of pelagic finfish species, reducing their presence at the surface under certain conditions (Cowling et al 1996, Davis & Stanley 2002); therefore, in years when high winds are frequent, observational records like the MFish aerial sightings data should contain fewer records of schools. To account for the influence of the natural environment on the *apparent* abundance, appropriate environmental variables are included in models when estimating reference points such as indices of relative abundance. Similarly, factors related to the fishing operation are included to account for the total fishing effort expended from day to day or differences in the operational effectiveness of different vessels in the fleet. Historically within MFish projects, standardisations using methods like the generalised linear model have included both of these "classes" of variables (environmental and operational).

A third class of variable is also important. These factors provide information on targeting preferences like fish size and the timing of targeting particular species. Ultimately they influence landed fish size and catch volume. Their importance is most obvious in mixed-species fisheries, but they can also be important for single species in fisheries where effort is not related to the amount of fishing. For example, in the purse-seine fishery, where methods are being developed to use aerial sightings data to estimate annual indices of relative abundance, these factors can provide information on when flying effort is being expended on the species of interest. A list of these variables would include the following:

1. the current market value;
2. the availability of more valuable species;
3. the amount of available quota;
4. the amount of available bycatch quota or ACE (annual catch entitlement);
5. fish quality or fat content;
6. preferred fish size and the size of available fish;
7. the timing of the fishing season relative to the fishing year;
8. the vulnerability of non-fish bycatch species; and
9. the degree to which preferred species occur in mixed schools with other species.

While these factors include "market variables", they do not all relate directly to the marketing of fish. For example, two of those listed (3, 4) are directly related to the amount of available quota, while another (9) is a function of the relative behaviours of different species. Interactions between the factors can result in complex systems of quota and target management. Because this class of variables is broader than "market variables" only, a more appropriate classification would be one that includes all the listed variables, like "quota-management variables" or "target-choice variables". The latter is used throughout the remainder of this document.

In terms of the Quota Management System (QMS), there is no difference between "quota" and "bycatch quota". However, fishing companies distinguish between the two in discussions related to topics of this nature. They refer to their need to acquire additional quota or ACE from other fishers or companies to cover quota over-runs that occur as a result of excess bycatch. Thus, fishing companies distinguish between at least two functions of quota. Both are considered in the present discussion to highlight this distinction.

1.2.2 The targeted species

Here we are interested in the pelagic schooling group that includes jack mackerels, (*Trachurus declivis*, *T. murphyi*, and *T. novaezelandiae*), skipjack tuna (*Katsuwonus pelamis*), blue mackerel (*Scomber australasicus*), trevally (*Pseudocaranx dentex*), and the two kahawai species — kahawai (*Arripis trutta*) and Kermadec kahawai (*Arripis xylabion*), although commercial catch of Kermadec kahawai is probably negligible. Jack mackerels are often referred to as the single-species grouping jack mackerel (JMA), under which landings are recorded on catch-effort returns; similarly, the two species of kahawai are landed under the single-species grouping KAH. Because interactions between species have important influence on the choice of target, the following discussion is written with the aim that all species within each fishery must be considered for a complete understanding of the target variations that have occurred.

1.2.3 The fisheries

The main fisheries considered here are those in which the domestic purse-seine and TCEPR charter-boat fleets operate. While the purse-seine fleet targets and lands all the species listed above, the TCEPR fleet lands only jack mackerel and blue mackerel in appreciable quantities and targets only jack mackerel. Thus, there appears to be greater potential for inter-species interactions to influence target-species choices in the purse-seine fleet. However, interactions usually involve only two species at any time, which can happen in either fishery. Furthermore, in the TCEPR fishery other species can be taken as bycatch, including barracouta, snapper, John dory, and gurnard. Therefore, the complexity of quota and target management arising from the influence of "target-choice variables" can be similar in both fisheries, particularly at the level of the individual vessel.

The purse-seine fishery

Historically, the purse-seine fleet has fished predominantly in Fisheries Management Area (FMA) 1 (Figure 1), although FMA 2 was an important area (particularly until 1991) when Watties Ltd operated a cannery in Gisborne. Considerable effort was also expended in FMAs 3, 7, and 8, but closing of the Sanford Ltd factory in Nelson in November 2002 marked a large reduction in purse-seine effort on the west coast (mainly in the South Taranaki Bight and around Kahurangi in north Westland), in Golden and Tasman Bays, and on the east coast around Kaikoura. This reduction of effort in the "southern fishery" first began with the sale of the Sealord Ltd purse-seiner *Shemara* in April 1996.

Current purse-seine fishing is based mainly in Tauranga, comprising the "domestic" fleet operated by Sanford Ltd (five vessels) and Pelco Ltd (two vessels). The "domestic" fleet has fished New Zealand waters since 1976, though its present complement dates back only to 1996. A separate fleet of super-seiners are operated by Sanford Ltd (two vessels) and Talley's Frozen Foods Ltd (one vessel) mainly to target skipjack tuna, both within New Zealand waters and further north in the Pacific fishery. This fleet does not target other species of the domestic fishery (kahawai, blue mackerel, jack mackerel, and trevally).

The TCEPR charter fleet

The TCEPR charter fleet comprises eight BATMs (big automatic trawling machines) chartered from Russia and the Ukraine by the following five fishing companies.

Fishing company	Year of entry to the fishery	No of BATMs
Independent Fisheries	1985	2
United Fisheries	April 1998	1
Sealords	Early 1980s	3
Maruha	Mid 2004	1
Fish Marketing Ltd/Holdings*	2006	1

*Have not fished since June 2007

This fleet targets jack mackerel in JMA 7 and takes blue mackerel as bycatch within that fishery, recording this catch as landings from EMA 7.

Fishstocks and quotas

Jack mackerels were introduced into the QMS on 1 October 1996, within four quota management areas (QMAs), JMA 1, 3, 7, and 10 (Figure 1) (Ministry of Fisheries, Science Group 2006). Previously jack mackerels were considered part of the QMS, although Individual Transferable Quotas (ITQs) were issued only in JMA 7 (Ministry of Fisheries, Science Group 2006). Quota in JMA 1 and JMA 3 was fully allocated as individual quotas (IQs) by regulation except for the 20% allocated to Maori. Before issue of the 1995 jack mackerel regulations, catch taken in the Muriwhenua area of JMA 1, north of 36° S to the limit of the Territorial Sea (12 nautical miles offshore), was not covered by the JMA 1 regulations. There have been no further changes to the jack mackerel quota.

Kahawai was introduced into the QMS on 1 October 2004 within six QMAs that differ from those used before this species was introduced — i.e., the definitions of KAH 1, KAH 2, and KAH 10 remained unchanged, but KAH 4 was formerly part of KAH 3, as was that part of KAH 8 that is south of Tirua Point; and the area of KAH 8 north of Tirua point was formerly called KAH 9. Reductions have been made to catch limits in KAH 1, firstly to the total catch limit in 1993–94 (from 1666 t to 1200 t) and then, following the setting of an initial TACC to 1195 t with the introduction of kahawai to the QMS in 2004–05, to the TACC in 2005–06 with a 10% reduction to 1075 t. No changes have been made to the catch limit in KAH 2 since its initial setting of 851 t.

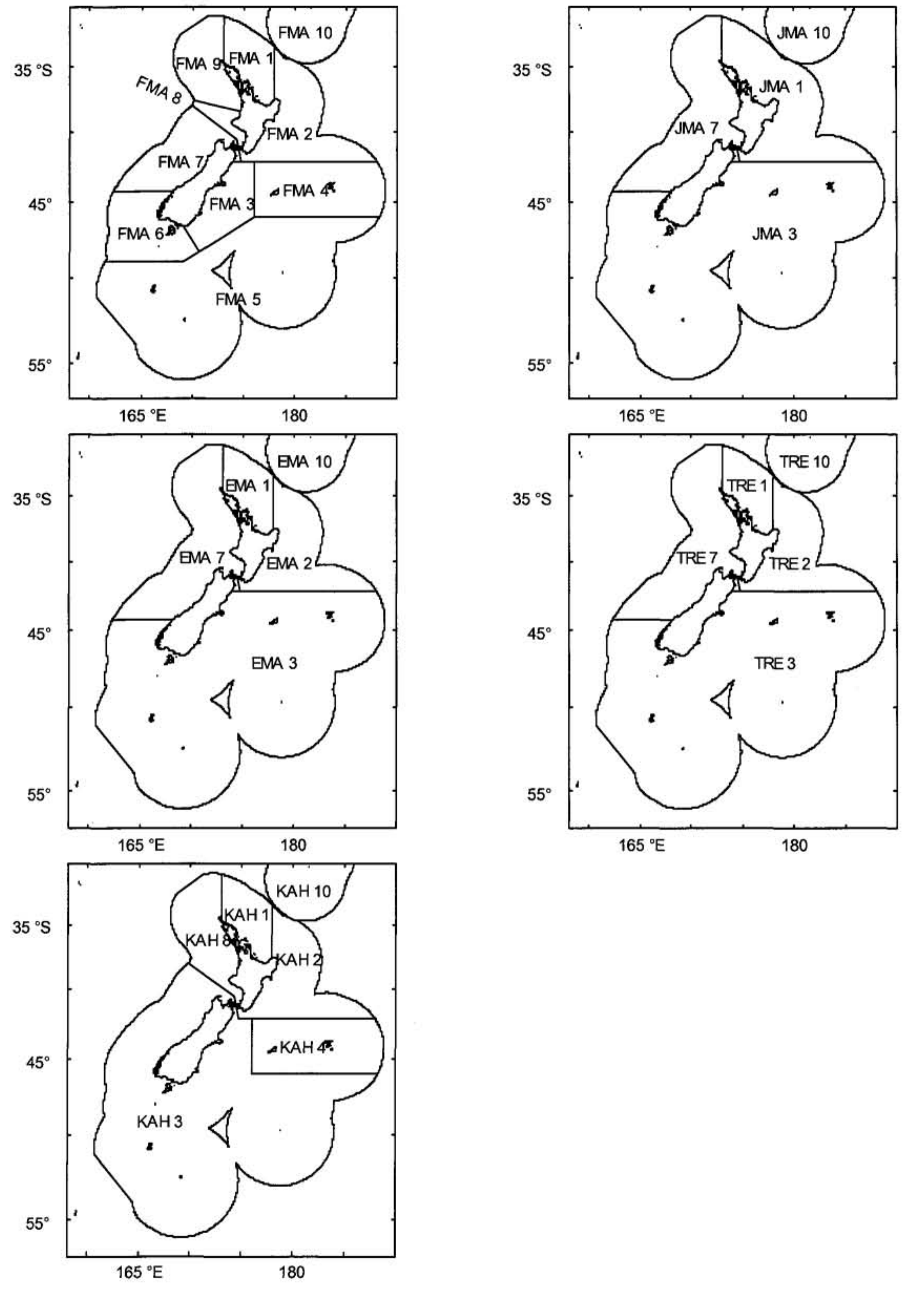

Figure 1: Quota Management Areas for jack mackerel (JMA 1, 3, 7, 10), blue mackerel (EMA 1, 2, 3, 7, 10), trevally (TRE 1, 2, 3, 7, 10), and kahawai (KAH 1, 2, 3, 4, 9, 10).

The catch limit in KAH 3 was reduced from 2339 t to 1500 t in 1995–96. This followed a voluntary agreement by the purse-seine fleet in 1991–92 not to fish in several near-shore areas in Golden and Tasman Bays, Cloudy Bay, and off Kaikoura, as a strategy to minimise local depletions and juvenile catch. The voluntary agreement is still observed.

Blue mackerel was introduced into the QMS on 1 October 2002 within five QMAs. There have been no changes to the original blue mackerel total allowable commercial catches (TACCs) within these Fishstocks.

Trevally was introduced into the QMS in 1986 within five QMAs, but, because the TACs were set under the provisions of the 1983 Fisheries Act, they refer to only the commercial catch limit. Although there were some increases to the original settings over the first six or seven years, they have remained effectively unchanged since 1992–93.

Skipjack tuna is the responsibility of the Western Central Pacific Fisheries Commission (WCPFC) and has not yet been introduced into the QMS.

In the purse-seine fishery, fishing companies now apply strategies that minimise the time that fish are kept in storage, particularly those targets that support what are considered high-volume, low-value fisheries. Therefore, companies manage their quota to ensure that orders for fish late in the fishing year (e.g., July–September) can be filled without storing fish caught during the previous season. This strategy can also result in some quota being carried over into the new fishing year when a fishing season is delayed by the non-availability of fish. Such carry-over is permissible under the allowance for a 10% carry-over of quota within the QMS.

2. METHODS

2.1 Data collection

Based on previous knowledge, a list of possible "target-choice variables" was drawn up. Discussions were held with those fishing company staff members either directing the targeting or having access to relevant information from most of the fishing companies operating or contracting vessels in the domestic purse-seine or TCEPR charter-boat fisheries. The information, which included both general comments (e.g., the range of factors resulting in start/end of fishing season) and data specific to the years of interest (e.g., species interactions leading to end of season in a particular year) was summarised under the following headings and expanded into a textual record by fishery/fishing gear and species.

- Market value.
- Preferential targeting:
  - skipjack over blue mackerel;
  - blue mackerel over jack mackerel.
- Available quota.
- Bycatch quota.
- Variations in spatial distribution.
- Length of season.
- Bycatch issues.
- Fish quality.
- Preferred fish size.
- Season versus fishing year:
  - dates.
- Non-fish bycatch issues.
- Mixed school issues.

2.2 Evaluating target-choice variables

One aim of this work was to provide a preliminary evaluation of target-choice variables for their use in a quantitative sense, i.e., within methods for standardising quantitative values such as indices of relative abundance using approaches like the Generalised Linear Model

(GLM) and Generalised Additive Model (GAM). As a basis for this preliminary evaluation, information collected under the headings listed in Section 2.1 was tabulated with the aim of reducing it to single-word or short-phrase summaries by fishery and species. Not all of the collected information could be summarised in this way.

3. RESULTS

3.1 The purse-seine fishery

3.1.1 Jack mackerel (almost exclusively JMA 1, potentially including JMA 3 & 7)

Jack mackerel is taken in a high-volume, low-value purse-seine fishery with recent sale prices for green product at $NZ0.86 per kilo. The JMA 1 season begins in mid to late winter and continues until as late as November, with targeting often interspersed with blue mackerel, as the availability of the two species changes near the beginning of the blue mackerel season.

The end of the jack mackerel season can occur with a shift in targeting, usually to blue mackerel, but sometimes to skipjack tuna, depending on the relative availability of the three species, the size and geographic positions of schools of the three species relative to the port of landing (usually Tauranga), whether orders of the more valuable species have been filled, and the degree to which jack mackerel schools are mixed with kahawai. With the relatively low current commercial quotas in KAH 1, the tendency for jack mackerel and kahawai to form mixed schools can inhibit the targeting of jack mackerel as fishing companies adopt strategies to maximise their jack mackerel catch while controlling their take of kahawai. This effect has become more pronounced over the last 15 years with each reduction to the allowable catch (see Section 1.2.3), so that a high proportion of the KAH 1 catch is now taken as bycatch.

Because of the timing of the jack mackerel purse-seine season, which usually straddles the end-beginning of consecutive fishing years, strategies targeting jack mackerel mixed in schools with kahawai can change throughout the season. Early in the season, which coincides with the latter part of the fishing year, some amount of kahawai quota for that year may remain uncaught, allowing fishers to target schools in which the kahawai component is high. However, later in the season, during the early part of the following fishing year, care is taken to ensure that maximising the catch of jack mackerel does not result in a high bycatch of kahawai. The skill of the spotter pilot is critical at this time in correctly determining the relative species proportions within schools and ensuring that jack mackerel schools containing more than the desired amount of kahawai are avoided.

Recent and current markets for domestic purse-seine-caught jack mackerel have preferred small fish. Although markets were developed for larger fish throughout the early to mid 1990s, when numbers of *T. murphyi* in JMA 1 were high, the catch of *T. novaezelandiae* (the smallest of the three jack mackerel species) has been high throughout the years that the JMA 1 fishery has been monitored (Taylor & Julian 2008).

3.1.2 Blue mackerel (EMA 1, 2, & 7)

Blue mackerel is the second-most-preferred purse-seine target species after skipjack tuna, although this has not always been the case, with kahawai occupying this position before reduced catch limits resulted in a shift to blue mackerel. Consequently, fishers do not usually target blue mackerel if skipjack schools are available, although this can vary depending on the size of skipjack schools, the geographical position of schools of each species relative to the port of landing, aspects of the current market like the relative values of the two species and whether there are outstanding orders, and how much blue mackerel quota remains uncaught after the arrival of skipjack tuna. Usually the blue mackerel season occurs between July and December (inclusive), with most fishing occurring between August and October (inclusive).

The end of the blue mackerel season usually occurs when fishers shift their targeting effort from blue mackerel to skipjack tuna, as skipjack schools become available following their migration into northern New Zealand waters during early to mid summer. Other patterns do occur, however, as can be seen in seasons when the availability of blue mackerel is high. Under this scenario, blue mackerel quota can be caught early and fishers may target jack mackerel while awaiting the arrival of skipjack. This occurred in 2006 when blue mackerel were available in late winter and were targeted almost exclusively into the early summer of 2006–07. Consequently, exclusive targeting of jack mackerel was delayed until EMA 1 quotas for 2005–06 were effectively caught, thus dispensing almost completely with the winter–spring jack mackerel season of 2005–06.

The New Zealand skipjack season occurs sometime between November and May (inclusive). Generally there is little overlap in targeting the two species, although occasional landings of blue mackerel can occur throughout the skipjack season, particularly when skipjack are temporarily unavailable or blue mackerel are available closer to Tauranga than skipjack.

Because the blue mackerel season straddles the end-beginning of consecutive fishing years, the end of one season and the beginning of the next usually lie within the same fishing year, but separated by six or seven months. The main market for the EMA 1 catch usually requires fish from about early spring. To minimise storage costs, one company manages their quota by carrying over a proportion from one season to the next, a strategy that can require trade-off in years of high blue mackerel availability. This could potentially result in the quota not being caught during a fishing year where onset of the second season is late because blue mackerel are unavailable. Under these circumstances a failure to catch quota would not necessarily be related to a reduced abundance in EMA 1.

The main market for blue mackerel landed in the EMA 1 purse-seine fishery takes up to 80% of the catch and requires premium fish. Sometimes fish-quality can be reduced when blue mackerel become bloated feeding on krill, with some suffering a burst gut after being caught, resulting in staining and reduced quality of flavour. However, the availability of alternative markets and the potential to gain higher prices elsewhere for fish affected in this way can ensure that highest prices are sustained.

3.1.3 Trevally (TRE 1)

While market prices for trevally have remained high, targeting decisions in the trevally purse-seine fishery are usually dominated by the availability of trevally to the fishery. Generally, trevally is fished independently of the other species with a major company usually dedicating a single vessel to landing most of their trevally quota.

3.1.4 Kahawai (KAH 1)

Current aspects of the kahawai fishery relevant here have been discussed within the section on jack mackerel.

3.1.5 Skipjack tuna (QMAs 1, 7, 8, and 9)

Fishing occurs mainly in North Island waters, mostly north of East Cape on the east coast and north of Wanganui on the west coast. Often, most, if not all fishing occurs on the east coast, but, in 2005–06, the catch was split roughly 1:4 between the east and west coasts. Deeper water and the tendency for larger, fast-moving schools on the west coast results in a much greater ratio of unsuccessful to successful sets than on the east coast. This also demands a higher level of competence from the spotter pilot when the fleet is fishing in this area, with adequate experience necessary for accurately determining the size of schools and the ability to provide predictive information on school behaviour being critical to successful sets.

When operating on the west coast, particularly if fishing effort is sustained for more than a few days, vessels from one company unload at Onehunga and fish are trucked to Tauranga. This method is believed to be very efficient, with a quicker unloading operation than in Tauranga and a reduced downtime of vessels from the fishery. This may go some way to offsetting the lower operational success rate on the west coast though the effects of these aspects of the operation have not yet been quantified. Some data are available that may allow relative success rates on each coast to be estimated.

3.2 The TCEPR charter fleet

3.2.1 Jack mackerel (JMA 3 & 7)

Targeting in JMA 7 is divided between two fisheries operating at different times of the year — a summer and a winter fishery. As the availability of hoki has become steadily later in the year (currently it is June–July), spawning jack mackerel have became more important as an alternative target before hoki fishing begins. It seems that the start of activity in the jack mackerel fishery occurs when catch rates in the squid fishery decrease to some low but unspecified level. Activity within this fishery benefits from the fleet strategy made available by the presence of eight vessels. There is further advantage for those vessels employing sonar over those with depth-sounder capability only.

The market for jack mackerel has strengthened over the last few years to the extent that one company believes it is preferable for skippers in this fishery to target jack mackerel and ensure a good catch than to pay high prices for hoki quota. Added targeting of the jack mackerel resource is also the result of poor catch rates in the hoki fishery over recent years. Larger fish are preferred but there may be some seasonality in fish size in some years — jack mackerel were small in late 2006, but their size increased later in 2006–07. This may be species-related (i.e., a predominance of *T. novaezelandiae*), but catch-sampling results for this period are unavailable at this time.

Bycatch constraints in this fishery arise from insufficient ACE for kingfish, John dory, snapper, barracouta, and gurnard. The impact of kingfish can be particularly high, with a current return of $2.50–4.00 per kg offset by a deemed value of $17.00 per kg. The availability of BAR 7 ACE can be important with one fishing company suggesting that barracouta can represent up to 100% of the content of a jack mackerel trawl.

According to one of the fishing companies, the fat content of New Zealand jack mackerel is highest during June–July, but no data are available to investigate this possibility.

A voluntary code of practice is followed in this fishery to avoid the catch of dolphin species. This was prompted when several dolphins were taken by a major player in the fishery more than 10 years ago. It is believed that current fishing practice avoids fishing activity between midnight and 4 a.m., the period when dolphins are known to be vulnerable to midwater trawling, although Baird (2007, 2008) has shown that tow-start-times continue consistently throughout the 24 h cycle.

3.2.2 Blue mackerel (EMA 3 & 7)

In the TCEPR fishery, blue mackerel are caught as bycatch of fishing effort targeting jack mackerels (*Trachurus* spp.). The preference for blue mackerel catch differs by fishing company and depends on the amount of blue mackerel quota each company owns. Most blue mackerel is landed from May to June (inclusive), but fishing companies with little quota must avoid blue mackerel catch, while those with more quota manage their blue mackerel bycatch to ensure that the best harvest levels are achieved. Strategies have developed to use quota more economically by "targeting" fish of particular sizes. Extracting a full harvest of blue mackerel from both the EMA 1 purse-seine and EMA 7 trawl fisheries has been attractive for at least the last five years, with international prices relatively high. A small price slump did occur during the 2003–04 fishing year, but more recently prices have recovered.

3.3 Summary of variables

3.3.1 Purse-seine

A summary of the information discussed in the previous section is presented in Tables 1–3.

Table 1: Relevant variables in the purse-seine fishery during 2004–05.

	EMA	JMA	KAH	SKJ	TRE
˙Market value	Increased markets	Stable	Increased markets	Stable	Up
Preferential targeting					
†Spatial variations					
‡Available quota					
Bycatch quota		KAH			KAH
*Fish quality					
Preferred fish size	Any	Small	Any	Not small	Any
*Season vs fishing year					
*Non-fish bycatch issues					
Mixed school issues		KAH			KAH
Season length					

˙Information from Sanford annual report, (2005).
*No issues during this year
†Poor EMA season on east coast (east Northland algal bloom in spring 2005 — fishing company anecdote) caused switch of effort to the west coast
‡No quota changes this year

Table 2: Relevant variables in the purse-seine fishery during 2005–06.

	EMA	JMA	KAH	SKJ	TRE
˙Market value	Increased markets	Stable	Increased markets	Stable	Up
†Preferential targeting	Early season	EMA			
Spatial variations					
‡Available quota					
Bycatch quota		KAH			KAH
*Fish quality					
Preferred fish size	Any	Small	Any	Not small	Any
*Season vs fishing year					
*Non-fish bycatch issues					
Mixed school issues		KAH			KAH
Season length					

˙Information from Sanford annual report (2006).
*No issues during this year.
†EMA season began early, so JMA season delayed for effort on EMA.
‡No quota changes this year.

3.3.2 TCEPR

Table 3: Relevant variables in the TCEPR fishery during 2004–05 and 2005–06.

	JMA	EMA
Market value	Strengthened recently	Good level sustained over last 5 yr
Preferential targeting		
Spatial variations		
Available quota		An issue with some companies
Bycatch quota	KIN, JDO, SNA, GUR, BAR	
Bycatch issues	Hotspots for SNA avoided	
Fish quality	Best in June–July	
Preferred fish size	Not small	Not small?
*Season vs fishing year		
Non-fish bycatch issues	Code of practice operating, but this may not be observed†	
Mixed school issues	Varying interactions dealt with by procuring available ACE	
Season length		

*Not an issue in this fishery
†Baird (2007, 2008) shows fishing throughout 24 h cycle.

4. DISCUSSION

The information gathered here provides useful background to the various purse-seine and TCEPR charter fisheries and serves as a basis for ongoing data collection to establish time series of those target-choice variables identified during the course of the work. In addition, this work represents a first step towards identifying the mechanisms by which these factors influence landed volumes and fish size, and towards providing quantified target-choice variables for potential use in future time-series modelling of data from these fisheries. The two have a complementary function — by working through the process of defining a quantifying method for the various factors, one discovers more about their underlying mechanisms. While it is possible that a number of the variables documented here could be included in models and standardisations as factors or categorical variables, it is ultimately more beneficial to investigate the feasibility of quantifying them as continuous variables where possible.

The following is a summary of the target-choice variables and some indication of how they could be translated into quantitative form.

4.1 Determining a true measure of relative annual market value

Initial investigation suggests that quantifying this variable may not be straightforward and may require consideration of a number of factors like the costs associated with fishing, if a viable estimate of market value is to be determined in economic terms. However, this may not be required if it is reasonable to assume that operational costs are constant across species. Generally, species will be targeted in the purse-seine fishery according to the "preferred-choice hierarchy": skipjack tuna, blue mackerel, and jack mackerel, with kahawai and trevally taken as bycatch or targeted when available. Given the relative market values of the first three of these species and the reduced quotas for the other two, this mechanism will probably persist unless there is some further change to catch limits or the market price of a species becomes so low that it is uneconomical to be landed.

This conclusion is based on the assumption that similar costs are incurred for each species, but is that realistic? Theoretically, it can be seen that differences in species distributions may lead to a lower-valued species being targeted despite the availability of a higher-valued species if the steaming distance to the latter is so much greater that the relative cost is prohibitive. Generally, this does not seem to happen, however, except at the beginning of a season before the volume of a higher-valued species has become large enough to guarantee the availability of enough fish to fill at least one vessel. One strategy has been adopted to reduce steaming costs, where west coast catch is landed at Manukau and shipped to Tauranga, an approach that results in a number of cost-saving benefits and probably offsets the added costs of a higher set-failure ("skunk") rate for west coast fishing.

Factors appear to interact differently in the TCEPR fishery, with the statement by one company that it is currently more viable for vessels to target jack mackerel than pay what they perceive as the high quota prices required to give them access to the hoki fishery. In this case it is the current market price of jack mackerel, and perhaps blue mackerel also, that provides a more economical alternative.

In conclusion, it may be enough for markets to be available for purse-seine-caught fish, because target-choice will most often follow the preferred-species hierarchical relationship. Other subtleties, like the timing of targeting, can probably be considered in terms of fish availability. In the TCEPR fishery, some research effort could be focused on the hoki versus jack mackerel targeting issue to determine whether an indicator of the relative benefits can be estimated, although collecting from fishing companies the type of information that would allow this estimation on an ongoing basis might be difficult.

One area in which the market value could be useful in investigating the mechanism of target-choice variables is in determining any trade-off between the deemed value of bycatch and the market value of the target species.

4.2 Defining preferential targeting

Preferential targeting is where expected targeting of a particular species is superseded by another in the short term. For example, in the FMA 1 purse-seine fishery during 2005–06, the blue mackerel season began early, continuing almost exclusively from late winter until early summer of 2006–07, resulting in a short, late season in the jack mackerel fishery. This variable is closely related to the length of season, i.e., the number of days a particular species was fished, but it does carry some additional information. Unlike some of the other factors, it could probably be defined adequately as a categorical variable.

4.3 Quantifying bycatch issues

Bycatch issues arise from the non-availability of ACE, the degree to which the target species is mixed in schools with other species and how this varies spatio-temporally, and where on the "deemed value continuum" the various bycatch species in a fishery lie. When ACE is unavailable for a particular bycatch species, fishers must avoid targeting their preferred species wherever the bycatch species occurs or face paying the deemed value if the bycatch species is landed. This risk increases with increasing mixing of the two species, but may not be so critical if the deemed value is low relative to the market value of the target species. In this case, fishers could write off the deemed value as a cost of landing the species of interest.

The availability of ACE can have a large influence on the targeting of some species under certain conditions. In the JMA 7 TCEPR fishery, barracouta ACE is plentiful, so, if fishers are competently managing their operations, bycatch of this species is unlikely to cause any reduction in jack mackerel targeting. By contrast, positions of snapper bycatch hotspots in this fishery are known and avoided because of the low availability and high cost of snapper ACE, and the price of snapper deemed value relative to the market value of jack or blue mackerel, although there is no evidence to suggest that this has a major effect on the landed volume of the target species. A more extreme situation is evident with the jack-mackerel-target, kahawai-bycatch relationship in the JMA 1 purse-seine fishery. Here the effect is more inhibiting on targeting because of the widespread spatial nature of the mixed schooling at a particular time of the year.

Further work here could focus on quantifying this inhibitory effect in such way that is consistent between fisheries, perhaps using as a basis the total amount of ACE available to the fleet in question. A possible approach is perhaps most clear in JMA 1, where quantification could incorporate information over an extended timeframe. Here, reduction in the allowable catch of kahawai over the last 15 years (see Section 1.2.3) underlies the increasing inhibitory effect over time of kahawai on jack mackerel targeting, through their presence together in mixed schools and the fishers' need to minimise their kahawai bycatch while maximising their landings of jack mackerel. The inhibitory effect increases with reduced catch limits, probably in a non-linear way.

Within the JMA 7 TCEPR fishery, six species, including blue mackerel, contribute to a complex bycatch situation. Here, blue mackerel is fished as a bycatch of jack mackerel targeting to the extent that, particularly for those with a higher share of the blue mackerel quota, this bycatch status might be better classified as "by-target". For those with a small share, however, the presence of blue mackerel could inhibit the targeting of jack mackerel under certain conditions. Other bycatch species with deemed values high enough to result in inhibition of jack (and blue) mackerel targeting are kingfish, John dory, and snapper.

Overall, the following three factors may be important in quantifying the effect of a bycatch species on fishing the target species.

1. The amount of ACE available, by vessel.
2. The spatio-temporal distribution of species proportions in mixed schools of the target and bycatch species.
3. A relative measure between the value of the target species and the deemed value of the bycatch species.

4.4 Fish quality

It is unclear to what degree fish quality really influences targeting. Generally, seasons of highest quality are known for each species within a fishery, but the presence of fish and their interaction with other species is probably more important. The fishers' control is probably limited to aiming to target a species at a particular time of the year. After that they may largely have to take what they can get, particularly in a trawl fishery where the fish cannot be sighted before being targeted.

4.5 Preferred fish size

Fish size can influence targeting. For skipjack tuna, which would usually be sighted by a spotter pilot before being taken by purse-seine, small fish are always avoided and the pilot can select schools according to the size of the fish. If fish in a school are outside the required size range then the school is unavailable or not yet recruited to the fishery. By contrast, small jack mackerel in the JMA 1 purse-seine fishery are preferred and, if absent, could result in reduced volumes of this species-aggregate being landed. Under these circumstances, quantification of a definitive variable would include information both on the market preference (i.e., preferred species size) and the size of available fish, which could be recorded by the spotter pilot (but is not currently).

4.6 Non-fish bycatch

This factor is an issue only in the TCEPR JMA 7 fishery. It reduces the amount of available fishing by several hours in each 24 h period. It is a constant amount for each vessel and does not require further consideration.

5. IMPLICATIONS FOR STOCK ASSESSMENT

Target-choice variables represent a little-known class of fishery information that includes "market variables". The work completed here is a "first cut" at summarising these factors as a basis for aiding in the interpretation of catch data at various levels and providing an interpretation of them as a preliminary to developing a set of values that can be used in a quantitative sense. This has included a preliminary description of the mechanisms by which these factors influence landing volumes and landed fish size. Summarising these factors, particularly in a quantitative sense, could provide useful input to stock assessments of the species mentioned here.

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