

Taihoro Nukurangi

Stock relationships of alfonsino and cardinalfish in New Zealand waters

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7. Executive Summary

The biological and fishery data for alfonsino and cardinalfish were reviewed. The alfonsino fishery is centered on two areas off the east coast North Island (BYX 2) and to the east of the Chatham Islands (BYX 3). Cardinalfish landings come mostly from two areas in the Bay of Plenty (QMA 1) and the Gisborne-Mahia area off the east coast (QMA 2), with around 50% of the catch as by-catch. In other regions of the globe alfonsino stocks appear to be contained within major eddy systems that entrap the pelagic larvae and juveniles. Similar comparative studies have been undertaken with cardinalfish. The major hydrological features off the east coast are the southward flowing East Auckland and East Cape Currents which form two permanent eddies at East Cape and off the Wairarapa, there are few data on current systems east of the Chatham Islands.

Stock discrimination techniques that have been applied to marine fishes were evaluated to identify appropriate techniques for determining the stock relationships of alfonsino and cardinalfish. Potential techniques for both alfonsino and cardinalfish include morphometrics and parasites. Parasite studies that included *Anisakis* species would require genetic identification of the two *Anisakis* species in New Zealand waters. Several stock discrimination techniques appear to be inappropriate for both alfonsino and cardinalfish for technical or biological reasons. These techniques are tagging, otolith microchemistry, life history traits, and genetics.

8. Objectives

Overall Objective:

To determine stock relationships of alfonsino (*Beryx splendens*) and cardinalfish (*Epigonus telescopus*) within the New Zealand EEZ.

Specific objective:

1. To determine the feasibility of discriminating stocks of alfonsino and cardinalfish within the New Zealand EEZ

9. Methods

This objective is a review process drawing together and assessing different sets of information relevant to determining stock relationships of alfonsino and of cardinalfish within the New Zealand EEZ. The review has considered global biological and fisheries data on *Beryx* spp., and *Epigonus* spp., hydrological data for the east coast and Chatham Rise, and included an assessment of appropriate stock discrimination techniques for marine fishes.

A synthesis of the biological, fisheries, hydrological and stock discrimination data permits the development and refinement of stock relationship hypotheses for alfonsino and cardinalfish. From this synthesis, NIWA identified appropriate techniques to determine stock relationships of alfonsino in BYX 2 and BYX 3 and cardinalfish in QMA 1 and QMA 2. The results were presented to the Deepwater Fisheries Working Group and the Inshore Fisheries Working Group in February 2000; feedback from these groups was used to fine tune the final recommendations on appropriate techniques for discriminating stocks in Objective 2.

The review of the biological and fisheries literature for *Beryx* spp., and *Epigonus* spp., and New Zealand fisheries data sources for *B. splendens* and *E. telescopus*, covered:

- The formal scientific literature (captured in ASFA, Current Contents, Fish and Fisheries Worldwide). Some early literature, not captured by electronic data bases, is held in the NIWA library, for example there are several papers on the meristics and morphometrics of *E. telescopus* in Russian, of which selected parts have been translated.
- The International Council for the Exploration of the Seas (ICES) literature. Much of the ICES literature is not formally published but is in the form of working group reports made available to member countries, including New Zealand; copies are held in the NIWA library. There are ICES reports on both cardinalfish and alfonsino fisheries in the Atlantic Ocean.
- NIWA publications and internal reports, and Ministry of Fisheries stock assessment documents specific to alfonsino and cardinalfish.
- Work in progress. There is a delay between the initiation of new scientific work and publication in the scientific literature. Therefore a component of the feasibility objective was to approach researchers in overseas laboratories (CSIRO, Hobart; Institute de Recherche pour le Development, New Caledonia; University

of Warwick) who might be working on the biology and stock discrimination of alfonsino and cardinalfish in other regions.

• Current Ministry of Fisheries projects being undertaken by NIWA: (a) Commercial catch sampling of alfonsino, and other species, projects INS9801 and INS199901, and (b) Stock assessment of cardinalfish, project CDL9801. Data in the TCEPR and CELR databases held by the Ministry of Fisheries were used to provide spatial and temporal distribution patterns of alfonsino and cardinalfish.

In addition to the biological and fishery data on alfonsino and cardinalfish further data sets were examined to:

- Describe the oceanographic features off the east coast and on the Chatham Rise. Many marine fish stocks are contained within oceanic eddies, which restrict movement of larvae and juveniles between regions. The key oceanographic features influencing larval and juvenile movements need to be considered for alfonsino in BYX 2 and BYX 3, and cardinalfish in QMA 1 and QMA 2. Oceanographic studies of this region have been carried out by NIWA staff and there are ongoing NIWA projects on the role of the Wairarapa eddy and East Cape current as a mechanism for larval retention (Chiswell and Roemmich 1998, Chiswell in prep.).
- Identify appropriate stock discrimination techniques. The stock discrimination techniques applied to marine fishes in general, and orange roughy and oreos in particular, have been documented and reviewed by NIWA under Ministry of Fisheries contract DEE9701 Smith (1998a). A framework has been developed for assessing data on the structure of orange roughy stocks (Smith 1998b).

10. Results

10.1 Biology and distribution of alfonsino Beryx splendens

B. splendens has a wide distribution in tropical and temperate waters of the Atlantic, Indian and Pacific Oceans (Kotylar 1996), where it occurs over seamounts and the continental slope in depths between 25-1200m, but is most abundant between 300-500m. In the western North Atlantic the peak spawning period occurs between July and September (Sherstyukov and Nostov 1986, Vinnichenko 1997, 1998), likewise in the North Pacific Ocean (Masuzawa et al. 1975, Uchida and Uchiyama 1986). In the southern hemisphere spawning occurs between November and March, with a peak in December and January around New Caledonia (Lehodey et al. 1997), and between January and March in the southeast Atlantic (Galaktionov 1984, Alekseev et al. 1986). Spawning has not been recorded within the New Zealand EEZ in spite of large fish caught off the east coast, leading to the suggestion that fish migrate to other areas to spawn (Horn and Massey 1989). However in other regions spawning fish have been caught on seamounts where there are all year fisheries, and there does not appear to be an extensive adult migration to spawning areas (Alekseev et al. 1986, Lehodey et al. 1997). Limited tagging studies on Japanese populations also indicate that adult alfonsino do not migrate over wide distances (Masuzawa et al. 1975).

The larvae and juveniles appear to remain in the pelagic environment for several months before settling on shallow seamounts. Ivanin (1987) caught juveniles, 54–96 mm long, at depths between 50–210 m in the Indian Ocean. The juveniles were captured where water depths were greater than 2000 m, and at considerable distances

from the continental slope and sea mounts, indicating a wide dispersal of pelagic juveniles. Such dispersal would promote gene flow amongst geographically isolated adult stocks. Other occasional observations of alfonsino larvae and juveniles support the long pelagic phase, with larvae found primarily in the upper 50 m in the central North Pacific Ocean (Mundy 1990, Boehlert and Mundy 1992).

French workers (Lehodey & Grandperrin 1996 and Lehodey *et al.* 1994, 1997) have described a model of larval and juvenile recruitment in an eddy system south of New Caledonia. In this seamount fishery there are size and depth related habitat differences: with juvenile alfonsino found in "vegetative" zones above shallow seamounts (< 400m), and adults found in "reproductive" zones above deeper seamounts (500–750 m). The reproductive zone corresponds to the fishery area and the life cycle is contained within a large eddy system ($23.5-25.5^{\circ}S$ and $167.5-171^{\circ}E$) which moves pelagic eggs and larvae from the reproductive zone to the vegetative zone and then the first maturing fish back to the reproductive zone (Lehodey *et al.* 1997). A similar picture of small immature fish in shallower water with larger spawning fish above off-shore seamounts was produced for alfonsino off Japan (Masuzawa *et al.* 1975) and for three populations of alfonsino in the central Atlantic Ocean (Alekseev *et al.* 1986).

Horn (1989) and Horn and Massey (1989) reported that the length frequency distributions of alfonsino varied substantially between grounds off the lower east coast of the North Island. Fish on the Palliser and Motukura Banks (Wairarapa coast) were generally small, with larger fish found to the north in the Madden Canyon and on the Tuaheni Bank (off Gisborne). This was reflected in the age composition which showed that on the Palliser Bank only 13% of alfonsino were >10 years, while on the Tuaheni Bank 54% alfonsino were >10 years (Massey and Horn 1990), and suggests an age related movement as reported for alfonsino in other regions (Masuzawa *et al.* 1975, Alekseev *et al.* 1986, Lehodey *et al.* 1997).

Gonadosomatic indices for alfonsino on Palliser Bank off the Wairarapa coast indicated a spawning period of July-August (Horn and Massey 1989). The lack of spawning fish on the Palliser Bank, along with a steep decline in fish frequency with increasing age, led Horn and Massey (1989) to suggest that the alfonsino off the east coast of the North Island are part of a non-reproductive zone (equivalent to the vegetative zone of Lehodey *et al.* 1997) where fish grow until near maturity and then move for reproduction. It is intuitively unlikely that these fish migrate long distances to spawn. Long distance spawning migrations have not been reported in other areas (Masuzawa *et al.* 1975, Lehodey *et al.* 1997). Thus it is likely that alfonsino spawn within the New Zealand EEZ and that the larvae and juveniles are entrapped within the Wairarapa eddy and recruit onto banks off the south Wairarapa coast. Small alfonsino < 20 cm have seldom been caught in New Zealand waters, but this may be due to selectivity of fishing gear (Horn and Massey 1989).

10.2 Stock discrimination of alfonsino

A spatial comparison of age/size classes and reproductive condition for alfonsino samples collected between 40° N and 40° S in the Atlantic Ocean lead to the hypothesis of 3 widespread populations contained within oceanic eddy systems (Alekseev *et al.*, 1986). There was considerable spatial isolation between juvenile and adult populations, indicative of passive larval and juvenile dispersal within eddies, and active recruitment of adults to spawning areas. Genetic data, based on one

allozyme locus, showed significant differences between regions, with 3 separate populations, one in the North and two in the South Atlantic Ocean (Alekseev et al. 1986). Within eddy systems there were no significant genetic differences between spatially isolated samples of juveniles and adults, demonstrating that these samples were drawn from the same genetic stock (Alekseev et al. 1986). However the genetic data presented by the authors are limited and it has not been possible to re calculate allele frequencies and re-analyse the data. The common view among Russian fishery scientists is that alfonsino form a series of independent populations based around seamounts in the northwest Atlantic with little adult movement among seamount complexes (Vinnichenko 1997, 1998). Absence of alfonsino on banks in the North Atlantic for several years following heavy fishing pressure (Vinnichenko 1998), coupled with no reports of adult alfonsino in the open ocean (Kotylar 1996) have been interpreted as indicating lack of short term movement (Vinnichenko 1998). A similar model of larval and juvenile dispersal, followed by adult recruitment to seamounts was proposed for B. splendens off New Caledonia, with marked age segregation over seamounts (Lehodey et al. 1994, 1997). Recent genetic analyses based on mitochondrial DNA of samples from New Caledonia found two distinct clades (A and W) that were interpreted as sibling species (Hoarau et al. 1999). Two hundred and fifty individuals were typed at the cytochrome b gene in samples from six sites in the EEZ of New Caledonia. The frequencies of the two types (= sibling species) changed along a north-south cline; but within each sibling species there was no regional differentiation (Hoarau & Borsa 1999). Small samples from the Atlantic Ocean, Southeast Australia and from the Chatham Rise were all of the same clade (A) suggesting that there is little genetic differentiation at the global scale within one clade or sibling species (Hoarau & Borsa 1999, Hoarau et al. 1999). Only one clade (A) or sub species was found among 12 specimens from the Chatham Rise (Hoarau et al. 1999).

In the Indian Ocean morphometric and meristic differences have been reported between regional samples. Unfortunately the location of the samples is not provided in the paper (Ivanin 1989) and it is only possible to guess at the spatial scale, which could be $7+^{\circ}$ of latitude in the Southern Indian Ocean. Specimens from the west Indian and east Indian Ridges differed in one meristic character, the number of dorsal spines; in five morphometric characters, measured as percentage of standard length: anteventral and antepectoral distances, length of the base of the dorsal and pectoral fins, and height of the anal fin; and in one morphometric character, measured as percentage of head length: orbit diameter (Ivanin 1989). These differences occurred between spatially isolated populations of adults (Ivanin 1989), in spite of the widespread distribution of pelagic juveniles (Ivanin 1987, Sherstyukov and Noskov 1986). Such results suggest that adults may not move great distances following recruitment.

A comparison of samples from three fishing grounds exploited by the Japanese fleet to the east of Japan found no differences in three meristic characters: fin ray counts, lateral line scale counts and vertebral counts, but differences in morphometric characters (Masuzawa *et al.* 1975). The authors reported that "the body depth in relation to body length appears somewhat lower in the fish from the Kyushu-Palao and Hawaii Ridges than in those form the Izu Ridge", and that "the specimens from the Kyushu-Palao Ridge appear to be broader in proportion to their weight than those from the Izu and Hawaii Ridges" (Masuzawa *et al.* 1975). Unfortunately the raw data were not presented in the report, and the authors did not comment on the significance of the morphometric differences, but given the wide spatial separation of the fisheries (the samples were collected from the Izu Ridge 29° 54' N, 133° 19'E and Hawaii Ridge 32° 43' N, $172^{\circ}11$ 'E), they concluded that the stocks were independent (Masuzawa *et al.* 1975).

10.3 The alfonsino fisheries in New Zealand

Commercial quantities of alfonsino have been landed since the late 1970s and a fishery developed off the east coast of the North Island from 1983 onwards (Fig 1). During the decade 1983–84 to 1993–94 the total landings ranged from about 1500 to 2000 t, and increased to almost 3000 t in the late 1990s, exceeding the quota of 2727 t (Fig 1.)

The major fishery for alfonsino in the New Zealand EEZ has been off the east coast of the North Island in BYX 2 (= QMA 2), where the species is taken in a midwater trawl fishery, both as a target species and as bycatch in bluenose, gemfish, and rubyfish target fisheries. This fishery was initially concentrated on banks and seamounts between Gisborne and Cape Palliser, but more recently has concentrated in the northern part of BYX 2. The northern boundary of BYX 2 at Cape Runaway effectively defines the north-western limit of the present fishery, but it might extend westwards to the Bay of Plenty seamounts as these are explored. The statistical fishing areas, the QMAs (1-10), and the alfonsino fishstocks are shown in Figure 2.

The catch has increased rapidly from the Chatham Rise part of BYX 3 (= QMA 3, 4, 5 & 6) from 1994–95 (Fig 1). Alfonsino are caught in a target trawl fishery and a long-line fishery for alfonsino, groper, and ling to the south-east of the Chatham Islands (Annala *et al.* 1999).

The spatial and temporal distributions of the alfonsino fisheries were determined from a NIWA extract of estimated catches in the Ministry of Fisheries catch/effort database. Extracts cover the fishing years 1989–90 to 1998–99, and come mainly (89%) from the TCEPR forms. There is reasonable agreement between these catch values, the landing values from the same database, and the QMS landings reported in Annala *et al.* (1999), see Table 1. The catch data have not been groomed for errors.

Alfonsino catch by QMA

The largest and most consistent catch of alfonsino has been taken from QMA 2 (= fishstock BYX 2). The estimated catch values of 1,400 to 1,500 t taken from QMA 2 (Table 2) understates the reported QMS landings of 1,500 to 1,800 t presented by Annala *et al.* (1999). The latter approximate or exceed the TACC which has risen from 1,274 t to 1,575 t over this period. Catches in QMA 4 reached 200 t in the 1994 and 1995 fishing years, and from 1996 to 1999 were 700 t to 900 t. Catches in QMA 3 have generally been 200–300 t, reaching 400 t in the 1995 and 1996 fishing years.

Catch distribution within QMAs

Catches localised to fishing statistical areas for the three main QMAs (2, 3, 4) are presented in Table 3 and Figure 3. Data from areas QMA 3 are included to clarify the pattern of catches in the Cook Strait-Mernoo Bank region (QMA 3) and the eastern Chatham Rise (QMA 4), as sub regions of fishstock BYX 3 described in the Ministry of Fisheries tender.

In QMA 2, the largest alfonsino catches have consistently been taken from areas 14 and 204, centered on the Ritchie Hills and Madden Bank; lower catches have been taken from area 13, which includes the northern part of the Ritchie Hills complex. Consistently high catches have also been taken from area 15, which includes a complex of hills off the Wairarapa coast (Table 3).

In QMA 3, consistent catches averaging 200 t have been taken in the Kaikoura region (area 18), but only small catches on the western Mernoo Bank (areas 19, 21, 23). In QMA 4, there were small catches on the eastern Mernoo Bank (area 24). Small catches have been made along the northern Chatham Rise (areas 402, 404, 49, 52), but the largest catches in QMA 4 have been made east and south-east of the Chatham Islands (areas 406, 412, 51), mainly since 1996 (Table 3, Figure 3).

Alfonsino as target or bycatch

Almost all (99.6%) of the New Zealand alfonsino catch is taken by trawl, 59% by near-bottom trawl (as defined by fishers). The remaining 0.4% is a minor bycatch on lines and in deepwater setnets.

For the period 1989–90 to 1998–99, 68% of the alfonsino catch is targeted (annual values are 54–89%, with no trend). Of the amount recorded with another target species, 48% is recorded as a bycatch of hoki, 20% a bycatch of orange roughy, 11% a bycatch of bluenose, 10% a bycatch of cardinalfish, and 5% a bycatch of gemfish.

There are differences in the extent of targeting between QMAs. In QMA 2, 74% of the alfonsino catch is targeted, 9% is a bycatch of hoki, and the remainder is taken about equally when targeting orange roughy, cardinalfish, bluenose and gemfish. In QMA 3, only 42% of the alfonsino catch is targeted, 55% being taken as a bycatch in the large Cook Strait hoki fishery. In QMA 4, 67% of the alfonsino catch is targeted, 15% a bycatch of orange roughy, and 13% a bycatch of the hoki fishery on Mernoo Bank.

The geographic distributions of alfonsino catches taken as a target species or bycatch within QMAs are essentially similar (Table 4). In QMA 2 the targeted catch is taken from the Wairarapa Hills and the southern and central Ritchie Bank, while a little more of the bycatch is also taken from the north-eastern Ritchie Hills (area 204) as a bycatch of orange roughy and cardinalfish. In QMA 3 the targeted catch is taken from the Kaikoura region (area 18) plus the western Mernoo Bank (areas 21, 23), while the bycatch is restricted to the former. In QMA 4 the targeted catch is from three areas (51, 406, 412) east of Chatham Islands, while the bycatch is taken from area 51 as a bycatch of hoki and area 404 on the north-eastern Rise as a bycatch of hoki and hake.

Catch by season

In QMA 2, mean monthly alfonsino catches ranged between 50 t and 230 t during the years 1990 to 1998, with a peak in spring and summer (September to February). This pattern was driven by the relatively large targeted catch, but was also apparent in the bycatch of alfonsino taken with bluenose, cardinalfish, hoki, and gemfish. This pattern was reasonably consistent between years. The bycatch with orange roughy did appear to have a seasonal pattern in the mean monthly values, but this varied between years. When the catch is examined more closely by region and by year (Figure 4), but not by

target species, the spring-summer peak seems to be bimodal, and although one or both modes are generally present there are differences between regions and between years.

In QMA 3, mean monthly alfonsino catches ranged between 2+ and 45 t during the years 1990 to 1998. High catches were often taken in January and February, but there was no consistent seasonal pattern (Figure 5). The targeted catch usually peaked in January and February and again in August and October. The bycatch in the hoki fishery was variable through most of the year, but dropped to zero in July and August when fishing vessels target spawning hoki schools, possibly away from the grounds that yield alfonsino, and when they take relatively little bycatch.

In QMA 4, mean monthly alfonsino catches ranged between 1+ and 95 t during the years 1990 to 1998. Highest catches were strongly seasonal, taken from September to March. This was consistent between years, and occurred whether alfonsino were targeted or taken as bycatch (Figure 5), apart from rather irregular catches in the hoki target fishery.

Catch by area by season

The largest alfonsino fishery occurs in QMA 2. It can be considered as four areas, with statistical fishing areas combined into approximations of the main fishing grounds centered on hill complexes: East Cape, Ritchie, North Wairarapa, and South Wairarapa (Figure 4). The fishery has shifted northwards over time, from the Wairarapa Hills and Madden Bank to the Ritchie and East Cape Hills. The seasonal pattern is often of highest catches in spring and/or summer, but with regional and annual variations. There is a slight and inconsistent trend for the peak of catches to become smaller over time, especially on the main Ritchie ground.

The catch in QMA 3, much of which is taken in the hoki fishery, has no regular seasonal pattern (Figure 5). The catch in QMA 4, principally taken from east of the Chatham Islands, has a strong pattern of higher spring and/or summer catches (Figure 5).

10.4 Major oceanographic features off the east coast of New Zealand

The major oceanographic feature off the east coast of the North Island is the southeastward flowing current, the East Auckland Current, north of East Cape, and the East Cape Current (ECC), south of East Cape (Figure 6). These currents bring subtropical water down the east coast of the North Island and result in the subtropical convergence over the Chatham Rise, where they meet the northward flowing Southland current (Heath 1975). The East Auckland Current diverges near East Cape with some water flowing north and east, and the rest flowing southwards as the ECC. The divergence at East Cape and again at 42°S along the Chatham Rise create two permanent eddies at East Cape and off the Wairarapa (Chiswell and Roemmich 1998). Such eddy systems could entrap larval and juvenile fishes and retain them until settlement; retention times within the eddy system have been estimated to be as high as 2-3 years (Chiswell and Roemmich 1998). Chiswell and Booth (1999) determined geostrophic currents and modelled the distribution of passive tracers in the ECC to simulate larval concentrations. These simulations were compared with distribution of rock lobster Jasus edwardsii phyllosma larvae off the east coast and provided strong evidence that rock lobster larvae are trapped in the Wairarapa eddy. Eggs, larvae and juveniles of alfonsino and cardinalfish could be similarly held in these eddy systems but their residence times would be dependent upon larval and juvenile behaviors such as diel migration patterns and swimming speeds. The extent of exchanges of lobster larvae between the ECC and water farther to the east on the Chatham Rise are unknown (Chiswell and Booth 1999); however the Wairarapa eddy does not extend beyond about 180°, thus alfonsino spawned near the Chatham Islands could be entrapped within another eddy system east of the Chatham Islands. Unfortunately there are no data on current systems east of the Chatham Islands (Sutton, NIWA, pers. com.).

10.5 Techniques for determining stock relationships in marine fishes

There is no generally accepted definition of a fish stock, but most definitions have the common elements of spatial and temporal isolation, and in many cases reproductive isolation. There are several techniques available for determining stock relationships in marine fishes; they measure different biological parameters and thus describe different biological structures. These techniques have been reviewed by Smith (1998a) in relation to stock discrimination of orange roughy and black and smooth oreo within the New Zealand EEZ; and are summarized under 5 categories that measure:

- *phenotypic* variation, such as meristic and morphometric characters, which have a genetic basis but expression of the character is determined by the biotic and physical environment experienced by individuals;
- *acquired* markers, such metal ions and elements in otoliths, or body parasites in soft tissues, that accumulate during an individuals life;
- *genotypic* variation, such as allozymes and DNA, inherited characters that are passed down generations and not modified by the environment, although some genetic loci might be under selection so that frequencies of alleles change from generation to generation within a stock;
- *life history traits*, such as size and age at settlement and/or first reproduction, that have an underlying genetic basis but are modified by the physical and biotic environment experienced by individuals;
- *movement* of adults and sub adults by physical tagging.

In addition, biological data on the distribution of spawning fish, larvae, juveniles and adults, coupled with hydrological data, contribute to the development of a stock structure model. The larval and juvenile phase may promote gene flow and thus limit the opportunity for genetic isolation; alternatively larvae may be retained within eddy systems, isolating stocks. Discrete post settlement areas, coupled with an absence of extensive adult movements, may lead to the development of differences in life history traits and acquired characters that are determined in the late juvenile and adult stages.

The stock discrimination techniques can be grouped into ecological and genetic approaches to stock structure (Smith 1998a). Ecological approaches, based on differences in phenotypic variation, acquired markers, or life history traits, provide a measure of stock relationships, but because of sensitivity to environmental parameters, need to be assessed for temporal as well as spatial variation. Stocks defined by ecological approaches may reflect differences in post-settlement habitat quality, and hence production of the stock, and thus are relevant to short term management goals. However ecological stocks that are environmentally determined may not be reproductively isolated and thus may not be stable over time. Inter year environmental differences could affect the phenotypic and acquired characters, so that

measured differences are due to year class variation rather than reproductive isolation. In addition life history traits may change in response to fish density and fishing pressure and thus require a time series to establish differences among regions.

Genetic methods, based on differences in inherited characters, provide an alternative approach to stock discrimination. A significant genetic difference is a sufficient but not necessary condition for separate stock management. Genetic stocks have continuity over time; larvae and juveniles recruit back to their natal stock and remain discrete from other stocks over time, whereas ecological stocks may recruit from a common larval pool but undergo differentiation in the nursery and adult feeding areas due to environmental differences. Genetic methods have been used extensively for stock discrimination over the past twenty years, in part because the focus of stock discrimination has been on defining reproductive isolation, and because a range of new and more sensitive genetic tools have become available with the rapid developments in molecular biology. However in comparison with freshwater teleosts many marine species show low levels of genetic differentiation between regions (Ward et al. 1994, Shaklee and Bentzen 1998), which may be attributed to genetic exchange through planktonic juvenile dispersal and/or adult migration in the absence of major physical barriers between ocean basins (Grant and Bowen 1998). Even a low level of exchange, of the order of tens to hundreds of individuals per generation, will be sufficient to eliminate genetic differentiation in the absence of local selection or sweepstake events (Waples 1998).

10.6 Assessing data derived from different techniques for determining stock relationships

The application of ecological and genetic techniques to stock discrimination will result in the description and definition of different biological units. Ideally inferences about stock relationships are based on information gained from several techniques. For all techniques the null hypothesis is a single stock with no differentiation in the study area. A significant difference between sites is indicative of isolation among the sampled groups with limited larval and/or adult exchange, although such differences need to be verified with temporal samples.

For each technique an out-group sample, taken outside the study area, is desirable to assess the sensitivity of the technique for resolving the stock structure question. A lack of significant differences among samples taken within the study area may indicate that the samples were taken from the same stock unit, alternatively if the technique also shows no significant differences among samples from the study area and the out-group sample then the technique maybe insensitive to stock structure over the spatial scale in question. For all techniques the smaller the spatial scale the less likely that there will be biological differences among samples, due to larval drift and adult movement.

10.7 Potential stock models for alfonsino in New Zealand waters

The main alfonsino fishery is centered on seamounts or submarine hill complexes along the east coast of the lower North Island (QMA 2); about one quarter is taken as bycatch. The second most important alfonsino fishery occurs east of the Chatham Islands, at the easternmost end of QMA 4; about one third is taken as bycatch. Catch data from research trawl surveys show that the species is distributed right along the northern edge of the Chatham Rise but there is an apparent gap between the Mernoo Bank and the southern Wairarapa coast (Anderson *et al.* 1998), although this may be an artifact of the data based on fewer trawl hauls. A moderate fishery for alfonsino, both targeted and bycatch, occurs in the southern Cook Strait to Kaikoura region (within this apparent gap), extending out to Mernoo Bank. This fishery is geographically closer to the seamount fisheries in QMA 2 than those in QMA 4.

There are four potential stock models for alfonsino in BYX 2 and BYX 3, which are outlined in Figure 7. The different models are produced by differences in movement patterns of both larvae and juveniles and/or adults.

- 1. Two or more isolated stocks that do not exchange adults or larvae and juveniles; such a model would lead to genetic and ecological isolation.
- 2. Two or more ecological stocks in which adults do not move between areas, but there is larval and juvenile drift through oceanic currents between areas. Such stocks would potentially differ in characters that are determined late in the life cycle, such as microchemistry of the outer margin of the otolith, the prevalence and intensity of parasites, and morphology.
- 3. Two or more pools of larvae that remain isolated due to containment within eddy systems, but some adults move between regions. Such a structure would lead to potential differences in characters determined early in the life cycle, such as meristics and the nucleus of the otolith, but no genetic differences.
- 4. One stock with movement of both adults and larvae among regions. Such a structure would not be expected to show differences with any stock identification technique.

The biological data, reviewed above, on global populations of *B. splendens* indicate that models three and four, with extensive adult movement (Figure 7) are the least likely stock structures for BYX 2 and BYX 3. Stock hypotheses for the Atlantic and New Caledonia populations are based on larval and juvenile drift within large scale eddy systems. Such hypotheses are illustrated by models two and four in Figure 7. For New Zealand it has been suggested that alfonsino might be contained within a large gyre system, or complex of gyres, that reach from the east coast of the North Island to the Louisville Ridge (Horn, NIWA, pers com.), based on the presence of alfonsino on Louisville Ridge seamounts.

The New Caledonia alfonsino stock is contained within an eddy system, between 23.5–25.5°S and 167.5–171°E, which moves pelagic eggs and larvae from the reproductive zone to the vegetative zone and then the first maturing fish back to the reproductive zone (Lehodey *et al.* 1997). The three Atlantic populations of alfonsino are also contained within large gyres and, although not well defined, appear to cover wide areas, about 7° of latitude and at least 10° of longitude (Alekseev *et al.* 1986). The New Zealand alfonsino fisheries in BYX 2 and BYX 3 occur over 38.5° to 43°S, 175°E to 175 °W, an area approximately four times that of the New Caledonia fishery, but smaller than the gyres containing the Atlantic populations.

10.8 Potential stock discrimination techniques for alfonsino

Acquired character: microchemistry. Given the large collection of alfonsino otoliths held by NIWA and the wide application of otolith microchemistry to stock discrimination (Thresher 1999), microchemical analyses of the otolith would be feasible. However microchemical analyses are inappropriate for alfonsino (and for cardinalfish) for technical and theoretical reasons. Most of the available alfonsino otoliths were not collected for, and are not suitable for microchemistry analyses. Many of the microelements (such as Na, K, Cl) used in chemical stock discrimination studies are sensitive to post mortem handling procedures, such as alcohol storage (Proctor and Thresher 1998, Thresher *et al.* 1999).

Freshly collected and dried otoliths could be used for microchemical analyses. However recent reviews of the application of microchemical techniques to stock separation suggest that the technique is inappropriate for oceanic fishes that occupy a relatively homogeneous saline environment (Thresher *et al.* 1999), but is more appropriate for estuarine and freshwater species that are exposed to different water chemistries (Thresher 1999). Furthermore the wide diurnal temperature range, from 8 to 15°C experienced by juvenile alfonsino during vertical migration (Galaktionov 1984), may produce complex microchemistry profiles but with little spatial differentiation.

Many elements occur at low concentration and only just above the detection limit in otoliths (Thresher pers com). For marine fish in general the small differences reported between sites have not been confirmed with repeat samples (Proctor and Thresher pers com). The lack of significant regional differences in otolith chemistry across a broad geographical range, and across many elements for the deep water orange roughy, lead to the conclusion that this approach was not useful for stock discrimination in this species (Proctor and Thresher pers com). Other oceanic species such as hoki (Kalish et al. 1996) and bluefin tuna (Proctor et al. 1995) have shown no regional differentiation in elemental concentrations. In hindsight the major application of microchemistry has been to measure changes in strontium levels to determine movement between marine and freshwater environments (Thresher 1999). In a review of otolith microchemistry, Thresher et al. (1999) concluded that: "while potentially very promising, the science of analysis of otolith composition is still developing, and major methodological issues still need to be worked out and factored into the science. Ultimately, no one yet fully understands the mechanisms of elemental deposition or the magnitude of the factors that can alter this deposition. Until the field matures and differences among individuals and stocks can be anambiguously replicated using a range of techniques, management decisions based on otolith chemistry as a sole or major input would be unwise."

Microchemical analyses of dried otoliths is not recommended as a tool for stock discrimination of alfonsino.

Genetics. A wide variety of genetic tools are available for estimating genetic diversity within and between regional samples of fish. Originally only allozyme techniques were available, but DNA based approaches have been applied since the mid 1980s for stock discrimination. In general DNA based methods are more time consuming and costly than allozyme methods, by up to a factor of ten. A limited allozyme analysis of alfonsino samples from the Atlantic Ocean showed regional population structure with one esterase marker (Alekeseev et al. 1986). Although it is not possible to re-calculate the data, the authors concluded that their genetic data supported a three stock hypothesis based on esterase allele frequencies, distribution of adults and juveniles, and oceanic circulation patterns (Alekeseev et al. 1986). Given that allozyme methods can be applied at relatively low cost then they could be used to compare allele frequencies between samples from the Wairarapa (BYX 2) and east Chatham Island (BYX 3) fisheries. The methods would need to include esterase markers, which differentiated alfonsino stocks in the Atlantic. The same class of genetic marker has been used to distinguish snapper Pagrus auratus stocks off the east coast of the North Island, but only between stocks north and south of East Cape (Smith et al. 1978), which is a major barrier to many coastal species. However the alfonsino stocks distinguished with esterase markers in the Atlantic are separated by considerably greater distances than those separating the fisheries in BYX 2 and BYX, and the stocks occur in separate water masses. Figure 3 in Alekeseev *et al.* (1986) appears to show two genetic groups: one in the North Atlantic and one in the South Atlantic; the genetic data do not appear to separate alfonsino stocks over a smaller spatial scale within the South Atlantic Ocean.

More recent DNA based studies, albeit on small samples of alfonsino, showed no genetic differentiation between the Chatham Rise, Australia, New Caledonia and the North Atlantic Ocean (Hoarau & Borsa 1999, Hoarau *et al.* 1999). This finding is in common with several genetic studies of pelagic species, or species with long pelagic larval and juvenile stages (Grant & Bowen, 1998; Shaklee & Bentzen, 1998). Such findings indicate that mobile oceanic species show little genetic differentiation over relatively short spatial scales (and even wide spatial scales), and that discrete local genetic stocks have not evolved due to gene flow.

Genetic techniques are not recommended as a tool for stock discrimination of alfonsino over the relatively small spatial scale within the New Zealand EEZ.

Acquired character: parasites. Fish acquire parasites through their diet or through inoculation. If the parasites, and/or their intermediate hosts, have a restricted distribution compared with the final host, then only some groups of fish will be exposed to the parasite, and the parasite can be applied as a biological tag (Smith and Wootten 1978). Several groups of parasites such as myxozoa, copepods, and larval stages of nematodes (e.g. Anisakis sp.), and cestodes (e.g. Hepatoxylon sp.), have proved useful for stock discrimination of mid- and deep- water teleosts (Lester et al. 1988, Kahn and Tuck, 1995, Mackenzie and Longshaw, 1995, Sewell and Lester 1995), including species occupying seamount habitats (Humphreys et al. 1993, Whitaker and MacFarlane 1997). No parasite studies have been undertaken for stock discrimination of alfonsino.

In New Zealand waters the prevalence and abundance of Anisakis in smooth oreo *Pseudocyttus maculatus* from area OEO 3A was less than in three areas to the south of the Chatham Rise, although this difference was based on a small sample from OEO 3A (Smith *et al.* 1999). The prevalence of Anisakis also shows differences among samples of barracouta *Thyrsites atun* from the east coast South Island and the Chatham Islands, and in arrow squid Nototodarus sloanii over the same areas (Hurst unpubl.). In smooth oreo the number of Anisakis larvae increased with fish size, presumably because Anisakis is long lived and accumulates over the life of the host. For long lived host species such as orange roughy the abundance and prevalence of Anisakis may indicate year class differences rather than stock differences between samples (Lester *et al.* 1988). Jones and Gibson (1993) also reported variation in orange roughy parasite numbers between tows, due to variation in host size. Therefore regional comparisons of parasite markers in alfonsino should compare fish of similar ages.

Genetic studies on Anisakis have shown that the species consists of several species. Samples of blue cod Parapercis colias, red cod Pseudophycis bachus, and barracouta Thyrsites atun from New Zealand waters carry two species of Anisakis: Anisakis simplex C and A. pegreffi. (Mattiucci et al. 1997). These species can only be distinguished by molecular techniques (Mattiucci et al. 1997) and have not been recognized in previous parasite studies in New Zealand waters (Wharton et al. 1999). It is recommended that a two stage parasite analysis be undertaken; first to identify appropriate parasite markers and, second to compare regional samples from the Wairarapa (BYX 2) and east Chatham Island (BYX 3) fisheries. If significant numbers of *Anisakis* are found then these should be identified to the species level, with a genetic technique, as these species may have different intermediate hosts and different distributions within the New Zealand EEZ

Tagging. Tagging experiments off Japan released 3925 alfonsino between 1957 to 1974 with 146 recaptures. Of the recaptured fish only 26 had moved from the initial tagging sites, but even these distances were small, up to 76 miles (Masuzawa *et al.* 1975). Hook tagging of alfonsino has not been successful in New Zealand (Horn 1989). In the short term mechanical tagging does not appear to warrant further application with alfonsino in New Zealand waters.

Life history traits: age at settlement or maturity. Ageing studies with alfonsino have found no obvious features in the otolith that might be linked with settlement or with the onset of sexual maturity (Horn, NIWA, unpublished observations). Therefore these traits are not applicable to alfonsino with current technologies.

Life history traits: size at age. Growth rate may vary between areas resulting in different mean lengths at age between areas. This trait has been used to support stock differences in hoki (Horn and Sullivan 1996) and ling (Horn 1993) within the New Zealand EEZ. A current Ministry of Fisheries project (INS9801) is undertaking shed sampling and aging of alfonsino in BYX 2, but not BYX 3 and therefore length-at-age data will be available only for one fishery area. The cost of undertaking a specific project to collect length-atage data for BYX 3 solely for stock discrimination is probably not warranted. Length-atage data require a time series to establish stock differences, and have been used primarily to support stock differences measured with other techniques. Based on preliminary observations there are not likely to be significant differences in length-atage between alfonsino from the Chatham Rise (BYX 3) and east coast (BYX 2) fisheries (P. Horn, NIWA, unpubl. observ.).

Phenotypic characters: morphometrics. Characters that are determined late in the life cycle may distinguish adult stocks derived from a common larval pool, but among which there is little exchange following recruitment. In the Indian Ocean six morphometric characters differed between spatially isolated populations of adult alfonsino (Ivanin 1989). In the northern Pacific Ocean differences in body depth and width were reported among samples from different alfonsino fishing grounds, although no statistical analyses were presented to support regional differences (Masuzawa *et al.* 1975). In both studies the differences were found between widely separated samples collected over a greater spatial scale than of interest within the New Zealand EEZ. In the Pacific Ocean samples were taken from the Izu Ridge at 29° 54' N, 133° 19'E and Hawaii Ridge at 32° 43' N, $172^{\circ}11'E$ (Masuzawa *et al.* 1975). In the Indian Ocean samples were taken from West Indian and east Indian ridges which are separated by as much as $7+^{\circ}$ of latitude (Ivanin 1989).

Intraspecific stocks of other species within the New Zealand EEZ have been described based on morphometric characters. Colman (1995) measured length, width, and thickness of otoliths from approximately 1000 ling *Genypterus blacodes* and made 6 morphometric measurements on approximately 1000 ling heads. There were significant between area and between sex differences in otolith shape, with a northern group (Chatham Rise, Canterbury, and west coast South Island) and southern group

(Puysegur, Snares, and Southern Plateau), although samples from Otago did not fit into either region (Colman 1995). The head morphometrics also showed highly significant between area and between sex differences, with a northern group (Chatham Rise and Canterbury) and southern group. There was suggestion from the pooled data that fish from the Canterbury Bight may be a separate group from those on the Chatham Rise (Colman 1995).

Morphometric measurements on much smaller samples of hoki *Macruronus novaezelandiae* heads found significant differences between the two spawning grounds in Cook Strait and off the west coast South Island (Livingston and Schofield 1996). Samples from non-spawning areas were different to the spawning area samples, although the Chatham Rise sample resembled the Cook Strait sample more than the west coast, and a Campbell Plateau sample was closer to the west coast than the Cook Strait sample (Livingston and Schofield 1996). Likewise morphometric measurements on much smaller samples (n = 38 per sample) of southern blue whiting *Micromesistius australis*, found useful discriminators and separated the samples into three areas: Bounty Platform, Campbell Island Rise and Pukaki Rise (Hanchet 1999).

It is recommended that morphometric measurements be made on two sets of similar size fish from the Wairarapa (BYX 2) and east Chatham Island (BYX 3) fisheries.

Phenotypic characters: meristics. The meristic characters, such as the number of vertebrae and numbers of fin rays, are determined early in the life cycle; for example the number of vertebrae is determined during the embryonic stages (Taning 1946, Fahy 1976 Lindsey 1988). Thus meristic characters may differ among adult stocks recruited from different pools of larvae. Samples of adult alfonsino from the West Indian and East Indian ridges differed in one out of eight meristic characters, the number of dorsal spines (Ivanin 1989). The spatial distance between the Indian ridge populations was not given (Ivanin 1989), but was probably much greater than that between alfonsino fisheries in BYX 2 and BYX 3. Samples from three fishing grounds in the northern Pacific Ocean to the east of Japan found no differences in three meristic characters, fin ray, lateral line scale, and vertebral counts, but differences in morphometric characters (Masuzawa *et al.* 1975).

The meristic characters have a genetic basis (Christiansen *et al.* 1988), but the differences in vertebral numbers and fin rays are modified by environmental factors, such as water temperature, so that stock differences are due largely to environmental rather than genetic variation (Taning 1946, Fahy 1972, Brander 1978, Hulme 1995). Among sample differences in meristic character require care in interpretation, as some meristic characters exhibit temporal and year class variation within fish stocks (e.g., Blouw *et al.* 1988). Not all meristic characters have been useful for stock discrimination; for example Sharp *et al.* (1978) reported differences among samples of capelin *Mallotus villosus* for morphometric but not meristic characters. Therefore prior to undertaking large scale regional comparisons a pilot study should be undertaken to determine the potential of meristic characters to discriminate among samples.

It is recommended that the number of dorsal spines, the only meristic character to differentiate alfonsino stocks in the Indian Ocean (Ivanin 1989), should be included in initial testing of morphometric characters.

10.9 Biology and distribution of cardinalfish *Epigonus telescopus*

The black cardinalfish *Epigonus telescopus* has the widest distribution of the species in this genus, and is found in the North Atlantic from Iceland to the Canary Islands, in the western Mediterranean, and in the South Atlantic, the Indian Ocean and the southwest Pacific Ocean (Abramov 1992). The species occurs between 200–1400 m but is most common between 600–900 m, overlapping the upper end of the depth range for orange roughy and the lower end for alfonsino and bluenose in New Zealand waters. Limited information on cardinalfish juveniles indicate that they are pelagic and undergo major ontogenetic changes (Mayer 1974). In the New Zealand EEZ spawning probably occurs in the early winter, based on limited observations (Field *et al.* 1997). There is no information on spatial distribution of spawning areas (Field *et al.* 1997)

10.10 The cardinalfish fishery in New Zealand

Several species of cardinalfish are widely distributed in New Zealand waters but only *E. telescopus* reaches commercial size and quantities. The fishery for *E. telescopus* developed from a small fishery in the mid 1980s to around 4000 t per annum by the mid 1990s, and has since declined (Fig. 1). Black cardinalfish were initially taken as a bycatch in the alfonsino and bluenose fisheries and in the orange roughy fisheries, but were targeted from about 1990. *E. telescopus* appears to have an almost continuous distribution off the east coast of the North Island, from the Bay of Plenty southwards, and along the northern Chatham Rise, based on the Ministry of Fisheries trawl survey database (Anderson *et al.* 1998). Most of the catch has been taken from QMA 2, but catches from QMA 1 rose during the mid 1990s (Fig. 1).

Spatial and temporal distributions of the commercial fisheries were determined from the estimated catches in the Ministry of Fisheries catch/effort database. The data cover the fishing years 1989–90 to 1997–98, and come mainly (85%) from the TCEPR forms, the catch data have not been groomed for errors. Apart from 1995–96, there is reasonable agreement between these catch values and the landings reported in Annala *et al.* 1999 (Table 5). Most (92%, from fishing years 1989–90 to 1997–98) of the catches are taken from QMA 1 and QMA 2, with some modest catches from QMA 3 in the early 1990s (Table 6).

Cardinalfish catch distribution within QMAs

The estimated catches in QMA 1 and QMA 2 were broken down by fishing statistical areas (Table 7, Figure 8). In QMA 1, most of the catch is taken in area 8, extending from the north-western Bay of Plenty to the northern tip of Great Barrier Island, on seamounts east of Great Barrier and the Mercury Islands (*see* Figure 1 in Clark & Anderson 1999). In 1997–98, moderate catches were also made in area 10, the eastern Bay of Plenty, on seamounts in the north of this statistical area.

In QMA 2, the most consistent catches were taken in area 13 (Gisborne-Mahia) and in the northwest corner of adjacent area 204, centred on the Ritchie Hills. Less consistent catches have been made in areas 11 and 12, centred on East Cape, and in area 15, on the Wairarapa Hills.

Cardinalfish as target or bycatch

For the period 1989–90 to 1997–98 about half the cardinalfish catch was recorded as targeted (annual values 34–66%, with no trend). Of the amount recorded with another target species, 79% is recorded as a bycatch of orange roughy, 10% a bycatch of alfonsino, and 7% a bycatch of hoki. In QMA 1, 54% of the cardinalfish catch is targeted, 45% a bycatch of orange roughy, and 1% a bycatch of alfonsino. In QMA 2, 57% of the cardinalfish catch is targeted, 34% a bycatch of orange roughy, 6% a bycatch of alfonsino, and 2% and 1% a bycatch of hoki and oreos respectively.

The geographic distribution of cardinalfish catches taken as a target species or as a bycatch is essentially similar, particularly in QMA 1 (Table 8). In QMA 2, on the main ground (Ritchie Hills), a higher proportion of the cardinalfish catch is taken when targeted (78%) than when taken as bycatch (62%) (Table 8).

Cardinalfish catch by season

In QMA 1, mean monthly cardinalfish catches ranged between 25 + and 95 t over the period 1989–90 to 1997–98, with no obvious pattern or trend. When the targeted catch, and the bycatch taken with orange roughy, are examined separately, and by individual year, there is also no clear seasonal pattern. Targeted fishing began in October 1994 and has continued irregularly since then. The bycatch with orange roughy began in May 1990, continued sporadically (and at less than 200 t per year) until 1995, then increased, but with no consistent monthly or seasonal pattern.

In QMA 2, mean monthly cardinalfish catches ranged between 60 and 330 t over the period 1989–90 to 1997–98, with lowest catches in winter (June to September) and highest but variable catches in spring through autumn (Figure 10). Targeted catches showed the greatest seasonal variation. The cardinalfish bycatch with orange roughy peaked between February and April, and the cardinalfish bycatch with alfonsino occurred mainly in October and November. These broad patterns generally held for individual years (Figure 9), although there was often considerable variation for particular months.

Cardinalfish catch by area by season

Because there was a general trend in QMA 2 for cardinalfish landings to be higher from spring through summer than in winter, a more detailed analysis was made of catches by area, year, and month (Figure 11) to determine how consistent this was between areas, and between years. Four areas were chosen, combining statistical fishing areas into approximations of the main QMA fishing grounds centred on hill complexes: East Cape, Ritchie, North Wairarapa, and South Wairarapa.

High catches were made in spring, summer, or autumn in all areas. Within an area, the seasonal pattern is sometimes consistent between years for a short time, but then changes, usually to no seasonal pattern. Catches on the main ground, Ritchie Hills, have been highest but have no clear seasonal pattern. Catches on the northern (East Cape) ground became significant only in 1994. Catches on the North Wairarapa ground ceased after 1993, and catches from the South Wairarapa ground diminished from 1997.

These patterns are for all cardinalfish catches, whether the species was targeted or taken as a bycatch. There are insufficient data to examine these two categories separately. From analyses of other fisheries, such as rubyfish (Paul 1997), in this region, it seems likely that the stated target species is not always the actual species targeted. Also, there is a complex relationship between the "midwater" (actually, near-bottom) trawl fisheries in QMA 2 for orange roughy, alfonsino, rubyfish, cardinalfish, and bluenose. As quotas for each of these are approached or filled, vessels move to different localities or fish different depths within the region. The spatial and temporal pattern of cardinalfish catches is thus highly dependent on the pattern of fishing for these other species, particularly orange roughy.

10.11 Stock discrimination of *Epigonus* species

There have been few stock relationship studies on *E. telescopus* and other species in the genus. Initial biological studies focused on resolving confusion associated with taxonomy of *Epigonus* (Mayer 1974, Kamysheva 1985, Abramov 1992). A preliminary electrophoretic survey of *E. denticulatus* found no variation in two protein systems (Titova 1980). Most meristic studies of *Epigonus* species have been limited to taxonomic rather than stock identifications (Abramov 1992), although morphometric characters in *E. denticulatus* show differences between samples from Hawaii and the southern Ocean (Kamysheva 1985). Parasite studies of *E. telescopus* have reported the presence of *Anisakis* in one specimen in the North Atlantic (Koie 1993), and monogeans in the Mediterranean Sea (Cave *et al.* 1994). A comparison of northern and southern hemisphere populations of *E. telescopus* showed significant differentiation in three out of ten morphometric characters, but no differentiation in six meristic characters, leading to the suggestion that the northern and southern populations are subspecies (Mayer 1974).

10.12 Potential stock models for *E. telescopus*

A comparable set of four models used for alfonsino (Figure 7) apply to potential stock relationships for *E. telescopus* in QMA 1 and QMA 2. Larvae may be entrained within the East Cape Eddy thereby restricting movement of larvae and juveniles between QMA 1 and QMA 2, alternatively larvae and/or adults may move from QMA 1 to QMA 2 via the East Cape Current (Figure 6). The very limited biological data on *E. telescopus* favour stock relationship models with extensive larval/juvenile exchange.

Cardinalfish in QMA 1 and QMA 2 are caught at, or in the close vicinity of, seamounts or submarine hill complexes from outside Great Barrier Island to the southern Wairarapa coast. Thus the distribution of cardinalfish appears to be discontinuous along this north-east and eastern coast, and dependent on seafloor topography. However the spatial distribution of cardinalfish catches is also dependent on the fishing pattern for other species, in particular orange roughy which are associated with seamounts.

The seamount-based grounds are spaced at approximately equal distances apart, from north to south. The boundary between QMA 1 and QMA 2, at Cape Runaway, separates two major submarine features, the chain of seamounts on the eastern side of the Kermadec Ridge, and the seamounts of the East Cape Ridge and canyons of the Kermadec Trench. It does not subdivide any apparent seamount or canyon-edge grounds south of 37°S, but north of this latitude it approaches the north-east trending Kermadec seamounts.

East Cape appears to be a barrier for several shallow water species and there is genetic differentiation between snapper *Pagrus auratus* populations from the Bay of Plenty and Hawke Bay (Smith *et al.* 1978). It is not known if the seafloor topography and/or currents at 500+m create a boundary for deepwater fishes, but for orange roughy (*Hoplostethus atlanticus*) no genetic differentiation was found among populations from the Bay of Plenty and east coast central North Island (Smith and Benson 1997), although there is genetic differentiation among samples north and south of the Chatham Rise (Smith *et al.* 1997).

Several seamount species have wide pelagic dispersal of larvae and juveniles, but following recruitment there is little adult movement between seamount complexes (Martin *et al.* 1992, Humphreys *et al.* 1993); such a stock model implies gene flow and that stock differences, if they develop, would be detected with characters/markers acquired/developed late in the life cycle, post settlement.

10.13 Potential stock discrimination techniques for cardinalfish

Acquired character: microchemistry.

Dried otoliths from cardinalfish could be used for microchemical analyses, to test for differences in microchemistry of the outer part of the otolith. However as discussed for alfonsino this technique is not appropriate for a bentho-pelagic species and is not recommended for cardinalfish.

Acquired character: parasites. In New Zealand waters the prevalence of the parasite Anisakis spp. has been applied as a stock discrimination tool with some evidence of success (Lester *et al.* 1988, Smith *et al.* 1999, Hurst, NIWA unpublished observations.). As for alfonsino it is recommended that a two stage parasite analysis be undertaken; first to identify appropriate parasite markers and, second to compare regional samples from the East Auckland (QMA 1) and Wairarapa (QMA 2) fisheries. If significant numbers of Anisakis are found then these should be identified to species level, with a genetic technique, as these species may have different intermediate hosts and different distributions within the New Zealand EEZ

Acquired characters: mercury levels. High levels of mercury $(0.59-2.15 \text{ mg.kg}^{-1})$ were reported in cardinalfish from the east coast (Tracey 1993), above the maximum permissible level (0.5 mg.kg^{-1}) set by the New Zealand Department of Health. Some sectors of the New Zealand fishing industry have additional data on mercury levels in cardinalfish, but have not been able to release data due to commercial sensitivity of the information. Unpublished results for a sample from the Lord Howe Rise also show high levels of mercury $(0.34-1.56 \text{ mg.kg}^{-1})$, but these estimates were from another laboratory employing a different analytical technique (Tracey, NIWA unpublished observations). Given that mercury accumulates with age and that cardinalfish are long lived (15–60 years, Tracey unpublished) then any differences in mercury levels are likely to be age related rather than stock related. This character is not recommended as a stock discrimination tool for cardinalfish. Genetics. A wide variety of genetic tools are available for estimating genetic diversity within and between regional samples of fish. Many marine species have shown little genetic differentiation over wide sea areas (Grant and Bowen 1998, Shaklee and Bentzen 1998), probably due to unrestricted gene flow, through adult movement and/or drift of pelagic eggs and larvae. Given the wide spatial distribution of *E. telescopus* in the Pacific and Atlantic Oceans, it seems unlikely that genetic differences would develop and be maintained over the relatively short spatial scale within the New Zealand EEZ. East Cape appears to be a barrier for several shallow water species with genetic differentiation of snapper populations (Smith *et al.* 1978); but no genetic differentiation was found in the deepwater orange roughy populations from the Bay of Plenty and east coast central North Island (Smith and Benson 1997). Given the lack of evidence for genetic differentiation of orange roughy stocks over the same range, genetic techniques are not recommended for stock discrimination of cardinalfish in QMA 1 and QMA 2.

Tagging. No tagging experiments have been carried out with cardinalfish. Given their depth range in New Zealand waters mechanical tagging is inappropriate for this species.

Life history traits: age at settlement or maturity. Preliminary ageing studies with cardinalfish, carried out as part of Ministry of Fisheries contract CDL9801 have found no obvious features in the otolith that might be linked with settlement or with the onset of sexual maturity (Tracey, NIWA, unpublished observations). Therefore these traits are not applicable to cardinalfish with current technologies.

Phenotypic characters: morphometrics. Morphometric methods have been applied successfully to other species within the New Zealand EEZ (Colman 1995, Livingston and Schofield 1996, Hanchet 1999). Three out of ten morphometric characters showed differences between northern and southern hemisphere populations of *E. telescopus* (Mayer 1974): head height: standard length, snout length: standard length, length of second spine of the anal fin (A11): standard length.

It is recommended that morphometric measurements be made on two sets of similar size cardinalfish from the East Auckland (QMA 1) and Wairarapa (QMA 2) fisheries.

Phenotypic characters: meristics. A comparison of northern and southern hemisphere populations of *E. telescopus* showed no significant differentiation in six meristic characters: dorsal fin, pectoral fin, gill raker, pyloric caeca, pleural ribs and epipleural ribs (Mayer 1974). Given the lack of differences over this wide scale further meristic counts over a small spatial scale within the New Zealand EEZ are not likely to be informative and therefore not recommended for cardinalfish.

11. Conclusions

1. Alfonsino have a wide distribution in the Atlantic, Indian, and Pacific Oceans where they are most abundant between 300–500 m. The species appears to be subdivided into regional stocks contained within large scale oceanic eddy systems. The larvae and juveniles are pelagic and drift considerable distances from the spawning area; adults do not appear to make extensive migrations.

2. Few stock discrimination studies have been undertaken on alfonsino. Allozyme markers distinguished up to 3 stock groups in the central Atlantic while morphometric characters have shown differences among widely separated samples within the Indian Ocean and within the North Pacific Ocean. A unit stock was described off New Caledonia based on water currents and distribution of juvenile and adult fish. DNA studies suggested that there are two sibling species present in New Caledonian waters, but only one is present in New Zealand based on one small sample from the Chatham Rise. There is no genetic differentiation among small samples of alfonsino from New Caledonia, Australia, New Zealand and the North Atlantic.

3. The major oceanic feature off the east coast of the North Island is the southward flowing East Auckland current which brings subtropical water down the east coast of the North Island. The East Auckland Current diverges near East Cape with some water flowing north and east, and the rest flowing southwards as the East Cape Current ECC, until it reaches the Chatham Rise and is deflected eastwards. The divergence at East Cape and the eastward deflection at 42°S along the Chatham Rise, create two permanent large scale eddies at East Cape and off the Wairarapa. There are few data on water currents and gyres on the eastern Chatham Rise.

4. The New Zealand alfonsino fishery is centered on two areas off the Wairarapa coast, and to the east of the Chatham Islands. Spawning has not been recorded in New Zealand waters but large and maturing fish are caught off the Hawke Bay region, and larvae probably become trapped in the Wairarapa eddy system. It is not known if alfonsino also spawn off the Chatham Islands and if the larvae become entrapped in a separate eddy east of the Chatham Islands. There are two potential stock models: one stock with extensive larval dispersal but little adult movement between the eastern Chatham Rise and Wairarapa following recruitment; or two stocks with larvae entrapped in separate gyres, and little adult movement between regions.

5. Discrimination techniques that measure characteristics that are acquired (parasites) or determined (morphometrics) late in the life cycle are most appropriate for a species with wide larval dispersal and limited adult movement. Parasite studies applying *Anisakis* should attempt to identify *Anisakis* to the species level, using a genetic test. Several other techniques appear to be unsuitable based on biology of alfonsino: tagging, otolith microchemistry, genetics, meristics and life history traits.

6. There is far less information on the biology and potential stock structure of cardinalfish. The species occurs in the Atlantic, Indian, and south west Pacific Oceans at depths of 200–1400m. The juveniles are pelagic, but adult movements are unknown. The species is widespread in the New Zealand EEZ, with many records from bycatch in the orange roughy fisheries. Two fisheries have developed: in the western Bay of Plenty (QMA 1) and on the Ritchie Hills outside Hawke Bay (QMA 2).

7. Several stock discrimination techniques appear to be inappropriate for cardinalfish: genetics, tagging, otolith microchemistry and meristics. The most appropriate techniques would be based on characters/markers developed/acquired late in the cycle such as morphometrics and parasites.

12. Publications

None.

Report presented to the Deepwater Fisheries Working Group, Greta Point, February 2000.

13. Data storage

This is a review project and no biological data have been collected. Copies of the listed references are available from NIWA.

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Fishing Year	Database	Database						
	Estimated catches (t)	Landings (t)						
1989–90	1,711	1,684	1,688					
1990–91	1,630	1,700	1,664					
1991–92	1,731	1,828	1,641					
1992–93	1,818	1,974	1,780					
1993–94	2,053	2,160	2,001					
1994–95	2,109	2,091	2,223					
1995-96	2,641	2,921	2,906					
1996–97	2,734	3,024	2,953					
1997–98	2,686	2,937	2,898					
1998-99	2,956	3,290	2,624					

Table 1: Alfonsino estimated catch (database), reported landings (database), and listed QMS landings from all areas of the New Zealand EEZ (Annala *et al.*, 1999). Values in tonnes

Note 1: Values for 1997-98 and 1998-99 from Ministry of Fisheries (unpub.)

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Table 2: Alfonsino estimated catch (t) by fishing year and QMA, including 'QMA-unknown' but excluding extra-territorial catches

		.,			Fishi	ng year	•			
QMA	89-90	90–91	91-92	92-93	93–94	94-95	95–96	96–97	97–98	98–99
1	11	20	7	4	6	4	. 10	31	9	31
2	1,491	1,405	1,391	1,581	1,561	1,456	1,442	1,405	1,296	1,407
3	170	174	182	129	184	373	406	371	279	339
4	14	29	124	52	204	215	693	852	984	763
5		<1	<1	1			<1	<1	<1	<1
6		<1			2		9	<1		<1
7	2	2	2	<1	5	1	7	20	6	6
8	13		1	<1	<1	1	<1	<1	<1	<1
9		<1		··· 1·		<1	<1	<1	· <1	<1
10			<1	<1		3		<1	<1	
Unknown	10	<1	23	51	91	55	72	55	107	409
Total	1.711	1.630	1.731	1.818	2.053	2.109	2.641	2.734	2.686	2.956

	Stat.		Fishing year								
QMA	Area	89-90	90–91	91–92	92-93	93-94	94-95	95-96	96–97	97–98	98-99
2	11		1	1	1	61	28	51	6	15	21
	12		<1	1	<1	28	180	59	22	38	79
	13	48	130	278	107	196	128	146	143	130	389
	14	583	384	144	266	403	311	551	683	663	278
	15	375	213	343	569	440	320	361	421	288	476
	16	2	<1	1	1	19	1	4	3	1	<1
	201	<1			<1	•	9	<1	3	2	<1
	203						15	1			
	204	483	677	625	637	413	464	258	124	148	160
	205					1		12	<1	<1	3
3	18 -	110	157	152	110	177	258	337	316	222	231
	19	60			2	<1	9	13	1	<1	30
	20	-	12	4	<1	1	7	3	28	25	4
· · ·	21	<1	4	5	16	5	70	51	6	10	54
	22		<1	<1							
	23				<1		30	1	20	21	20
	24					1					
	26			20							
4	49		6	<1	<1	<1	2	1	4	6	<1
	50			1			10	1	6	14	91
	51				22	4	8	409	466	222	213
	52			<1	<1	<1	<1	<1		3	
	401	4	.17	50	2	3	11	<1	52	85	18
	402		3	8	6	13	8	2	3	1	10
	403	<1			<1	<1	1	<1			1
	404	10	3	8	17	9	49	7	11	71	43
	406						1	95	115	361	166
	407				<1		<1			1	1
	410		<1				1	4	2	1	
	412			56	4	174	125	174	194	220	221

Table 3: Alfonsino estimated catch (t) in QMA 2, QMA 3, and QMA 4, by fishing year and fishing statistical area

,

			Catch (t)	Catch	n as % QMA		<u> </u>	Bycatch	(t) with r	nain targe	t species
<u>QMA</u>	Area	Target	Bycatch	Target	Bycatch	ORH	HOK	BNS	SKI	CDL	Other
2	11	11	172		5	91		4		77	
	12	271	136	3	4	46	2	3	7	70	9
	13,204	4,890	635	47	- 16	201	16	117	16	239	46
	14	3,146	1,176	29	31	5	396	437	248	1	89
	15	2,231	1,648	21	. 43	221	968	134	106	199	20
	16	11	21		1		8	2	1		10
	201	1	14			3				10	
	203		16		•	15				1	
	205	13	3				1		2		
	<u>Total</u>	<u>10,844</u>	<u>3,824</u>								
3	18	741	1,330	68	88	26	1,262	1		24	16
	19	99	15	9	1		15				
	20	1			5	1	79				2
	21	. 159	64	15	4		46				18
	22		1								1
L	23	93	1	8			1				
	26		20		1		20				
	Total	<u>1,093</u>	<u>1,514</u>								
4'	401		244		19		225				19
	.402		54		4		53				
	403		3				3				
	407		1				1				
	404	27	201	1	15		53				148
ļ	410	2	5				1				4
ļ	49	ļ	18		1		11				7
	52		3			3					
	50	101	21	4	2		21	1			
	51	1,286	59	49	4	14	42				3
	406	709	27	27	2	17	10				
	412	495	673	19	51	565	107				1
	Total	2,622	1,309								

Table 4: Distribution, by statistical fishing area, of alfonsino catches in QMA 2, QMA 3 and QMA 4, taken as a target species and as a bycatch. Total of 1989–90 to 1998–99 values

×'

Note: 1. Statistical fishing areas are listed from west to east

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Table 5: Cardinalfish estimated catch (database) and reported landings (Annala *et al.*1999) values (t) compared. Reported values for statistical areas in QMAs only; 'area-unknown' and extra-territorial values excluded

Fishing year	Database (t)	From Annala et al. (t)
1989-90	2,169	2,385
1990–91	4,137	4,311
1991–92	1,621	1,821
1992-93	1,912	2,096
1993–94	2,829	2,972
1994–95	3,306	- 3,479
1995–96	3,293	4,150
1996–97	3,884	4,045
1997–98	2,220	2,338

Table 6: Cardinalfish estimated catch (t) by fishing year and QMA

								Fis	shing year
QMA	89–90	9091	91-92	92–93	93–94	94–95	95–96	96–97	97–98
1	2	86	<1	<1	99	1,078	1,310	1,832	1,060
2	2,140	3,492	1,404	1,395	2,439	2,083	1,900	1,944	1,072
3	28	552	187	515	274	119	33	82	49
4	<1	5	15	1	3	1	4	8	13
5	0	2	1	0	3	0	8	0	0
6	0	<1	0	0	0	0	0	0	1
7	0	<1	<1	1	8	18	30	19	25
8	0	0	15	0	0	6	0	0	0
9	0	0	0	0	0	0	<1	0	0
10	0	0	0	0	3	0	6	0	<1
Total	2,169	4,137	1,621	1,912	2,829	3,306	3,293	3,884	2,220

	Stat.								Fish	ning year
QMA	Area	89-90	90–91	91–92	92-93	93-94	94–95	95-96	96-97	97-98
1	2		24	<1						
	3	1	4			•		25		
	4							1	<1	
	5							<1		
	8		1		<1	98	1,069	1,284	1,830	848
	9	<1			<1	<1		<1	<1	20
	10	. 1	57	<1	<1	· <1	. <1	1	1	190
	106					<1				
	107						9	1	1	2
2	11	1	14	<1	19	159	470	516	68	114
	12	5	28	2	27	151	144	309	64	92
	13	1,234	2,357	632	415	1,176	879	689	971	81
	14	360	359	<1	1	67		<1	1	8
	15	180	234	208	248	394	319	81	363	26
	16	7		<1		2	2	6	27	2
	201	<1					1	<1		
	202					17	<1			
	203			<1		<1	7	· 21		
	204	353	498	561	686	473	261	279	428	741
	205		1			1				<1

Table 7: Cardinalfish estimated catch (t) in QMA 1 and QMA 2 by fishing year and fishing statistical area

. s.,

			Catch (t)	Catch as % of	f QMA catch
QMA	Stat area	Target	Bycatch	Target	Bycatch
1	2		24		1
	3	25	5	1	
	4	1			
	5				
	8	2,855	2,276	96	91
	9		20		1
	10	. 85	165	- 3	7
	106				
	107	1	11		
	Total	2,967	2,501		
2	11	541	821	5	11
	12	433	389	4	5
	13+204	7,979	4,810	78	62
	14	427	394	4	5
	15	834	1,259	8	16
	16	3	43		1
	201	22	8		•
	202	17			
	203	28			
	205		2		
	Total	10,284	7,726		

Table 8: Distribution, by statistical fishing area, of cardinalfish catches in QMA 1 and QMA 2, taken as a target species and as a bycatch, for fishing years 1989–90 to 1997–98 combined

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Figure 1: Catches and quota of alfonsino, and catches of black cardinalfish, for total New Zealand, and for the management areas considered in this report.



Figure 2: Statistical fishing areas and the standard QMAs (1-10) referred to in this study. For alfonsino, Fishstocks combine QMAs as follows: BYX 1 combines QMAs 1 and 9, BYX 2 = QMA 2, BYX 3 combines QMAs 3-6. For cardinalfish, Fishstocks are equivalent to QMAs.



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Figure 3: Mean annual catches (t) of alfonsino by fishing statistical area, fishing years 1989-90 to 1998-99.



Figure 4: Monthly trends in alfonsino landings (t) from four regions within QMA 2 (BYX 2), calendar years 1990 to 1998. The regions are based on fishing statistical fishing areas, and approximate separate fishing grounds centred on one or more submarine hill complexes. East Cape comprises areas 11, 12, and 202. Ritchie comprises areas 13, 203, and 204. North Wairarapa is area 14. South Wairarapa comprises areas 15 and 205.

QMA 3 - "North" QMA 4 - Target BYX QMA 4 - Bycatch BYX 100 75 50 25 200 150 100 50 50 **JFMAMJJASOND** J F M A M J J A S O N D JFMAMJJASOND 100 75 50 25 200 150 100 50 50 JFMAMJJASOND JFMAMJJASOND JFMAMJJASOND 100 75 50 25 200 150 100 50 • JFMAMJJASOND JEMAMJJASOND JFMAMJJASOND 100 75 50 25 200 150 100 50 · 50 J F M A M J J A S O N D JFMAMJJASOND J FMAMJJA SOND 100 75 50 25 200 150 100 50 JFMAMJJASOND JFMAMJJASOND JFMAMJJASOND 100 75 50 25 200 150 100 50 50 J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D 100 75 50 25 200 150 100 50 50 . JFMAMJJASOND JFMAMJJASOND JFMAMJJASOND 100 75 50 25 200 150 100 50 JFMAMJJASOND JEMAMJJASOND JFMAMJJASOND 100 75 50 25 200 150 100 50 FMAMJJASOND J JFMAMJJASOND J F M A M J J A S O N D

Figure 5: Monthly trends in alfonsino landings (t) from the northern part of QMA 3, and from QMA 4 (in combination being the main fisheries in BYX 3). QMA 3 "North" comprises areas 18-24 and 26, but with 81% of the total landings from area 18. QMA 4 comprises areas 49-52 and 401-412.



Figure 6. Major current systems which may influence the distribution of cardinalfish *Epigonus telescopus* and alfonsino *Beryx splendens*.



Figure 7: Four potential stock models for *Beryx splendens* in BYX 2 and BYX 3. The solid arrows represent adult movements and the dashed arrows larval and juvenile movement; the irregular dark shading represents the known distribution of adults.



Figure 8: Mean annual catches (t) of cardinalfish by fishing statistical area, fishing years 1989-90 to 1998-99.



Figure 9: Monthly catches (t) of cardinalfish, calendar years 1990 to 1998, QMA 1 and QMA 2 combined.



Figure 10: Mean monthly catches (t) of cardinalfish, calendar years 1990 to 1998, QMA 1 and QMA 2 separately, taken in target fisheries and as a bycatch of orange roughy and alfonsino.



Figure 11: Monthly trends in cardinalfish landings (t) from four regions within QMA 2, calendar years 1990 to 1998. The regions are based on fishing statistical fishing areas, and approximate separate fishing grounds centred on one or more submarine hill complexes. East Cape comprises areas 11, 12, and 202. Ritchie comprises areas 13, 203, and 204. North Wairarapa is area 14. South Wairarapa comprises areas 15 and 205.

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