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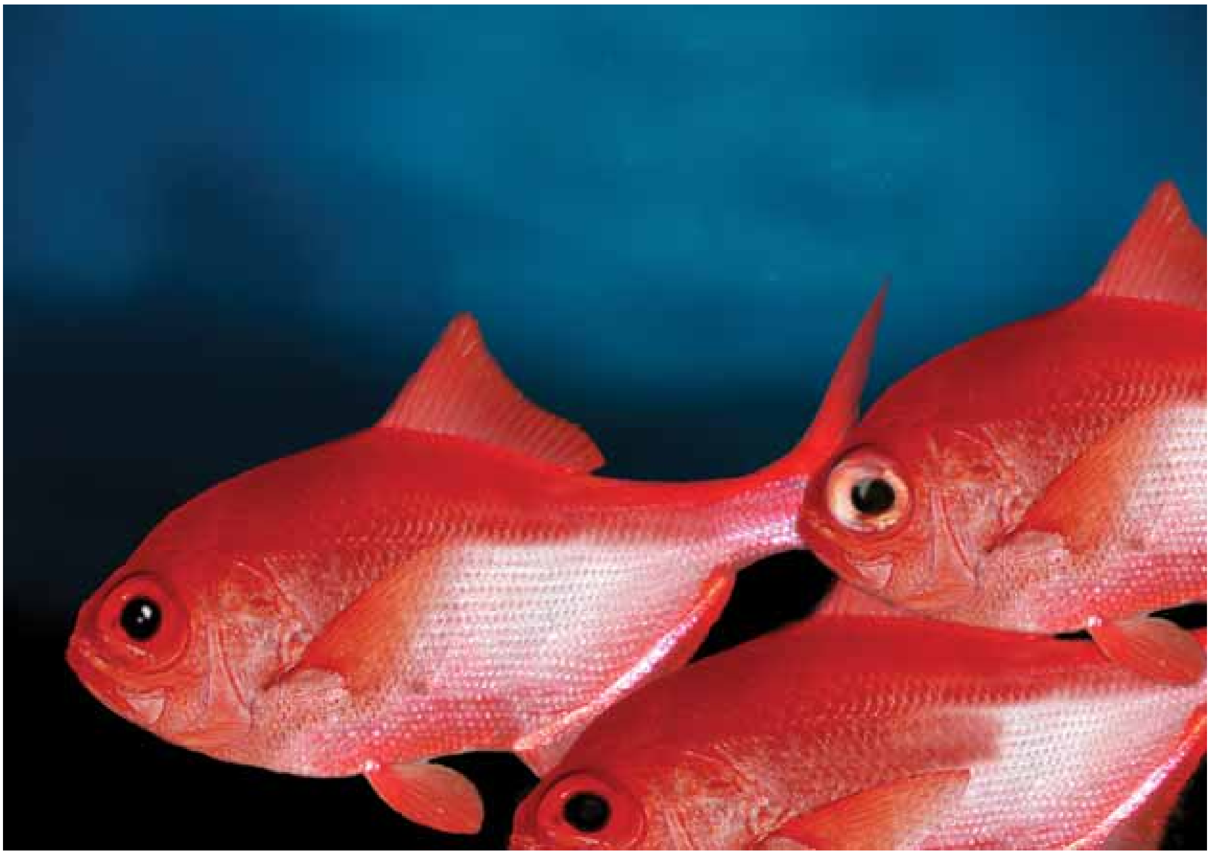

Cover: Photo collage by Emanuela D'Antoni (FAO).
Note: At the sea depths where alfonsino are usually found, light of red wavelengths has been mostly attenuated and so alfonsino appear black when seen in their natural habitat.

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GLOBAL REVIEW OF ALFONSINO (*Beryx* spp.), THEIR FISHERIES, BIOLOGY AND MANAGEMENT

By
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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS DOCUMENT

The Fisheries and Aquaculture Department of the Food and Agriculture Organization (FAO) has been working on regional and global issues arising from the exploitation and management of deep-sea fisheries and the related conservation concerns since these fisheries began to expand. This publication encompasses the results of an international workshop on the assessment and management of alfonsino fisheries, held at FAO headquarters in Rome, Italy, on 10–12 January 2012. This international workshop brought together 12 fisheries experts from around the world (Chile, Japan, New Zealand, Portugal, the Republic of Korea, the Russian Federation, and the Ukraine) who work on management aspects of this species to synthesize their experience and information available on management of this genus. It was apparent that much useful information existed not only in formal reports and peer-reviewed papers but also in the grey literature and personal files and experiences. This report is an endeavour to document this information.

FAO. 2016.
*Global review of alfonsino (*Beryx *spp.), their fisheries, biology and management*, by Ross Shotton. FAO Fisheries and Aquaculture Circular No. 1084. Rome, Italy.

ABSTRACT

Alfonsino (*Beryx splendens* and *B. decadactylus*) are benthopelagic species found in waters of 25-1 300 m depth, commonly in aggregations over rocky bottoms. They are distributed along the European and African coasts, around oceanic islands of the Atlantic Ocean and in the Indian Ocean. Alfonsino is also found in the northern Tasman Sea, along the Pacific coast of the Japanese Archipelago, the Southern Emperor and Northern Hawaiian ridges and westwards towards Chile.

Alfonsino are fished around the Azores, in the Southeast Atlantic, and in the Southwest Indian Ocean. There is also a small fishery for them in coastal waters of Australia and New Zealand and a Japanese fishery on the Southern Emperor seamounts and in the southern area of the Northern Hawaiian Ridge. A major fishery, now closed, existed around the Juan Fernández Archipelago in the Eastern Pacific.

Alfonsino have a schooling behaviour that is evident throughout their life: they form aggregations during the day and scatter above the bottom at night. Tagging studies indicate limited migration, possibly with regional differences. Feeding occurs mainly in the morning and evening twilight hours, and there is an increase in feeding with the intensity of tidal flow. Alfonsino feed for longer periods when there is less food available.

Alfonsino reach a fork length of 15–20 cm in their first year, about 25 cm after 3 years and 40 cm after 10 years. In the Canary Islands, the oldest fish examined were 9 years old (38 cm); 11 years (40 cm) in the Azores; and 12 years in Madeira (41 cm). On the South West Indian Ridge, the maximum length of alfonsino was 60 cm fork length and with a maximum weight 6 260 g. Growth-related parameter values and length–weight relations determined for several oceanic areas are reviewed.

Alfonsino begin to mature in their second year, and most are mature by their fifth or sixth year; 50 percent maturity occurs at lengths from 23 to 44 cm. Alfonsino spawn during the spring and summer with several spawning episodes. Alfonsino larvae are presumed to develop from epipelagic eggs. Differences in the sex ratio of alfonsino occur in different areas.

Hypotheses of alfonsino population structures are reviewed. Two genetic clades have been identified that appear to coexist, and single stocks are known to span broad areas. DNA studies of *decadactylus* indicate that there are genetic differences between stocks in the Azores and the western North Atlantic, but not with the eastern North Atlantic. In the Southern Indian Ocean, some studies have been done but the conclusions are constrained by the nature of the sample size and their geographical distribution. A review of the implications of the genetic studies for population structure is given. Population biology parameters and estimates of stock sizes in different regions are reviewed. Ecosystem effects do not seem to be significant as bycatch, as recorded, is minor in alfonsino fisheries. The role of alfonsino as a possible prey species remains unknown. Little has been documented about the impact of trawl fishing for alfonsino on fragile benthic fauna.

Because the size and value of the harvests of alfonsino in any one fishery are usually too small to justify expensive management measures and fisheries research for alfonsino, their management often does not attract adequate attention. Effective management of high seas alfonsino fisheries will depend on the ability of regional fisheries management organizations to manage fishing effort targeting alfonsino stocks and ensure compliance with conservation regulations.

Given the importance of fish processing at sea, studies are provided to determine appropriate product conversion factors from which round weights can be estimated from production records.

CONTENTS

ACKNOWLEDGEMENTS

The participants of the workshop on management and assessment of alfonsino held at FAO headquarters in Rome, January 2012, are gratefully acknowledged for their contributions to this review, first, through their attendance at the workshop, and second, for providing additional information to the main author as the report evolved. Special thanks are due to Vladimir Vinnichenko, Knipovich Polar Research Institute of Marine Fisheries and Oceanography, Murmansk, the Russian Federation, for clarifying the information on alfonsino fisheries in the Atlantic Ocean and for supporting the revision of the text for this area. The contributions of Mário Rui Pinho, Department of Oceanography and Fisheries, University of the Azores, Horta, Portugal, and Merete Tandstad, FAO Fisheries and Aquaculture Department, to the technical review and editing of this document are also gratefully acknowledged. The author is grateful to Jessica Fuller and Monica Murchio for their assistance in the final editing of this document.

ABBREVIATIONS AND ACRONYMS

AFMA	Australian Fisheries Management Authority
ANCOVA	analysis of covariance
ASPIC A	Stock Production Model Incorporating Covariates
B_{MSY}	biomass at maximum sustainable yield
BYX	*Beryx* spp. (FAO species code)
CAY	constant annual yield
COFI	Committee on Fisheries
CPUE	catch per unit effort
CV	coefficient of variation
DALP	direct amplification of length polymorphism
DNA	deoxyribonucleic acid
ECDTS	East Coast Deepwater Trawl Sector
EEZ	exclusive economic zone
ENSO	El Niño Southern Oscillation
EV	exploration vessel
FV	fishing vessel
FAO	Food and Agriculture Organization of the United Nations FL fork length
F_{MSY}	fishing mortality at maximum sustainable yield
GPS	Global Positioning System
GSI	gonadosomatic index
ICES	International Council for the Exploration of the Sea
IFOP-Chile	Instituto de Fomento Pesquero
K	von Bertalanffy growth coefficient
L	fish length
$L_{m50\%}$	length at which 50 percent of fish are mature M mortality (natural)
MCY	maximum constant yield
M&F	male and female
MEY	maximum economic yield
MSY	maximum sustainable yield
mtDNA	mitochondrial DNA
N	North
NAFO	Northwest Atlantic Fisheries Organization
NEAFC	North East Atlantic Fisheries Commission
OASIS	Oceanic Seamounts: an Integrated Study PCR polymerase chain reaction
q	catchability coefficient
QMA	Quota Management Area
RBC	recommended biological catch
RFLP	restriction fragment length polymorphism
RFMO	regional fisheries management organization
RNA	ribonucleic acid
RV	research vessel
SAI	significant adverse impact
SEAFO	South East Atlantic Fisheries Organisation
SE–NHR	Southern Emperor Seamounts and Northern Hawaiian Ridge
SESSF	Southern and Eastern Scalefish and Shark Fishery
SIODFA	Southern Indian Ocean Deepsea Fishers Association SL standard length
SPRFMO	South Pacific Regional Fisheries Management Organisation
SSCP	single strand conformation polymorphism
SSFZ	Southern Subtropical Frontal Zone

SWIR	Southwest Indian Ridge
t_0	age at length zero
TAC	total allowable catch
TACC	total allowable commercial catch
USSR	Union of the Soviet Socialist Republics
VME	vulnerable marine ecosystem
W	fish weight
Y/R	yield per recruit
Z	mortality (instantaneous)
3D	three-dimensional

1. INTRODUCTION

Alfonsino fisheries are found in almost all seas where moderately deep waters exist, in both tropical and temperate latitudes – the Northeast Pacific seems to be the notable exception. Alfonsino is a popular food species, and its fisheries provide employment and valuable commercial activity. As with almost all fisheries, if its bounty is taken for granted, harvests become unsustainable and society loses a valuable renewable resource. This publication was written because fisheries for alfonsino make a valuable socio-economic contribution on a global basis but information on this species is widely scattered. A major objective of this document was to collate the wide range of information that exists on all aspects of alfonsino and its fisheries.

In several ways the splendid alfonsino (*Beryx splendens*), hereinafter "alfonsino", typifies the problems associated with many high seas deepwater fish species. The productivity of the species is moderate and its biological characteristics makes it susceptible to overfishing in the absence of effective management measures. In many areas, the size and value of the harvests of alfonsino are usually too small to justify expensive management measures. Currently, only three countries have specific management research programmes for this species: Portugal (in the Azores), Japan and New Zealand. To the extent that fisheries occur in Chile and Australia, catches are monitored. Further, because catches in any one area are frequently small, catch amounts are often aggregated with other species in catch reports, which further complicates management of this species.

Within this context, a workshop on the assessment and management of alfonsino fisheries was held in Rome, Italy, from 10 to 12 January 2012.[1] The workshop endeavoured to achieve the following:

- Describe the main taxonomic aspects and distribution (see Chapter 2)
- Review the various national and regional fisheries for this species (see Chapter 3)
- Provide an introduction to behaviour, movement and development (see Chapter 4)
- Provide a review of age, size and growth rates (see Chapter 5)
- Provide a review of maturity, sex ratios and spawning (see Chapter 6)
- Identify knowledge of stock/population structure (see Chapter 7)
- Provide a review of natural mortality (see Chapters 8)
- Provide a review of ecosystem implications of fisheries (see Chapter 9)
- Document management practices (see Chapter 10)
- Provide a review of conversion factors (see Chapter 11)

In addition to the information presented at the workshop, literature relating to alfonsino biology and its fisheries and management has been reviewed and included in this report. Many of the references cited were difficult to access, as a considerable amount of information on alfonsino and its management resides in the grey and black literature and much remains in personal and company files. However, much work also exists in peer-reviewed journals.

2. ALFONSINO

2.1 Taxonomy

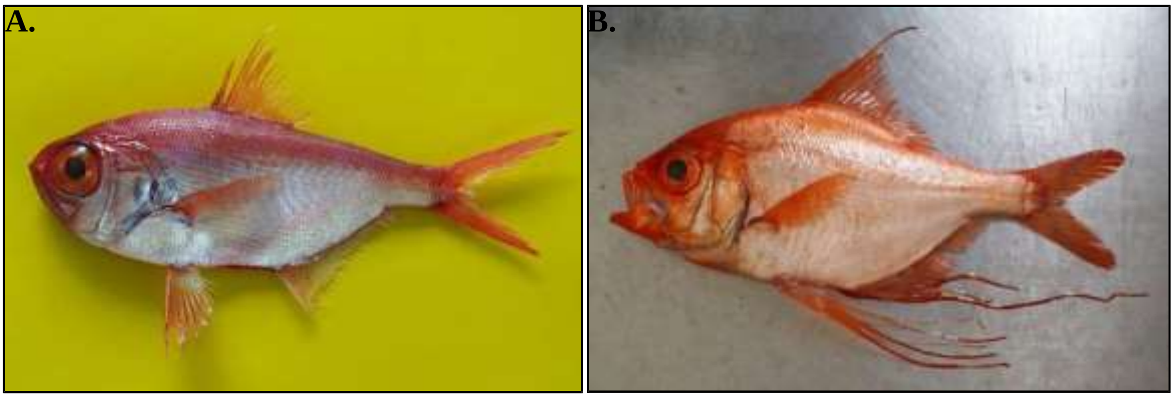
The Berycidae (alfonsinos) family are a member of the order Beryciformes. The family includes ten species in two genera, *Beryx* and *Centroberyx*. Generally, the common name "alfonsino" is used to refer to splendid alfonsino, *Beryx splendens* (Lowe 1934;[2] Plate 1.A). There is also another species of

[1] See Appendix 1 for the agenda of this meeting, and Appendix 2 for a list of participants.

[2] Alfonsino was first described in 1834 by the Reverend R.T. Lowe, vicar for Lea in the United Kingdom of Great Britain and Northern Ireland. He may have been on some form of biological expedition to Madeira, Portugal, because this species was first formally described from there. He also produced several publications on the fauna and flora of these islands. The alfonsinos are named after Alfonso, either a local fisher or one of the various European royals of this name – from the Old German "ready for battle".

alfonsino that, in some regions, is important in the fisheries and is variously referred to as longfinned beryx, red bream or broad alfonsino, *B. decadactylus* (Plate 1.B). *Beryx splendens* can be distinguished from *B. decadactylus* in having a shallower body and fewer dorsal-fin soft rays (13–15 dorsal–fin soft rays for *B. splendens* versus 16–20 for *B. decadactylus*). *B. splendens* is distinguished from other redfishes and the closely related roughies (*Trachichthyidae*) by having only four dorsal-fin spines (Last, Yearsley and Ruello, 2001). Indeed, at least in the region of the Azores, both species of *Beryx* can be found in the catch. Busakhin (1982) provides an account on the systematics and distribution of the Berycidae in the world's oceans. The expansion of distant-water fishing by the then Soviet Union in the 1950s–1970s provided the impetus for much work by that State on the biology and taxonomy of this family, not least *B. splendens*, which forms the basis for understanding the ecology of these fishes today.

PLATE 1
A. Splendid alfonsino (*Beryx splendens*). B. Red bream (*Beryx decadactylus*).



Courtesy of O. Alvheim.

Anon (2009) reports alfonsino to have 4 dorsal spines, 13–16 soft dorsal rays, 4 anal spines, and 26-30 soft anal rays. The first infraorbital bone has a spine projecting laterally on its anterior end and the lateral line extends to caudal fin. In young fishes, the second dorsal ray is elongated.

Ward *et al.* (2001) note that alfonsino can be distinguished from *B. decadactylus* by protein fingerprinting. With this method a major band can be seen at P1.6 (rather than P1.3) and they both may be distinguished from other redfishes by the presence of a minor band at P2.5 and a major band just below P5 (a figure of the protein band separation can be found in Ward *et al.*, 2001).

Ivanin and Rebyk (2012) report that for alfonsino:

- standard length (SL) = 0.91 cm fork length (FL);
- SL = 0.77 cm total length;
- FL = 0.84 cm total length.

Kozlov (2014) reports total length as 1.18 cm fork length.

2.1 What sort of a fish is alfonsino?

Alfonsino is a benthopelagic species found over a wide range of depths, 25-1 300 m, in aggregations over rocky bottoms. It normally lives close to, or within 5–20 m, of the bottom of the upper slope between 200 and 1 240 m in depth but typically around seamounts and deepwater reefs in waters 200-800 m deep. It may be found above seamounts in schools about 10–50 m in vertical extent (Maul, 1981). The life cycle of alfonsino passes through the epipelagial, mesopelagial and upper bathypelagial oceanic regions.

It is reported to grow to 70 cm length[3] but is commonly reported in catches with lengths up to 40 cm in

[3] Unless otherwise noted, "length" in this publication refers to "fork length".

length. It has a maximum weight of 4 kg and matures at about 30 cm in length. The main market for this species is Japan and the Far East, although Europe and United States of America also provide good markets for alfonsino (Japp and Wilkinson, 2007).

Beryx decadactylus is also benthopelagic and found on rocky bottoms. It normally lives near the bottom of the upper slope between 200 and 900 m depth (extremes of 25–1 240 m) and is most commonly found between 400 and 600 m (Maul, 1981, 1986).

On the Seine and Sedlo seamounts in the Northeast Atlantic investigations using longlines from the seamount summits to 2 000 m depth conducted as part of the project “Oceanic Seamounts: an Integrated Study” (OASIS) found that alfonsino and other mesopelagic feeders dominated the upper-slope assemblages (< 800 m) (Menezes *et al.*, 2009).

2.2 Global distribution of alfonsino

Alfonsino (*B. splendens*) is widely distributed and can be found in the deep-waters of the Atlantic, Indian and Pacific oceans. In the Atlantic Ocean, alfonsino are found in the continental slope regions of the West Atlantic from Nova Scotia to Brazil, the Corner Rise seamounts and around other oceanic islands in the South Atlantic (Alekseev *et al*., 1986). In the East Atlantic it is distributed along the European and African coasts from Iceland and Norway to South Africa and also around the islands of the Azores, Madeira, Canaries, Saint Helena and Tristan da Cunha. It can also be found on ocean ridges and seamounts, including the Sierra Leone Elevation and Walvis Ridge. It is also present in the Mediterranean Sea (Nielsen 1973; Maul 1981, 1986, 1990; Busakhin 1982; Orsi Relini *et al*., 1995).

In the Indian Ocean, alfonsino is found across a broad region that includes the Arabian Sea in the north, and tropical and middle latitudes in the south. As such, it can be found along the east coast of Africa, near the Mascarene and Seychelles islands, over the Saya de Malha Bank, along the Mozambique and Madagascar ridges and near the Australian coast including the West Australian Basin and Great Australian Bight. Relatively large concentrations of alfonsino are localized over the ridges of the middle part of Indian Ocean, i.e. the Southwest Indian Ridge (SWIR), Mid-Indian Ridge and Ninety East Ridge. On the SWIR the large catches of alfonsino occur at depths of 200-800 m (Ivanin and Rebyk, 2012).

In the Pacific Ocean alfonsino is found in the northern Tasman Sea (especially on the seafloor ridges of that area), the Southern Emperor and Northern Hawaiian Ridges, and the Juan Fernández Ridge and archipelago that extend westwards from Chile. Alfonsino in the Northwest Pacific are distributed along the Pacific coast of the Japanese archipelago and the islands of Izu, Ogasawara (Bonin) and Nansei, south of about 37°N (Honda *et al*., 2004). In the Southern Emperor/Northern Hawaiian Ridge, alfonsino are distributed over seamounts located between the Hancock seamounts (about 30°N) and the Koko seamounts (about 36°N), at depths of 300-1010 m (Yanagimoto and Nishimura, 2007). Honda (2012) reports that on the Southern Emperor Seamount and Northern Hawaiian Ridge alfonsino inhabit the flat summits and slope areas. Pakhorukov (2005) noted that in the Milwaukee seamounts region alfonsino shoals were distributed at depths of 520 m. Alfonsino are also found in the Southwest Pacific to the south of Japan.

Beryx decadactylus has a worldwide distribution and sometimes taken in the same fishery as *B. splendens*. This species can be found throughout the Atlantic, in the western Mediterranean as well as in the Indian and Pacific Oceans, in tropical, subtropical and some temperate areas (Maul, 1981, 1986, 1990; Busakhin, 1982). In the Northeast Atlantic, *B. decadactylus* is common in Spanish and Portuguese waters, including the Azores, Madeira and Canary Islands (Albuquerque, 1956; Maul, 1981, 1986, 1990).

2.2 Behaviour, movement and development of alfonsino

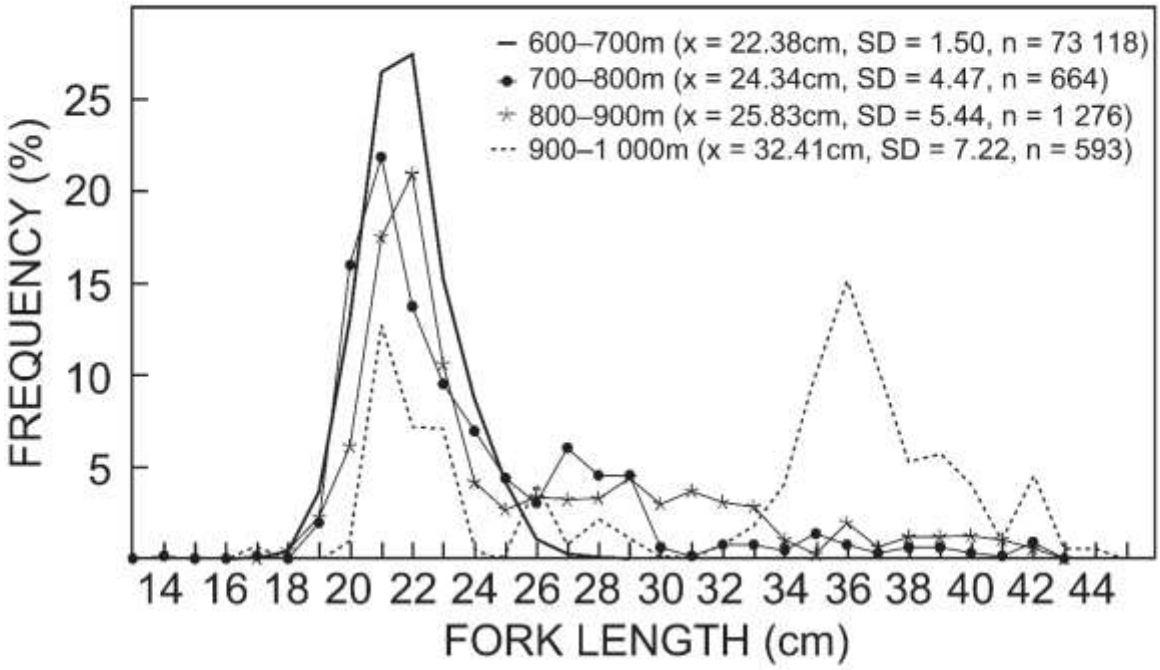
2.4.1 Introduction

The behaviour and movement of alfonsino is closely related to its feeding and reproductive activities and considerable information has been acquired on the movement of alfonsino from the fisheries and in studies of the population/stock structure of this species (see Section 6). More detailed information on feeding by alfonsino is given in Section 9.3 “Feeding and the role of the species in the ecosystem”. Of course, alfonsino movement when feeding will be determined by the movement of its preferred prey and usually only general information is available in this regard. Information on ontogenetic movement of alfonsino is given in Section 5 “Maturity” and especially Section 5.5 on “Spawning” and Section 5.6 on “Post-spawning development”.

2.4.2 Development and movement

In the Southern Indian Ocean, Santamaría *et al.* (2006) found the length of alfonsino to vary between 14 and 44 cm. In the depth range of 600–700 m there was a unimodal distribution ranging between 18 and 28 cm (Figure 1). The length distribution of fish in the 700–800 m depth range was similar to that of fish in the 800–900 m depth range. In the deepest range samples, 900–1 000 m, alfonsino had a bimodal length distribution: one at 17–29 cm and the other at 32–44 cm. Mean fish length increased with depth, from 22.38 cm in the 600–700 m range, to 32.41 cm in the 900–1 000 m depth range. In the catches, 68 percent of alfonsino were one to three years old and 32 percent were 4 to 14 years old. No fish younger than five years old were found deeper than 700 m, and the oldest fish (eight to 14 years old) were mainly found deeper than 900 m (Figure 2). The age composition was similar in fish caught between 700 and 900 m deep, which Santamaría *et al.* (2006) concluded suggests that fish migrate to deeper waters as they age, as supported by other studies.

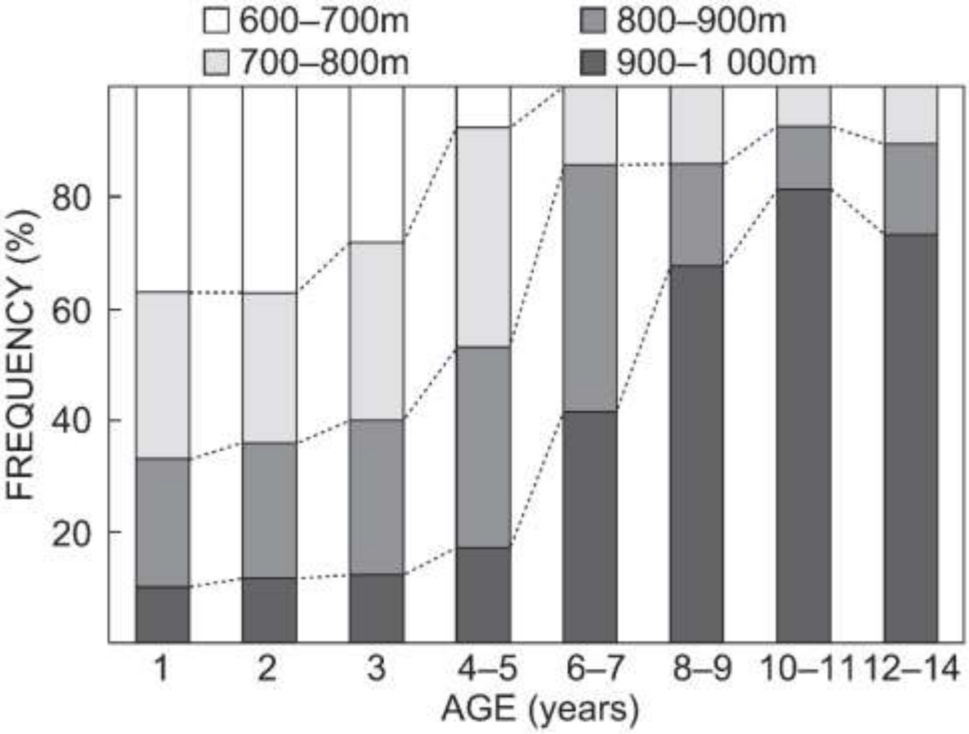
FIGURE 1
Length composition of *B. splendens* by depth strata of catches from Walters Shoals and Sapmer seamount



Source: Santamaría *et al.* (2006)

Seki and Tagami (1986) and Yanagimoto (2004) suggest that there is ontogenetic descent of alfonsino from the flat summits to slope areas in the Southern Emperor and Northern Hawaiian Ridge seamount areas as alfonsino increase in size and move into deeper waters. Lehodey *et al*. (1994, 1997) supported the hypothesis of Alekseev *et al*. (1986) that immature stages of alfonsino develop in “vegetative” zones before recruiting to the population of mature adults in deeper waters and had similar conclusion to the Japanese workers. In New Caledonian waters they differentiated areas where immature fish lived to those where they recruited on becoming mature. These latter areas had depths between 500 and 900 m over five seamounts ranging in depths from 500 to 750 m.

FIGURE 2
Age distribution of *B. splendens* by depth from Walters Shoals and Sapmer seamount



Source: Santamaría *et al.* (2006)

2.4.3 Schooling Behaviour

Widespread studies all show well developed schooling behaviour that is evident throughout their life. During the day the fish are in dense aggregations on the bottom, whereas at night they scatter above the bottom (Alekseev *et al.*, 1986; Galaktionov, 1984). At midday alfonsino aggregations occur so close to the bottom that they may not be detected by an echo sounder. Figure 13 shows an example of alfonsino aggregation during the day in the southern Indian Ocean. School formation in the evening hours was somewhat slower with a duration of 1–4 hours: the fish ascended to 100–150 m above the bottom and dispersed into small schools or as individuals. In the morning the formation of schools was slower: aggregations remained in the pelagic zone for 1-2.5 hours then descended to the bottom at 2 m per minute, breaking into small aggregations on the bottom. Galaktionov (1984) reported the time of the start of the formation of schools as between 17.00 and 18.00 hours and within 25–30 minutes the vertical extent of schools increased from 10–30 m to 50–70 m and increased horizontally from 40–50 m to 180–200 m.

Other workers found school formation by spawners was prolonged beginning in the second part of the day but only by 19.00 hours did the fish form discernible aggregations that moved off the bottom. School formation was complete by 19.00–20.00 hours and school thickness could be 130 m. From 04.30-06.00 hours large schools indicated by transects of one mile in length had been recorded. Schools were not observed in the pelagic zone during spawning. The schools were observed off the bottom for 2-3 hours during dawn and dusk with a school thicknesses of 60–80 m and transect lengths of 500–600 m.

2.4.4 Vertical Movement

Galaktionov (1984) notes that alfonsino undertake daily vertical migrations. Vertical movement does not exceed 2–3 m per minute. Vertical movement during night was over 50–100 m and did not exceed 4-5 m per minute. At dawn, descent was fairly rapid reaching 5 m per minute. Vertical distance travelled by juveniles has been observed at 350–400 m through waters of 8.3 to 15.0 °C. Alfonsino easily traversed the oxygen minimum layer (88.2-107 percent saturation). Other reports put vertical migrations over 350-400 m at 2–3 m per minute for juveniles; 150–200 m at 1–2 m per minute for adults through water temperatures of 7.6-15.5 °C and 53.4-107 percent oxygen saturation. Alfonsino aggregations were also recorded in waters of temperature ranging from 7.5 to 17^{o} C (Pshenichny *et al*., 1986; Vinnichenko, 1986, 1996a, 1997a) and 7.1°-16.6° (Pers. comm. V. Paramonov, YugNIRO, Ukraine), but without reference to depth.

Alekseev *et al.* (1986) note that foraging alfonsino reached 150–250 m off bottom. Lehodey and Grandperrin (1996b) also note that alfonsino migrate vertically, rising at night from depths where light and temperature are relatively stable year-round into shallower waters where seasonal temperature fluctuations would occur. Horn and Massey (1989) observed that on some days, alfonsino showed a reverse pattern to that of occurring near the bottom during the day and ascending to the midwater during the night. They concluded that no single consistent vertical migration behaviour could be attributed to alfonsino in New Zealand waters.

The main factor apparently determining the vertical migrations of alfonsino was the vertical movement of its prey, which were closely related to variations in ambient sunlight and moonlight and oceanographic conditions in the area of seamounts. Investigations revealed several types of alfonsino vertical migrations that served as a basis for short-term forecasting of fisheries conditions (Vinnichenko, 1986, 1997a, 1998; Anon., 1993). Acoustic surveys of alfonsino aggregations in the North Atlantic showed that alfonsino occurred over a wide depth range, from 150 to 950 m, and were found both near the bottom and in the pelagic zone. Further, the aggregations can appear and disappear for varying time periods. However, absence of alfonsino echoes did not mean their absence on a seamount as a greater or lesser part of the aggregation may be permanently near the seafloor in depressions and other bottom micro-relief where they cannot be detected acoustically.

Menezes *et al*. (2006) note that in the region of the Azores archipelago the demersal/deep water fish community is structured by depth, usually defined by three main assemblages between 50 and 1 200 m: the shelf, slope and deep strata. Of these, alfonsino and *B. decadactylus* are more associated with the slope/deep assemblages.

Uchida and Tagami (1984) and Parin and Pakhorukov (2003) found that in the Southern Emperor and Hawaiian Ridge seamount areas benthopelagic aggregations of alfonsino had a diel migration pattern with fish often 2–5 m above the bottom during the day and ascending to feed in the midwater during the night.

2.4.5 Horizontal Movement

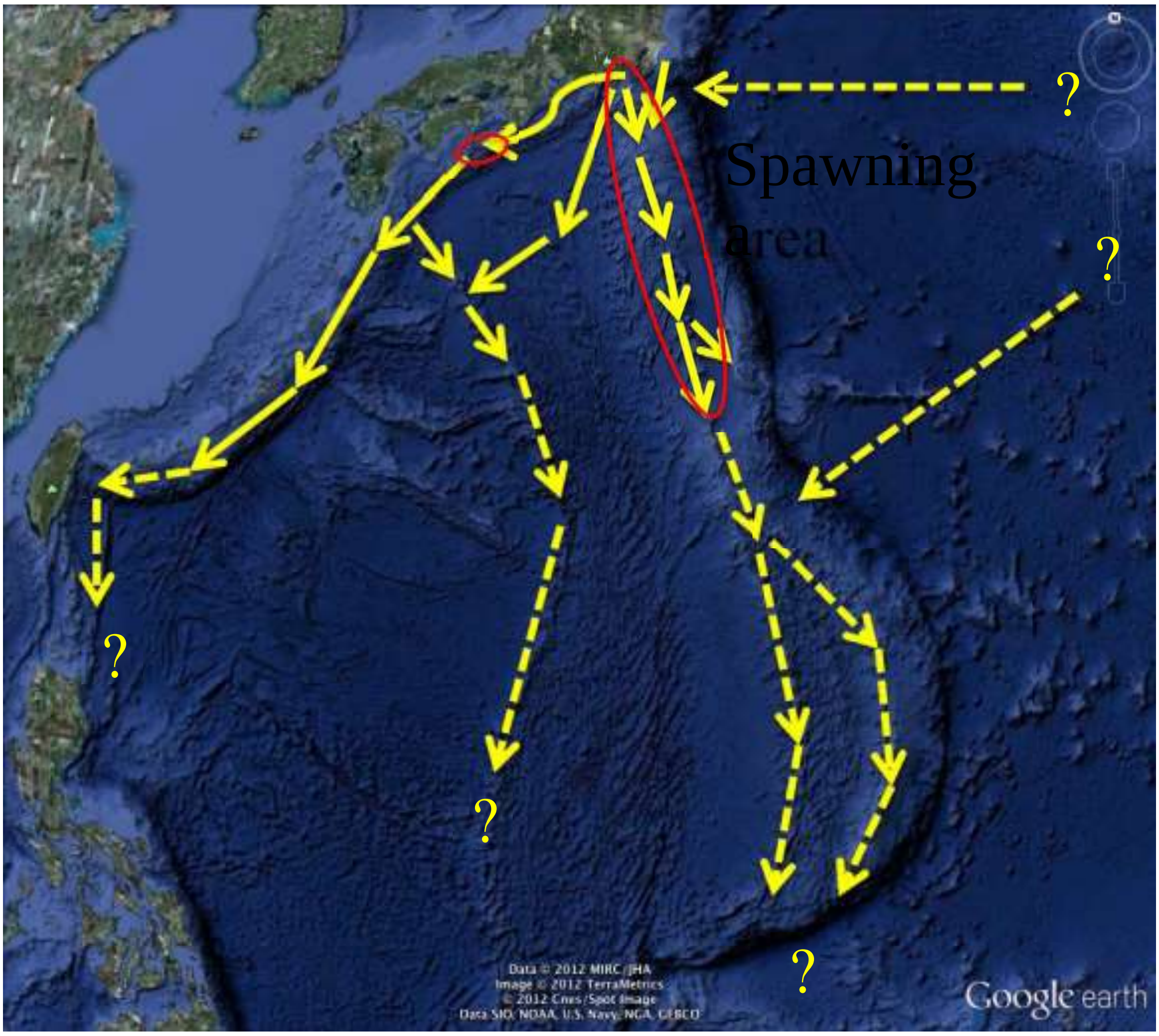
Alekseev *et al.* (1986) conclude that alfonsino are capable of fast movements around seamounts within their distribution range and undergo lengthy migrations, more than 1 000 nm in the northeast Atlantic and 700 nm in the southeast. They note that "spatial differentiation of the population is of an ontogenetic character. Galaktionov (1984) and Vinnichenko (1996a) were of the view that horizontal migration of alfonsino appeared limited by the area of seamounts and did not exceed a few miles.

Alekseev *et al*. (1986) note that only mature alfonsino were found above Corner Rise, immature alfonsino around the Azores during February-June, and exclusively immature fish off West Africa. Further south on Vavilov Ridge, only mature alfonsino were found while on the Ridge of Whales immature and maturing fish were found (predominantly immature fish in the southern part of this ridge). Alekseev *et al.* (1986) concludes that there are geographically distinct areas for functionally different stages of the alfonsino's life cycle. In the North Atlantic a population occurs in the subtropical eddy; two populations occur in the south Atlantic: one in the Southern Tropical Cyclonic gyre (Vavilov Ridge/ Angolan current) and a second corresponding with the middle position of the main flow of the Benguela current.

Ikegami (2004) undertook tagging research off Chiba, Japan that showed that tagged fish could be captured in the same place 9–12 years later: other fish were found to have moved 120 km over 9 years and 1 300 km over 5 years. He released 14 991 alfonsino in six batches from 1984 to 2002 and recaptured 610 fish, a recapture rate of 4.1 percent. The body size of the tagged fish ranged from 15-47 cm.

Average size of the released fish was 20–30 cm. In the Kochi Prefecture, alfonsino were recaptured in the same place up to 11 years later; 540 km away after 10 years and 660 km after 5 years. Nakajima (1998) who undertook tagging research in the same prefecture released 1 900 fish in 1985 with 86 recaptures, a recovery rate of 4.5 percent. The size of fish released was 16–24 cm with an average length of 19 cm. Plate 2 summarizes these results.

Plate 2
Possible Direction of Movement of Tagged Fish, Japan



Source: Hondo (2012)

B. decadactylus shows diel migration and often occurs 2–5 m above the bottom during the day and ascends to feed in the midwater at night (Uchida and Tagami, 1984; Parin and Pakhorukov, 2003). The life cycle of alfonsino passes through the epipelagial, mesopelagial and upper bathypelagial regions.

2.5 Alfonsino on the plate

Alfonsino has a short moderately-deep pale pinkish fillet that tapers sharply and is slightly convex above. There is no central red muscle band. The epaxial muscle line is parallel and the hypaxial line is converging. The horizontal septum is along the middle of the fillet. The epaxial line is much closer to the hypaxial line than to the dorsal margin. The integument is pink above and pinkish to white below. The peritoneum is black. When fillets are with skin, one can see that the scale pockets are moderate and indistinct. Alfonsino are considered good eating: their flesh is white when cooked, moist and reasonably soft (Last, Yearsley and Ruello, 2001).

3. ALFONSINO FISHERIES, THEIR EXPLORATION AND DEVELOPMENT

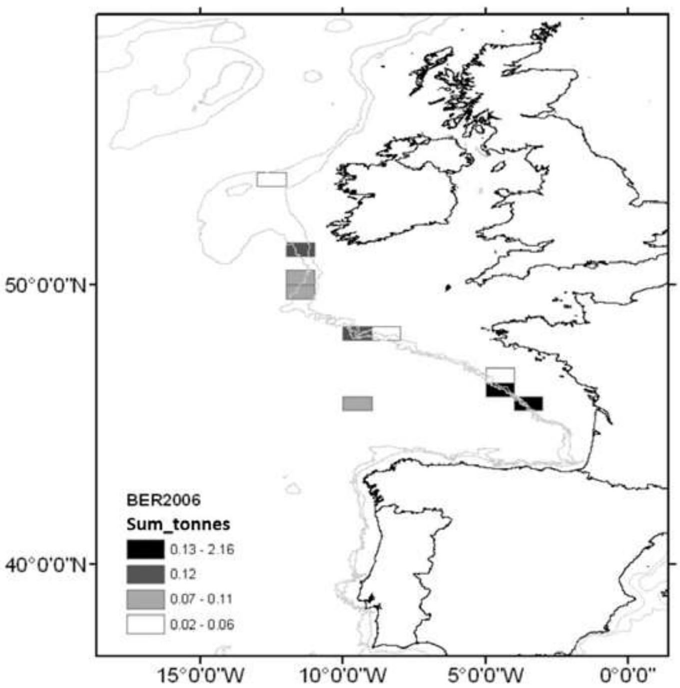
3.1 The North Atlantic Ocean

3.1.1 European Continental Slope

The International Council for the Exploration of the Sea (ICES) notes that in European continental waters *Beryx splendens* and *B. decadactylus* are generally considered as bycatch species in the demersal trawl and longline mixed fisheries targeting deep-water species (ICES, 2010a). For most of the fisheries, catches of these two species are reported as *Beryx* spp. The landings of *Beryx* spp. represent 5-10 percent of the total deep-water species caught in the region. French, Portuguese and Spanish trawlers and longliners are the main vessels involved in this fishery.

Areas that provide important catches are the Celtic Sea, Bay of Biscay and the West Iberian Sea (Figure 3). In all these areas, the catches have a high interannual variability. It is not known whether the annual variations in landings are a result of changes in fish abundance, changes in the targeting of the fisheries or result from more accurate reporting or monitoring of the landings. There was a general trend of increase in total landings until 2001, followed by a decrease thereafter. Total landings increased from 4 tonnes in 1992 to 266 tonnes in 1996. They then fluctuated considerably between 161 and 408 tonnes from 1996 to 2005. In the next 5 years (2005–2010), landings decreased from 185 to 41 tonnes (ICES 2010a).

Figure 3
Catches of alfonsino by vessels from France, Ireland, United Kingdom (England, Scotland and Wales) and Iceland, 2006



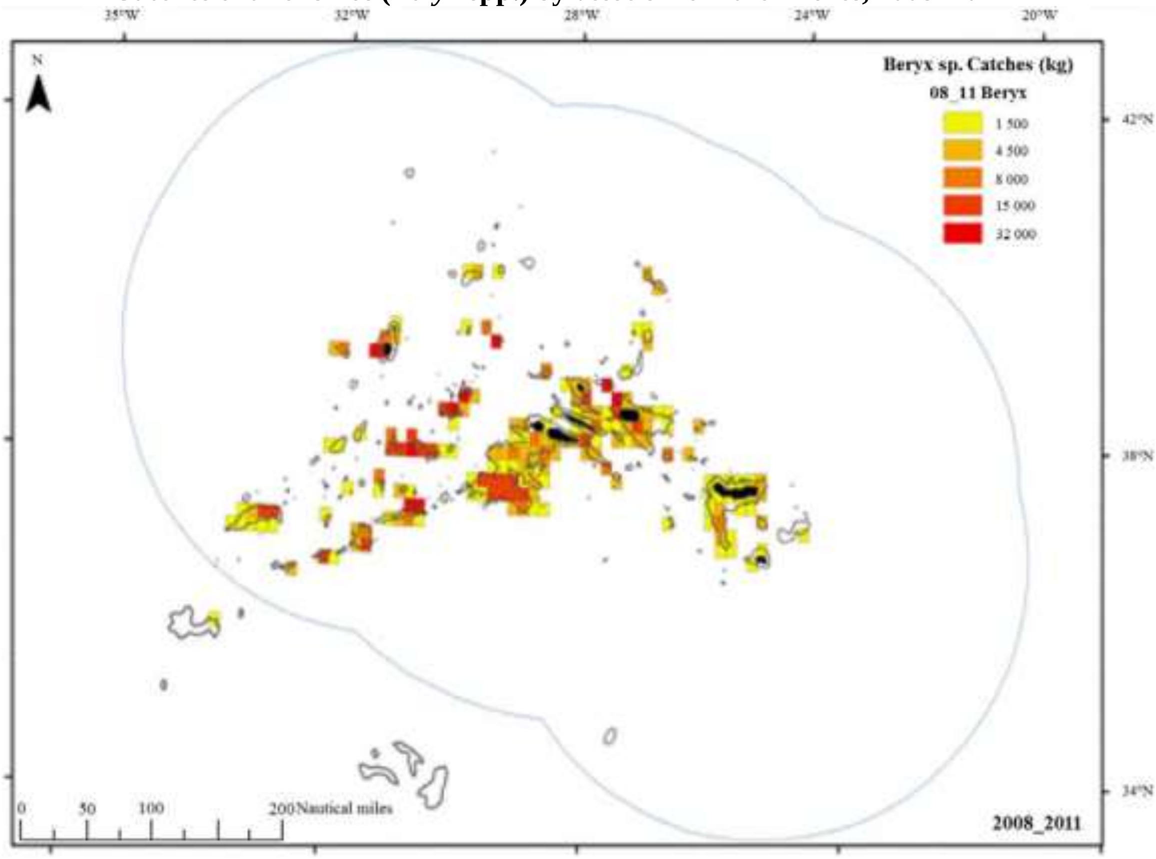
Source: adapted from ICES (2010a).

3.1.2 The Azores

Alfonsino and *B. decadactylus* are two of several deepwater species caught mostly by the Azorean longline fleet. This fishery for demersal species has traditionally been a multispecies deepwater fishery using a variety of hook and line gear types. These gear types include different types of handlines using from one to several hundred hooks to bottom longlines.

The commercial demersal/deep-sea fishery is concentrated mainly off the coast of the islands and on some well-known banks and seamounts relatively near the coast (Pinho and Menezes, 2005, 2009) down to 900 m using demersal hook and line gear. The fishing effort in the most recent decade of the fishery, mainly by longliners, has expanded to offshore seamounts, particularly for those concentrated along the Mid-Atlantic Ridge (Figure 4).

FIGURE 4
Catches of alfonsinos (*Beryx* spp.) by vessels from the Azores, 2008–2011



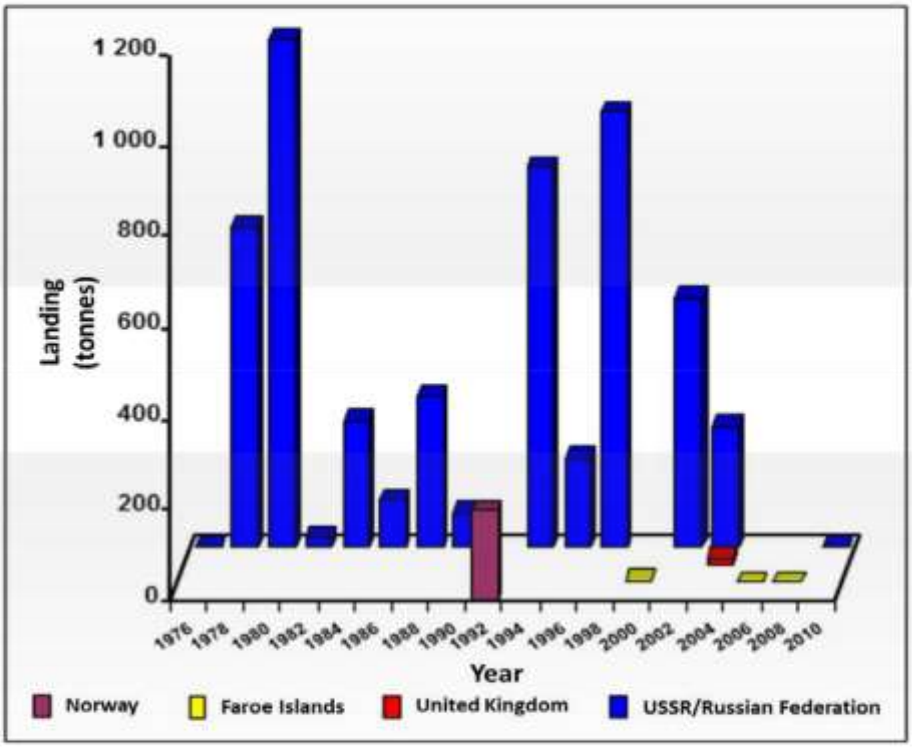
Source: adapted from ICES (2013)
Note: Colours are proportional to the average volume of the catches

Figure 4 shows catches by fleet from the Northern Azores area.

Alfonsino catches have a similar trend to that observed for *B. decadactylus*, but catches of alfonsino have always been greater. Reported landings from 1980 to 2005 show catches increased gradually to a peak of 410 tonnes in 1994 and then continuously declined. Over the last eight years of the series, catches fluctuated around 150 tonnes per year. The landings of alfonsino from 1980 to 2011 are presented in Table 1 and Figure 5.

Catches of *B. decadactylus* have always been modest. Available landings information from 1980 to 2011 shows that catches increased gradually to a peak of 234 tonnes in 1994 after which catches continuously declined. The decrease observed since the mid-1990s could be partly explained by a change in the fishing pattern of the longline fleet, which has directed its effort to black-spotted seabream (*Pagellus bogaraveo*), and also due to the total allowable catch (TAC) limits established by the European Union. The evolution of landings of *B. decadactylus* from 1980 to 2011 is presented in Table 2 and Figure 6.

FIGURE 5
Catches of alfonsino in the Northern Azores area, by year and country



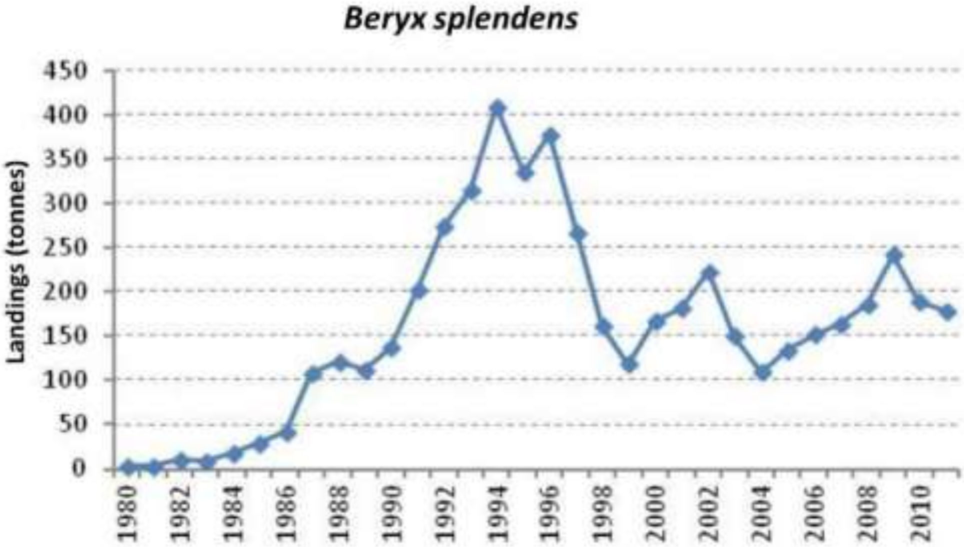
Source: adapted from Vinnichenko (2012)

TABLE 1
Landings of alfonsino in the Azores (ICES area X) 1980-2011

Year	Landings (tonnes)	Year	Landings (tonnes)
1980	3.0	1996	378.6
1981	4.1	1997	267.7
1982	11.3	1998	161.3
1983	9.6	1999	118.6
1984	18.5	2000	168.0
1985	28.8	2001	181.5
1986	42.3	2002	222.6
1987	108.2	2003	150.2
1988	121.6	2004	109.6
1989	112.7	2005	134.4
1990	137.4	2006	151.8
1991	203.3	2007	164.7
1992	273.8	2008	186.6
1993	315.6	2009	242.6
1994	409.5	2010	188.8
1995	334.9	2011	179.2

Source: Pereira and Pinho (2012)

FIGURE 6
Annual landings of *B. decadactylus* in the Azores (ICES area X), 1980–2011



Source: adapted from Pereira and Pinho (2012)

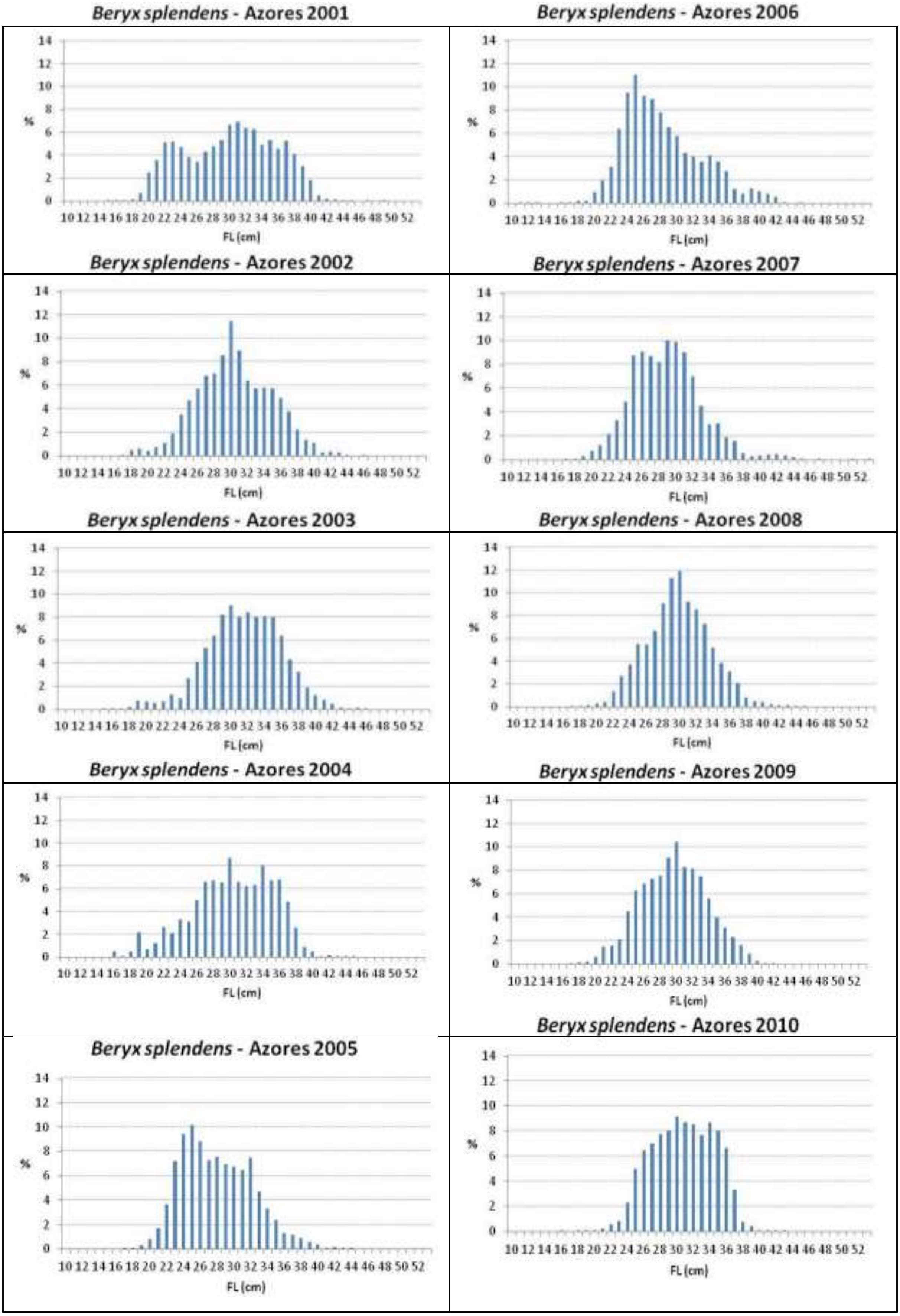
TABLE 2
Landings of *B. decadactylus* in the Azores (ICES area X) 1980–2011

Year	Landings (tonnes)	Year	Landings (tonnes)
1980	0.4	1996	171.2
1981	0.4	1997	110.7
1982	3.9	1998	68.1
1983	12.6	1999	56.3
1984	23.6	2000	35.5
1985	62.2	2001	17.4
1986	51.8	2002	19.7
1987	76.8	2003	22.0
1988	102.9	2004	29.0
1989	146.9	2005	23.1
1990	201.5	2006	39.6
1991	167.6	2007	46.2
1992	176.3	2008	63.4
1993	216.6	2009	68.3
1994	233.7	2010	50.8
1995	193.8	2011	46.7

Source: Pereira and Pinho (2012)

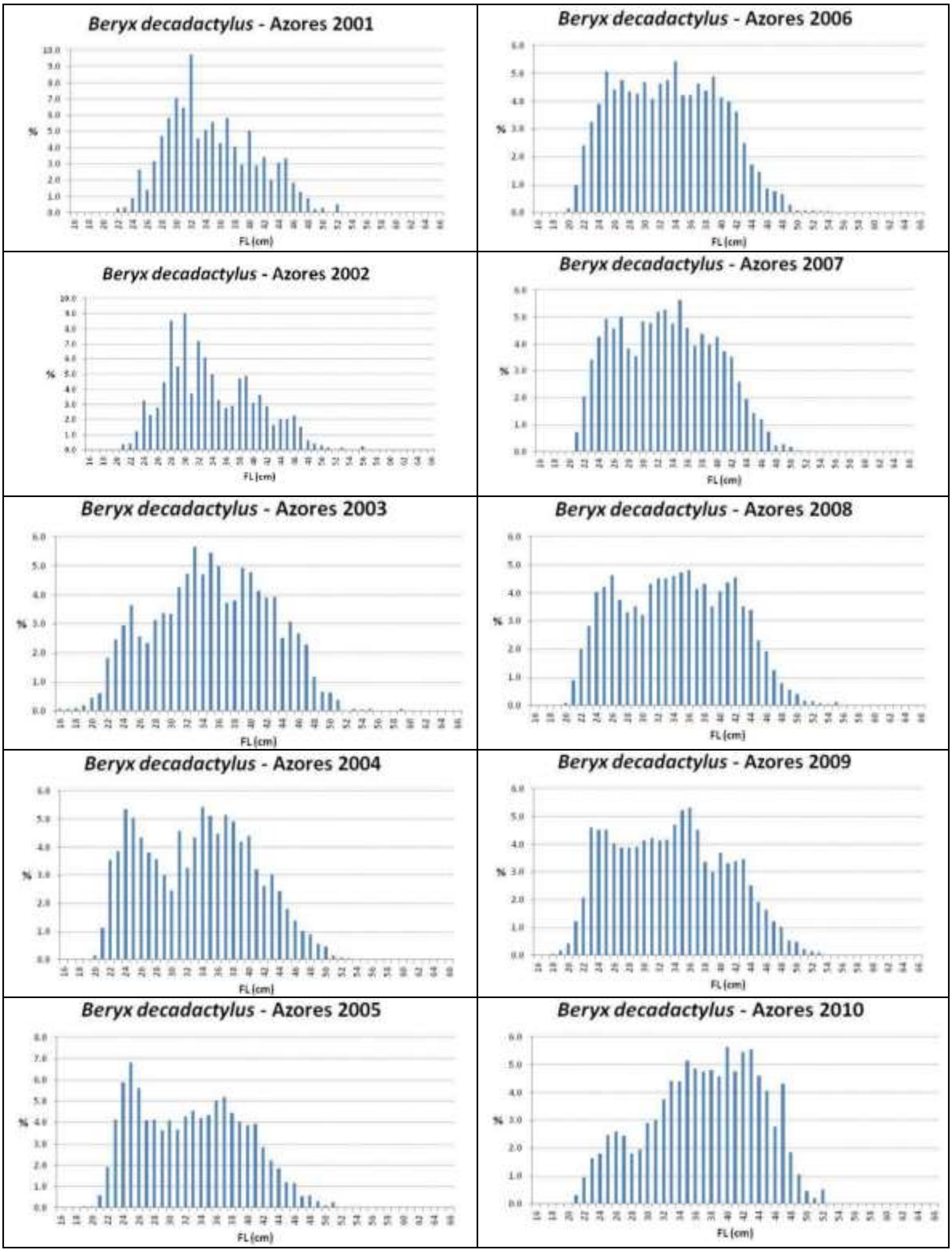
Figures 7 and 8 present size frequencies for the alfonsino catch and for *B. decadactylus* respectively for 2001–2010 and the size distribution of the landings (catch at size). They show some interannual variation with a general stability of the sizes caught over the period examined, but, as Figure 9 shows, there was a decreasing trend in weight over the period of exploitation examined, from 1991 to 2010.

FIGURE 7
Size frequencies of alfonsino catches by the Azores longline fishery



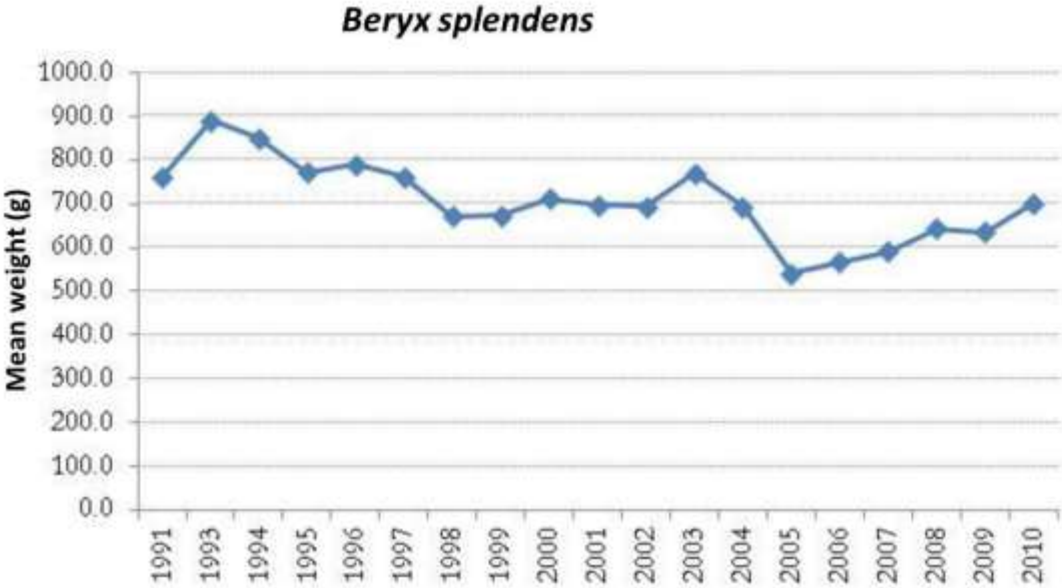
Source: Pereira and Pinho (2012)

FIGURE 8
Size frequencies of *B. decadactylus* from the Azores fishery, 2001–2010



Source: Pereira and Pinho (2012)

FIGURE 9
Mean weights of alfonsino from the Azores longline fishery



Source: adapted from Pereira and Pinho (2012)

The length compositions of alfonsino caught at Sedlo and Seine seamounts are shown in Table 3.

TABLE 3
Length composition of alfonsino and *B. decadactylus* caught on the Sedlo and Seine seamounts

Seamount		N	Min.	Mean	Max.	Mode	S.D.
Sedlo	*B. splendens*	296	29.5	36.4	42.5	37.0	2.4
Seine	*B. decadactylus*	14	26.0	34.8	47.0	28.5	6.4
Seine	*B. splendens*	82	20.5	25.1	34.0	24.5	3.2

Source: Menezes *et al.* (2009)

3.1.3 Canary Islands and Madeira

In the Canary Islands, alfonsino are the main target species and *B. decadactylus* is a secondary species in the small-scale demersal fishery off Gran Canaria and El Hierro Islands – it is caught with handlines and bottom drop lines at about 400–800 m. In Madeira, *B. decadactylus* is a bycatch species.

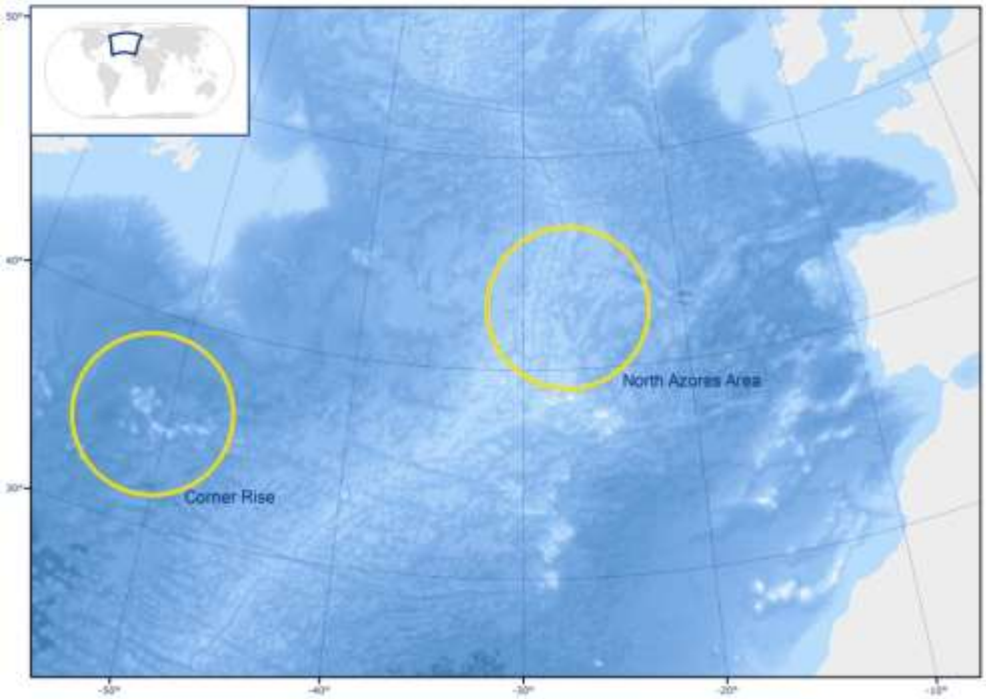
3.1.4 High seas of the North Atlantic Ocean

Fisheries in the high seas of the North Atlantic Ocean have occurred on seamounts north of the Azores and on the Corner Rise (see Figure 10).

North Azores seamounts

Commercial aggregations of alfonsino to the north of the 200–mile exclusive economic zone (EEZ) of the Azores (43–45°N, 23–32°W, Figure 9) are known from the Spektr, Bliznetsy, Agat and one unnamed seamount. The first commercial catches from the North Azores area were obtained by the EV *Volzhanin* (a vessel from the Union of the Soviet Socialist Republics [USSR]) in 1977. Dense aggregations were subsequently found in the area in August 1978 by the USSR EV *Andrus Johani*. In August–October of that year up to three trawlers fished the area with a total catch that exceeded 700 tonnes. In March and July 1979, aggregations of alfonsino on the North Azores seamounts were observed by the USSR vessels EV *Rzhev* and EV *Kapitan Demidov* and in April–May up to four trawlers fished the area for a total catch of about 1 100 tonnes.

FIGURE 10
Fisheries areas of alfonsino on the high seas of the North Atlantic Ocean



Source: Map modified from Vinnichenko (2012)

In the 1980s there was no commercial fishery for alfonsino on the North Azores seamounts. Fishing was resumed in September 1993 by a joint Norwegian–Russian expedition using the FV *Ramoen*. Aggregations of alfonsino were observed on three seamounts and catches were about 200 tonnes (Vinnichenko, 2002).

From 1994–2000 the fishery for alfonsino was continued by Russian commercial trawlers with annual catches of 200–960 tonnes (Table 4). There are no data for the target fishery in the 2000s. Only a small bycatch of alfonsino in the area was taken by the Faroe Islands, the United Kingdom of Great Britain and Northern Ireland and the Russian Federation. Russian research vessels found no commercial aggregations in the area from 2003–2004 (Shnar, Burykin and Sirota, 2005). Since the discovery of the alfonsino aggregations the total catch from the North Azores seamounts has been about 5 500 tonnes by mostly Russian vessels.

The Corner Rise

The Corner Rise is a cluster of seamounts between 34–37°N, 47–53°W that contains three fishable seamounts. Alfonsino aggregations on the Corner Rise were first discovered by the EV *Atlant* in 1976. In June–July of that year, up to 17 trawlers targeted these fish and their total catch was more than 10 000 tonnes (Table 5, Figure 11). Fishing stopped in September as a result of reductions in aggregation density and, thus, decreasing catches. Exploratory operations continued in this area until October but no further commercial aggregations were found (Vinnichenko, 1997a). In March–July 1977, eight trawlers fished on the Corner Rise; however, stable fish aggregations were not encountered on the seamounts. The total catch was only about 800 tonnes (Vinnichenko, 1997a).

From 1980–1986, there was no commercial fishery for alfonsino on the Corner Rise seamounts. The area was periodically surveyed by research and exploratory vessels. Alfonsino aggregations of different densities and stability on seamounts were observed and about 2 000 tonnes of alfonsino were taken. Following research by the USSR vessel EV *Sokrat*, a commercial fishery began on the Corner Rise in March–April 1987 by up to four trawlers that took a total of 2 300 tonnes (Vinnichenko, 1997a).

TABLE 4
Catch (tonnes) of alfonsino on the North Azores Seamounts (ICES Division Xb), 1977–2011

	Catch (tonnes)				
	Russian Federation	**Norway**	**Faroe Islands**	**England & Wales**	**Total**
1977	5[1]				5
1978	706[1]				706
1979	1 116[1]				1 116
1981	25[1]				25
1982	281[1]				281
1983	110[1]				110
1986	334[1]				334
1987	78[1]				78
1993		195[1]			195
1994	837[1]				837
1995	200[2]				200
1996	960[2]				960
1997			5		5
1999	550[2]				550
2000	266[2]			15	281
2008			2		2
2009			1		1
2010	5				5
2011	5				5
Total	5 478	195	8		5 696

[1] Data of logbooks and cruise reports of exploratory vessels
[2] Personal communications
Source: ICES (2012)

Neither investigations nor a fishery were carried out in the area over several subsequent years. Operations resumed in September 1994 when the Russian vessel FV *Petr Petrov* caught 400 tonnes of alfonsino. From one to five Russian trawlers operated on the Corner Rise in February-August 1995 catching a total of 3 500 tonnes (Vinnichenko, 1997a). Some exploratory work was done by a Canadian company in 1995 using bottom and midwater trawling that resulted in a catch of about 9 tonnes, mainly of snowy grouper and alfonsino (Kulka *et al.*, 2007). In the period 1996–2000, one Russian trawler continued to fish for alfonsino on the Corner Rise with annual catches of 628–780 tonnes. Since 2001 there has been no Russian fishery for alfonsino on the Corner Rise and Russian research vessels found no commercial aggregations in the area from 2003 to 2004 (Shnar, Burykin and Sirota, 2005). The total catch on the Corner Rise, taken mainly by the Russian Federation, has amounted to about 24 000 tonnes.

Spanish trawlers began fishing alfonsino on the Corner Rise in 2004 and were most active in 2005 when their catch was about 1 200 tonnes (Table 5). The catch then declined over the following two years, increasing again in 2009. There are no data for the fishery for the period 2010–2012.

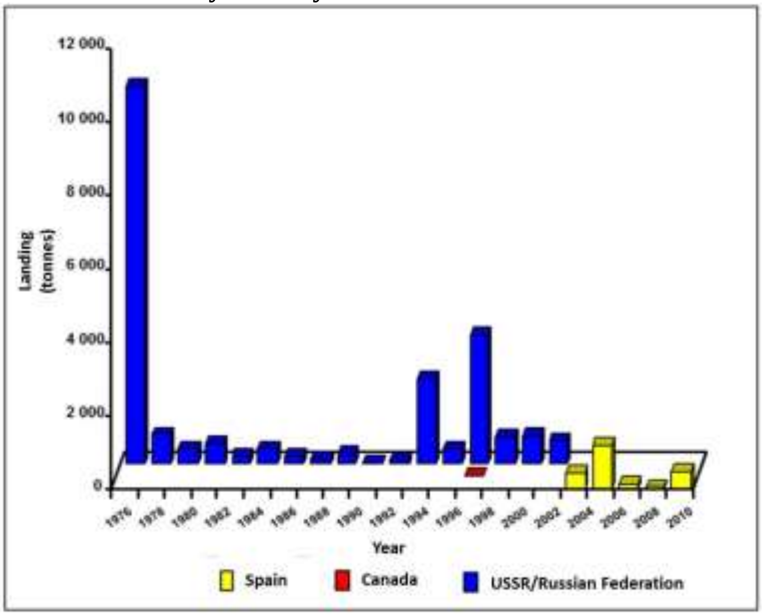
On the Azores seamounts, both small and large fish, ranging from 23 to 28 cm and from 36 to 43 cm, were caught. An increase in towing depth revealed an increase in fish size (Vinnichenko, 2012).

TABLE 5
International catch of alfonsino on the Corner Rise (NAFO Subarea 6GH), 1976-1999

	Catch (tonnes)			
	USSR/Russian Federation	**Spain**	**Canada**	**Total**
1976	10 200[1]			10 200
1977	800[1]			800
1978	400[1]			400
1979	530[1]			530
1980	200[1]			200
1981	390[1]			390
1982	210[1]			210
1983	160[1]			160
1984	240[1]			240
1985	10[1]			10
1986	110[1]			110
1987	2 300[1]			2 300
1994	400[2]			400
1995	3 500[2]		9[4]	3 509
1996	710[2]			710
1997	780[2]			780
1999	628[2]			628
2004		439[3]		439
2005		1 181		1 181
2006		149[3]		149
2007		54[3]		54
2009		490[3]		490
Total	21 568	2 313	9	23 890

[1] Data of logbooks and cruise reports of exploratory vessels.
[2] Personal communications, skippers.
[3] Data from Spanish papers (Durán Muñoz *et al*., 2005; González-Costas and Lorenzo, 2007).
[4] Total catch including alfonsino (Kulka *et al*., 2007).
Source: Vinnichenko (2012)

FIGURE 11
Alfonsino catch by country from Corner Rise Seamounts



Source: adapted from Vinnichenko (2012)

3.2 The South Atlantic

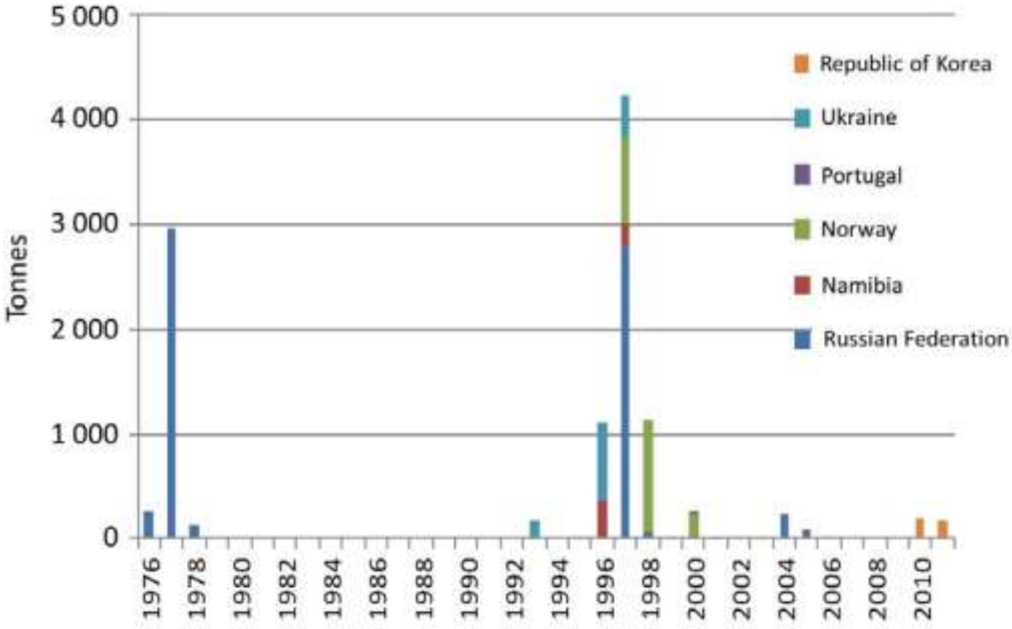
3.2.1 Overview of catches in the South East Atlantic Fisheries Organisation area

Figure 12 shows the reported alfonsino catches from the South East Atlantic Fisheries Organisation (SEAFO) area by flag State, showing evidence of the fishery being subjected to pulses of fishing effort.

3.2.2 Fisheries of the then Soviet Union

Paramonov (2012a) notes that Soviet research of the Walvis Ridge began in the late 1960s / early 1970s. Soviet research and fishing on the Walvis Ridge was episodic and opportunistic. Nevertheless, in 1968, the Soviet exploratory fishing vessel *SRTM-8613* found accumulations of armourhead, scorpionfish and alfonsino on the Valdivia Bank of the Walvis Ridge. Large USSR vessels from the Ukrainian Soviet Socialist Republic fished there in 1968–1970 with an average catch of 25–36 tonnes per fishing day. Throughout the 1970s, the banks of Walvis Ridge were appraised by passing exploratory fishing ships. Usually, no fish aggregations were found, or if so, then only in small quantities. After coastal States claimed their 200 nm EEZs Ukrainian survey work became mainly concentrated on the high seas. From 1981, Ukrainian survey ships and sometimes commercial ships from the USSR fished the banks almost annually. The last fishing activity by a Ukrainian vessel was in 1997. In the period 1968-1997 the Ukrainian fleet (both scientific and commercial) caught almost 10 000 tonnes of fish (Table 6) on the banks of Walvis Ridge.

FIGURE 12
Catch of alfonsino in the SEAFO area



Source: adapted from Nishida (2012)

TABLE 6
Results of fishery of the Soviet/Ukrainian fleet on the Walvis Ridge Banks

Year	Total catch (tonnes)	% of alfonsino in catch	Other species in a catch
1968–1970	2 823.1	Not known	Armourhead 55%, alfonsino + scorpionfish 45%
1981	460.6	93.4	Butterfish 2.1%, armourhead 1.3%, frostfish 2.8%, other 0.4%
1982	1 238.5	38.4	Horse mackerel 54.8%, butterfish 2.3%, armourhead 0.2%, other 4.3%
1983	376.9	50.4	Armourhead 3.7%, butterfish 1.7%, frostfish 6.5%, tuna 3.8%, Cape bonnetmouth 1.4%, other 32.5%
1984	194.1	53.2	Frostfish 14.0%, anchovy 25.6%, other 7.2%
1985	238.9	94.7	Armourhead 2.3%, butterfish 1.7%, horse mackerel 0.1%, other 1.0%
1987	29.5		Horse mackerel 100%
1988	150.6	85.6	Armourhead 14.4%
1989	1 277.0	30.5	Armourhead 38.2%, horse mackerel 16.2%, Cape bonnetmouth 5.5%, frostfish 2.8%, other 6.8%
1990	341.5	39.3	Armourhead 44.9% other 15.8%
1993	963.7	47.9	Armourhead 41.2%, horse mackerel 7.6%, butterfish 2.7%, other 0.6%
1995	233.7	22.2	Armourhead 72.2%, other 5.6 %
1996	1 063.5	70.4	Armourhead 26.3%, butterfish 3.3%
1997	409.1	95.6	Armourhead 4.4%
Total	9 800.7	46.9	Armourhead 22.3%, horse mackerel 14.2%, butterfish 1.6%, frostfish 1.4%, Cape bonnetmouth 1.1%, other 12.5%

Source: Paramonov (2012a)

Annual catches for the Soviet/Ukrainian fleet increased from 29.5 to 1 277 tonnes for an average increase of about 613 tonnes per year. All catches were by large-tonnage ships. Peak catches occurred in 1982, 1989 and 1996, at about seven-year intervals.

The target species during this time was alfonsino with armourhead (*Pseudopentaceros richardsoni*) being the next species most commonly taken. This was followed by horse mackerel (*Trachurus trachurus*, *Decapterus rhonchus*, and *Decapterus macarellus*), butterfish (*Shedophilus ovalis* and *Hyperoglyphe antarctica*), frostfish (*Lepidopus caudatus*), Cape bonnetmouth (*Emmelichthus nitidus*) and other species in minor amounts. Sharks and wreckfish (*Polyprion americanus*) were also common in longline catches.

The characteristics of the Walvis Bank seafloor features are summarized in Table 7.

3.2.3 Fisheries of the Republic of Korea

Trawlers of the Republic of Korea relocated to the Atlantic Ocean in 2011 and alfonsino became an important deep-sea species for these vessels in the Atlantic Ocean not only because of the volume of the catches but also because of its higher commercial value relative to other deep-sea species (except Patagonian toothfish). Indeed, the most valuable species taken in the area was alfonsino. Most alfonsino catches from vessels of the Republic of Korea have been exported to the Japanese market regardless of the market price there (Seok, 2012).

In 2010 and 2011, two midwater trawlers of the Republic of Korea caught alfonsino in the SEAFO area up to the TAC limit of 200 tonnes. In 2011 the total catch of one trawler of the Republic of Korea in the Atlantic Ocean was 482 tonnes. The difference in catch arose from the vessel fishing for alfonsino in the

FAO Area 34, which is adjacent to the SEAFO area.

The amount of alfonsino in the catch of the fishery of the Republic of Korea in 2011 was 23 and 92 percent from the SEAFO area and FAO Area 34, respectively. The mean size of alfonsino was 27.8 cm (n=289, 18–42 cm, mode: 26–27 and 28–29) and 29.2 cm (n=259, 20–48cm, mode: 27-28) for males and females, respectively. The mean weight was 0.52 kg (n=289, 0.12–1.70 kg, mode: 0.4–0.5) and 0.61 kg (n=259, 0.16–2.50 kg, mode: 0.4–0.5) for males and females, respectively.

TABLE 7
Banks of the Walvis Ridge and their fish fauna

Name	Size (nm)	Lat. S	Long. E	Min. depth (m)	Comment
Zubov (Northern) Bank	1 × 1.5	20° 45'	008° 40'	210	Suitable for bottom trawling. Common target species is alfonsino (about 50 percent) but also frostfish, oilfish (*Ruvetta ruvetta*), scorpionfish (*Scorpaena angolensis*), shark, albacore (*Thunnus alalunga*). Catch composition changeable, possibly because of the relative closeness of bank to the shelf
Valdivia Bank	10 nm^2	26° 10'	006° 20'	220	Target species armourhead, bycatch includes alfonsino, Cape bonnetmouth, frostfish, and oilfish
Smezhnaya		26° 10'	005° 35'	570	Small peak-type mountains located near Valdivia. Target species are alfonsino with armourhead and cardinal fish (*Epigonus telescopus*) bycatch
Perspektivnaya		25° 10'	005° 30'	573	
Schedraya		25° 37'	006° 13'	428	
Radostnaya Banks		24° 50'	006° 25'	590	
Sentyabrskaya Bank	3.5 dia.	30° 14'	003° 08'	550	Central part of ridge. Suitable for bottom trawling. Basic alfonsino with bycatch of
Alfa-2 Bank	5 × 2.5	32° 53'	002° 33'	480	Basic catch alfonsino with armourhead, butterfish and cardinalfish bycatch
Beta Bank	3 nm dia.	31° 45'	002° 10'	560	Basic catch alfonsino with armourhead, butterfish and cardinalfish bycatch
Vema Seamount	5 × 6	31° 30'	008° 10'	11–31	Not part of Walvis Ridge, but situated close by. Seamount has two peaks, not suitable for bottom trawling. Catches of horse mackerel with amberjack (*Seriola lalandi*), bream (*Brama brama*), oilfish, butterfish, Cape bonnetmouth, tuna bycatch
Alfa Bank		33° 17'	002° 26'	778	No commercial fish
Ewing Seamount		23° 10'	008° 20'	789	

Source: Paramonov (2012a)

Table 8 shows the catch results of the vessels of the Republic of Korea in the South Atlantic and Table 9 shows the fishing effort and CPUE of high-seas trawlers of the Republic of Korea fishing for alfonsino.

The increase in the catch in the South Atlantic Ocean in 2011 was attributed to a sudden transfer of vessels of the Republic of Korea to this area (Seok, 2012).

TABLE 8
Nominal catch (tonnes) of alfonsino by the vessels of the Republic of Korea in the Atlantic Ocean, 1998-2011, as estimated by the distant-water fishery information system of the Republic of Korea

	Eastern Central Atlantic	Southwest Atlantic	Southeast Atlantic
1998	0	0	0
1999	0	2	0
2000	0	4	0
2001	0	0	0
2002	0	0	0
2003	56	0	0
2004	0	0	0
2005	0	0	0
2006	0	0	0
2007	0	0	0
2008	0	0	0
2009	0	0	0
2010	0	0	0
2011	0	0	489

Source: Seok (2012)

TABLE 9
Fishing effort and CPUE of high-seas trawlers of the Republic of Korea fishing for alfonsino

	Demersal trawls	Midwater Trawls	Total	CPUE kg/hour
SEAFO	29 tows	1 tow	30 tows	663.9
	69 h 05 min	3 h 35 min	72 h 40 min	445.9
FAO Area 34	39 tows	7 tows	46 tows	25 191.3
	22 h 40 min	21 h 35 min	44 h 15 min	10 891.9
Total	68	8	76	SEAFO: 29 days FAO Area 34: 12 days
	91 h 45 min	25 h 10 min	116 h 55 min	

Source: Seok (2012)

In the SEAFO area, 35.5 percent of the catch was mackerel (*Scomber scombrus*) (35 tonnes), 22.8 percent was alfonsino, 14.6 percent was oil fish (*Ruvettus pretiosus*) and 12.3 percent was armourhead. A catch of 482 tonnes was taken in FAO Area 34, of which 92.3 percent was alfonsino and 4.7 percent was snake mackerel (*Promethichthys prometheus*).

3.2.4 Japanese exploratory fishing

Records are available of the catch of alfonsino by FV *Shinkai Maru* in 1979 on Bromley Bank No .2, South Atlantic, as shown in Table 10.

TABLE 10
Catch of alfonsino by FV *Shinkai Maru*, Bromley Bank No. 2, South Atlantic, 1979

Tow no.	69	70	71	72	73	74	75	76
Start time	07:05	10:35	13:35	16:55	20:03	23:25	02:45	06:05
Length of tow (min)	160	135	145	100	137	155	160	160
Start depth	650	238	325	250	650	700	232	232
Finish depth	500	500	500	550	500	550	550	550
Catch (kg)	100	0	0	0	900	800	1 350	0

3.2.5 Tristan da Cunha

The last record of trawl fishing for alfonsino on the banks around Christan da Cunha was in 2003 by the Mauritian-flagged vessel, FV *Bel Ocean II*, which caught 216 tonnes of alfonsino and 252 tonnes of bluenose warehou (*Hyperoglyphe Antarctica*) in 94 hauls. The FV *San Liberator*, then chartered by a New Zealand company , made three visits during 2000 to the end of 2001 and reported a total catch of 3 438 tonnes of alfonsino from 709 hauls together with 233 tonnes of bluenose warehou and 720 tonnes of blackbelly rosefish (*Helicolenus dactylopterus*). In 1997 the Argentinian-flagged FV *Azuchi Maru* caught 302 tonnes of alfonsino in 169 hauls and 665 tonnes of bluenose warehou. The FV *Zlatno More* also fished the Tristan grounds. Since 2003 there has been sporadic longliner fishing including effort by some European vessels (Pers. comm. C. Kilgour, Department of Fisheries, Tristan da Cunha).

The fishery was based on six main seamount areas, some larger than others and a few outlying seamounts including the Crawford Seamount area but all inside the Tristan da Cunha EEZ. The most productive ground was in 200 m; there was another less productive ground in 400 m in two very small restricted grounds for four of five “knobs” in all.

Alfonsino at Tristan da Cunha were found to be small and in shallow water only, which is usually the domain of smaller fish. The bulk of the bluenose warehou were reported to have worms quite badly. There is a distinct fishing season and poor catches outside of this period when it was not worth vessels fishing it. Early summer was reported to be the best fishing period. (Pers. comm. Capt. D. MacGibbon, Nelson, New Zealand).

3.3 The Indian Ocean

3.3.1 Exploratory fishing in the Omani EEZ

A survey by the RV *Al Mustaqila 1* in the southern area of Oman’s Arabian Sea (McKoy *et al*., 2009) caught 83.6 kg of alfonsino. This survey stratified the Oman offshore area into four zones (north to south) that were surveyed during five voyages. Alfonsino biomass for the strata was estimated using the swept-area method for trawl surveys (Table 11). Almost all alfonsino were taken during only one cruise during the pre-southwest monsoon period, when effort was directed to exploratory fishing in offshore and deep waters (> 250 m). During this survey programme all tows were completed during daylight hours, which may have resulted in lower catches of alfonsino than might have otherwise been the case.

TABLE 11
Estimates of alfonsino biomass derived from surveys of the RV *Al Mustaqila 1*

	Voyage				
	OMA070	**OMA00702**	**OMA00801**	**OMA00802**	**OMA00803**
Date of voyage	17/09/07 to 15/10/07	01/11/07 to 17/12/07	29/01/08 to 18/03/08	19/04/08 to 10/06/08	01/08/08 to 23/09/08
Estimated biomass (tonnes)	194	3	1	91	11
CV percent	40	100	100	100	91

3.3.2 Soviet/Ukrainian fishery in the Southern Indian Ocean

Development of the fishery

The SWIR is located in southwest part of the Indian Ocean about 1 000 nm east from the South African coast. Research of the SWIR fishes by Ukrainian fisheries scientists began in the 1970s. At that time Ukraine was part of the then Soviet Union, which was conducting marine studies of the world's oceans, including research of the Indian Ocean. With the change in emphasis to the high seas following the introduction by many countries of 200 nm EEZs, most Soviet deep-sea research relocated to the high seas. One of the few high-seas regions where fish aggregations were found was over the SWIR.

In August 1980 exploratory and research ships found commercial accumulations of fish on three banks of the SWIR, Geroevka (No. 150), and bank numbers 102 and 251, which were the shallowest banks. The most numerous species caught were Cape bonnetmouth (*Emmelichthus nitidus*) and butterfish[4] (comprising two species: bluenose [*Hyperoglyphe antarctica*] and *Schedophilus ovalis*). The fishing fleet also worked these banks. Catches are shown in Tables 12 and 13. Catch rates were high as virgin populations were being harvested. Alfonsino comprised only 0.8 percent of the total catch.

TABLE 12
Soviet/Ukrainian vessel catches by year

	Total catch (tonnes)	Catch by large-tonnage ships (tonnes)	CPUE of large-tonnage ships (tonnes/fishing day)
1980	6 910.4	6 910.4	24.2
1981	4 699.1	4 494.0	8.3
1982	2 036.4	1 880.8	6.2
1983	1 706.1	1 603.3	5.5
1984	120.5	97.6	4.2
1985	208.8	165.0	10.6
1986	14.6	9.1	1.1
1987	1 412.3	1 412.3	10.7
1988	204.0	204.0	3.8
1989	11.9	11.9	2.4
1990	15.0	15.0	0.8
1991	10.4	0	
1992	1 561.9	1 561.9	15.8
1993	1 317.1	1 308.1	11.6
1994	2 190.1	2 190.1	15.1
1995	2 764.9	2 764.9	12.2
1996	3 034.1	3 034.1	18.5
1997	1 436.9	1 436.9	10.0
1998	1 438.4	1 438.4	12.8
1999	2 362.4	2 362.4	14.1
2000	1 352.5	1 352.5	10.1
2001	799.4	799.4	7.1
Total	35 607.2	35 052.1	11.2

Source: Paramonov (2012b)

TABLE 13
Distributing of catches of middle-tonnage ships by year

Year	Total catch (tonnes)	CPUE of middle-tonnage ships (tonnes/fishing day)
1981	205.1	0.9
1982	155.6	1.8
1983	102.8	0.5
1984	22.9	0.3
1985	43.8	0.5
1986	5.5	0.2
1991	10.4	0.5
1993	9.0	0.1
Total	555.1	0.7

Source: Paramonov (2012b)

In the following three years (1981–84), the SWIR was often visited by scientific and commercial ships, and 11 new fishing banks were found. These banks were deeper than the first three that were surveyed, although minimum depths were less than 1 000 m. Subsequently, alfonsino became the main species caught displacing Cape bonnetmouth, bluenose and butterfish, coming to comprise about half of the total catch (Paramonov, 2012b). The total catch dropped from 4 700 tonnes in 1981 to 1 700 tonnes in 1984, and the CPUE of the large-tonnage ships dropped from 8.3 to 4.2 tonnes per fishing day.

In the period 1985–1991 interest in the Southwest Indian Ocean region declined. Most fishing activity was by middle-tonnage ships and only rarely were large-tonnage vessels active. The total annual catch in these years ranged from 10.4 to 208.8 tonnes and only in 1987 was there a large catch – 1 400 tonnes. This decline was attributed not solely to fishing pressure but also to natural fluctuations in fish biomass over time. In 2005 and 2007 catch rates by large-tonnage ships exceeded 10 tonnes per day.

In 1991 only commercial fishing was undertaken although vessels carried scientific observers. The vessels fished 14 banks and typically only one ship fished a particular bank. The main target species was alfonsino, which comprised 22–80 percent of the catch. The total annual catch for the period 1992-2001 was 800–3 000 tonnes. The average annual CPUE was 7.1-18.5 tonnes per fishing day. In 2001 the last ship was scrapped and fishing on the SWIR by Ukrainian ships came to an end. Ukrainian scientific and commercial vessels caught 35 000 tonnes of fish from the SWIR banks in the period 1980–2001. Table 14 shows the distribution of catches by year and average annual catch and effort.

Distribution of catch by bank

Most banks of the SWIR are unsuitable for bottom trawling because of their complicated bottom relief, which serves as natural habitat for alfonsino. Suitable grounds for trawling exist only on Gololobov Mountain (No. 360). Geroevka Bank (No. 150) was the most productive bank and provided almost one-quarter of the total catch, of which only a minor part were alfonsino.

The group of banks located approximately on 38°S were the next-most important fishing area (Nos. 480, 415, 102 and 560). Except for bank No. 102, which has a flat surface area, the banks with a middle minimum depth resulted in the best catches. A few of these are located to the north of the Southern Subtropical Frontal Zone (SSFZ). When the SSFZ approached these banks there was often an increase in catches. These were the main fishing grounds during the last years of Ukrainian fishing when the primary target species was alfonsino. The Gololobov seamount and Bank No. 422 are usually located to the south of Southern Subtropical Convergence Zone and accumulations of alfonsino associated with them appear to be displaced by the frontal zone to the south of the banks although it does not happen often. Alfonsino constituted 50–100 percent of the catch on the majority of the banks, and they were scarce (i.e. in the range 2.5–21.6 percent) only on the shallower banks.

TABLE 14
Composition of alfonsino of catches on banks, 1992–2001

Bank	Alfonsino (%)
480	84.0
415	87.7
102	67.3
560	85.0
700	74.5
710	79.9
360	97.3
422	100.0
640	95.0
630	70.0
251	21.6
358	8.6
150	2.5
690	52.9
Average	67.6

Source: Paramonov (2012b)

Characteristics of the catch
Ivanin and Rebyk (2012) note that on the SWIR the length of alfonsino in catches by the Soviet fleet ranged from 12 to 55 cm, with an average length of 27.2 cm, and ranged in age from 2 to 18 years. Most of the catch consisted of fish in the length range 24–32 cm. Fish weight ranged from 70 to 6 260 g, with an average weight of 437 g.

3.3.3 The Japanese fishery in the Indian Ocean

Exploratory fishing with a midwater trawl targeting mesopelagic fish resources was carried out during two surveys in different sequences of seasons from 2009 to 2010 in the high seas of the Southwest Indian Ocean by the Fisheries Research Agency of Japan. Catches consisted mainly of alfonsino (Honda, Sakaji and Nishida, 2012). Japanese research cruises by a single chartered vessel continued in 2012.

3.3.4 The fishery of the Republic of Korea for alfonsino in the southern Indian Ocean

From 29 August to 26 October 2009 one bottom longliner of the Republic of Korea caught 113 tonnes of fish from depths of 70–650 m in the Southern Indian Ocean. Bycatch fishes taken were seabream (*Crenidens crenidens*) (39.6 tonnes), *Polyprionidae* (7.7 tonnes), *Congridae*, *Kryphosidae*, big skate (*Raja binoculata*) and *Dentex* spp. Only 230 kg of this catch were alfonsino. Characteristics of the catch of alfonsino by a vessel of the Republic of Korea in the Southern Indian Ocean are provided in Tables 15 and 16.

TABLE 15
Nominal catch (tonnes) of alfonsino by the vessels of the Republic of Korea in the Indian Ocean, 1998–2011, estimated by the distant-water fishery information system of the Republic of Korea

2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	Total
65	50	0	0	0	0	0	0	0	0	0	0	0	0	115

Source: Seok (2012)

3.3.5 Other alfonsino fisheries in the southern Indian Ocean

From about 1996 a deepwater fishery developed in the Southern Indian Ocean for orange roughy (*Hoplostethus atlanticus*). As this fishery matured many vessels left the fishery while a small number of the vessels that had pioneered the fishery continued fishing but with an increasing emphasis on alfonsino. The number of vessels in this fishery has ranged from four to six. Most catches have been taken by vessels flagged to Mauritius, New Zealand, Australia, Namibia and now the Cook Islands.

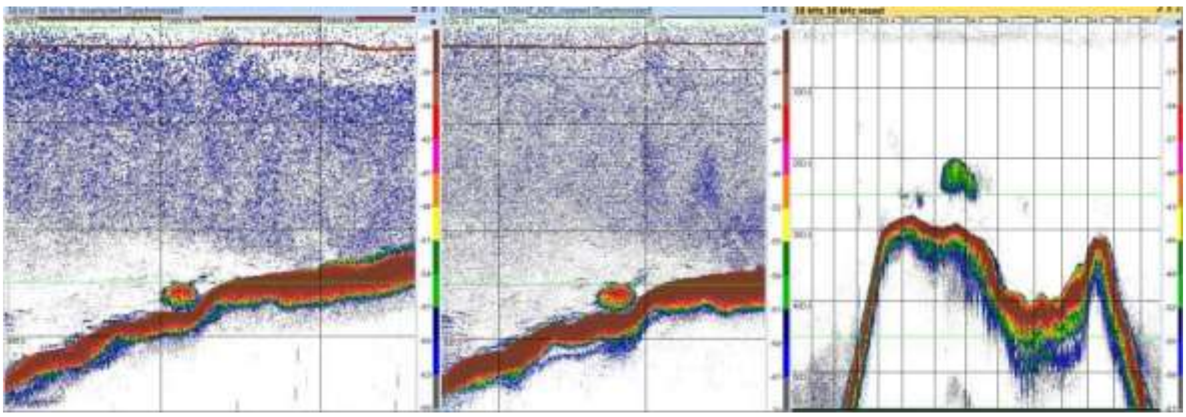
TABLE 16
Size information on the alfonsino catch of the Republic of Korea

	Mean size	No. measured	Range in length	Mode
	(cm)		(cm)	(cm)
Male	27.8	289	18-42	26-27
Female	29.1	259	20-48	27–28
	Mean weight		**Range in weight**	
	(kg)		(kg)	(kg)
Male	0.52	289	0.12-1.70	0.4–0.5
Female	0.61	259	0.16-2.50	0.4–0.5

Source: Seok (2012)

This fishery is undertaken using two different forms of midwater trawling. Most vessels (i.e. those with New Zealand captains) use aimed trawling. With this fishing technique the gear is only deployed when a concentration of alfonsino is found at which point the gear is set onto the fish. Usually, the gear does not touch the bottom and the vessels use pelagic trawl doors to achieve the manoeuvrability needed in this type of fishing. The time the gear is on the fish rarely exceeds 15 minutes and may be as short as 2 minutes if the vessel's captain is successful in targeting the fish aggregation. (see Figure 13). However, recent experience with a Japanese-flagged vessel shows that larger alfonsino can be taken by a larger-scale mid-water trawl.

FIGURE 13
Acoustic echo images of an alfonsino school obtained by the Sealord Net Towed AOS



Source: G. Patchell, Sealord Group, New Zealand

The right pane shows an alfonsino school in midwater as sonified by the Sealord Vessel's ES60 echosounder. This night time image, taken with the vessel's 38 kHz sounder, shows the mesopelagic species rising towards the surface. The centre pane was taken with the Sealord Net Towed AOS at 120 kHz. The right pane shows a daytime sonification. Alfonsino cannot be fished during the day by aimed trawling as they successfully avoid the net. During this time the vessels lay to.

The second method of midwater trawling involves towing a large net for extended periods. This method tends to be unselective both for the species that are caught and the sizes of alfonsino taken. Therefore, the alfonsino caught by this method are typically small and immature.

3.4 The North Pacific Ocean

3.4.1 The alfonsino fishery in the Japanese EEZ

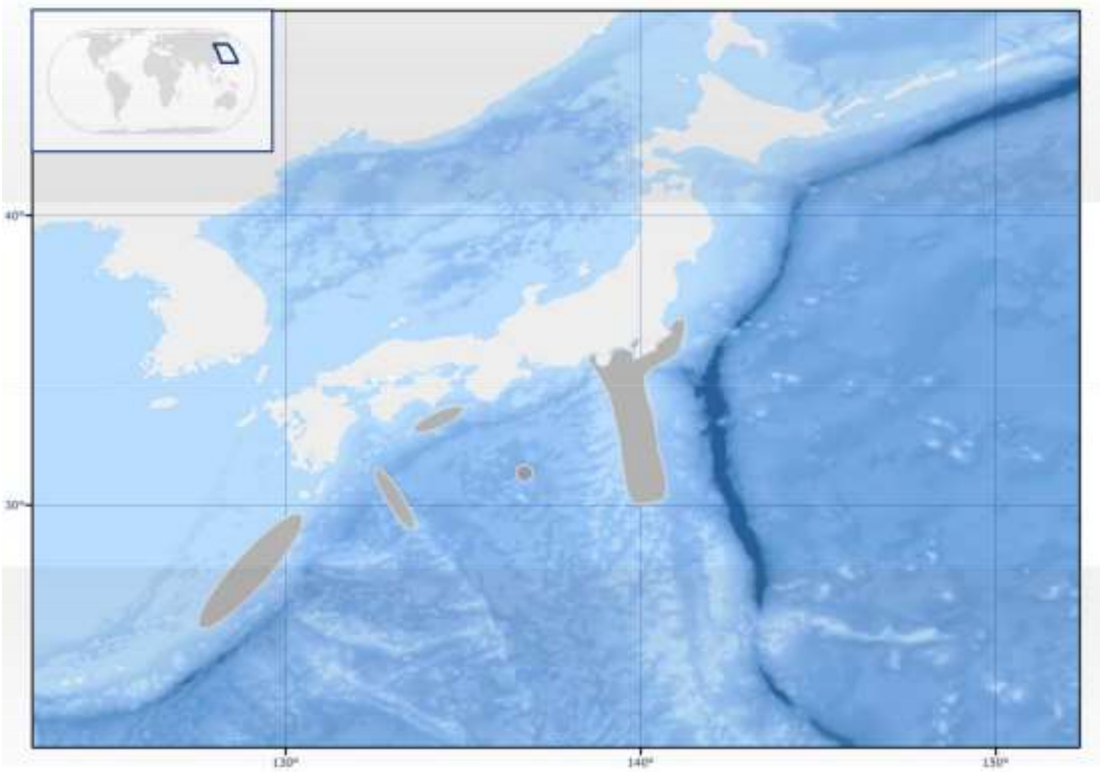
Alfonsino in the Japanese EEZ is mainly distributed at depths of 250-600 m and is usually fished by line and bottom longline. There are several fishing grounds and main landing ports, which are found in prefectures along the Pacific coast of the central and southwest Japan. This requires fishery management by local governments (Honda, Sakaji and Nishida 2012).

The main Japanese landing ports are:

- Shizuoka Prefecture: Shimoda, Inatori, Ito;
- Kanagawa Prefecture: Misaki;
- Chiba Prefecture: Katsuura, Choshi;
- Kochi Prefecture: Muroto.

Alfonsino catches in the five prefectures increased in 1970s reaching 8 000–11 000 tonnes in the 1980s then decreased to 6 000–9 000 tonnes in the 1990s and the first half of the 2000s. Catches were then stable at about 7 000 tonnes between 2005 and 2009 decreasing to 5 400 tonnes in 2010. Honda *et al.* (2004) report that the overall CPUE in the period 1985–2002 was generally stable following a period of slightly higher catch rates in the period starting in 1979. Honda *et al.* (2004) shows the area of the fishery in Figure 14.

FIGURE 14
Major fishing grounds of alfonsino (grey areas) in the EEZ of Japan



Source: Modified from Honda *et al.* (2004)

Table 17 provides the line fishing regulations for the Izu Islands.

Bottom longliners (about 100 gross tonnes) use about 10 000 hooks per set.

TABLE 17
Line fishing regulations for the Izu Islands

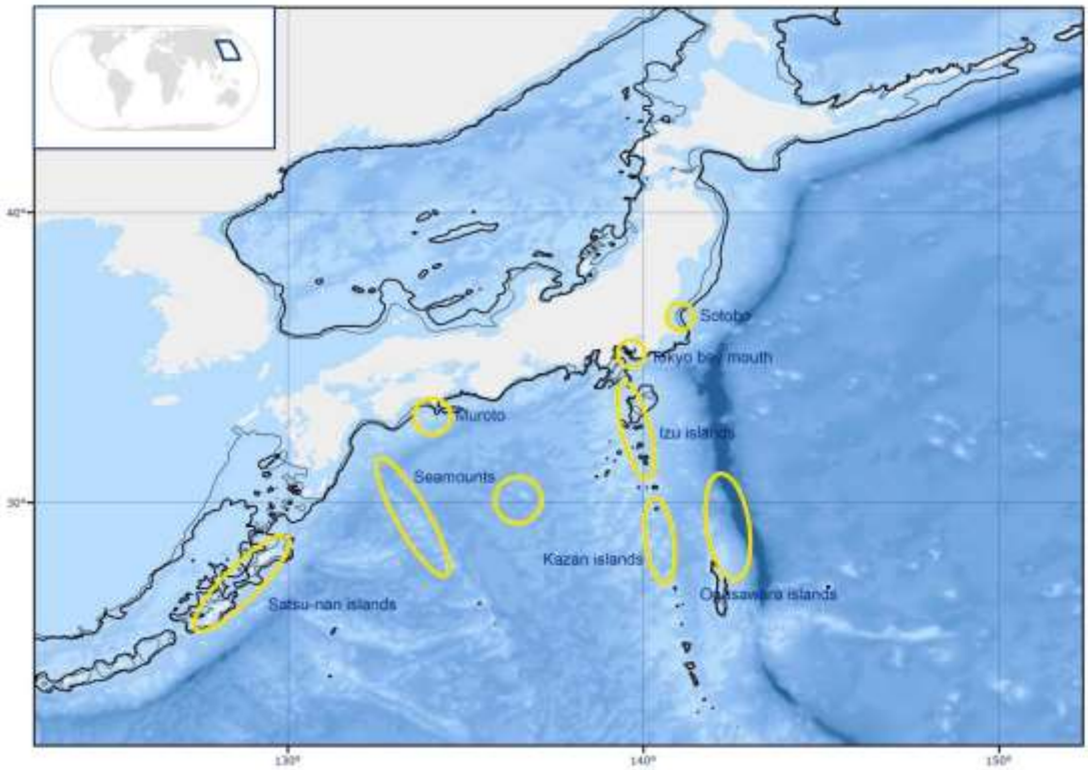
	Tokyo	Shizuoka	Chiba	Kanagawa
Release of young fish	< 22 cm around Oshima; < 24 cm around Kozu-shima; < 30 cm around Hachijo			
No. of hooks	50	50 (35 at night)		
Number of lines	2 per crew	1 per crew + 1		
Bait	Suary, use of sardine is prohibited			
Night operation	Prohibited	Voluntary	Prohibited around Oshima	

Source: Honda *et al.* (2004)

3.4.2 The Japanese fishery on the Southern Emperor Seamounts and Northern Hawaiian Ridge

Alfonsino inhabits the flat summits and slope areas of seamounts of the Southern Emperor Seamounts and Northern Hawaiian Ridge (SE–NHR), which are shown in Figure 15 (Honda 2012). Following the discovery of large concentrations of armourhead in the North Pacific in the Southern Emperor (Northern Hawaii Ridge region) by the then Soviet Union in 1967 Japanese trawlers started fishing in 1969 (Boehlert and Sasaki, 1988; Anon., 2003, Yanagimoto and Nishimura 2007). The fishery for alfonsino started in 1973 on Milwaukee Seamount.

FIGURE 15
Seafloor features associated with alfonsino catches off Japan



Source: Modified from Honda *et al.* (2004)

The Japanese alfonsino catch from this area increased suddenly in 1976 with the discovery of the main fishing grounds on the large northern seamounts of Koko, Yuryaku and Kammu of the Southern Emperor seamounts and the dramatic drop in catches of armourhead (Sasaki, 1986). Catches of alfonsino were sometimes large and were taken by trawl and longline. The fishery soon expanded southwards to encompass the much smaller Northern Hawaii Ridge guyot-type seamounts that included the Colahan, C-H, and Hancock seafloor features (Sasaki, 1986; Anon., 2003). Honda *et al.* (2004) reported a similar distribution in the western part of southern Japan but with a major expansion of the range of the fishery in a zone southward from the central part of the main island of Japan approximately along the 140°E meridian. Catches by Japanese vessels in this period do not appear to be well known and the fishery stopped with the declaration of the EEZ of the United States of America (Clark *et al*., 2007). Following this Japanese trawlers began fishing the Hancock seamounts, which they did until 1985.

An early report by Chikuni (1971) reported alfonsino to be present on the North Pacific Seamount Range between 30 and 40°N and just to the east of the 170°E meridian on the South Honshu Ridge, the Kinan Seamount Range and the Kyūshū Palau Seamount Range, to the south of western Japan, centred around the 20°N parallel. In the SE–NHR Japanese trawl fishing grounds were mainly between 300 and 400 m. Alfonsino was most abundant at depths of 300–500 m as indicated by the Japanese gillnet fishery (Yanagimoto 2004). Chikuni (1971) reported that alfonsino taken from the Milwaukee Seamount by the Japanese trawl fishery were mainly uniformly distributed in the 22–34 cm length range and were primarily taken at a depth of 320 m.

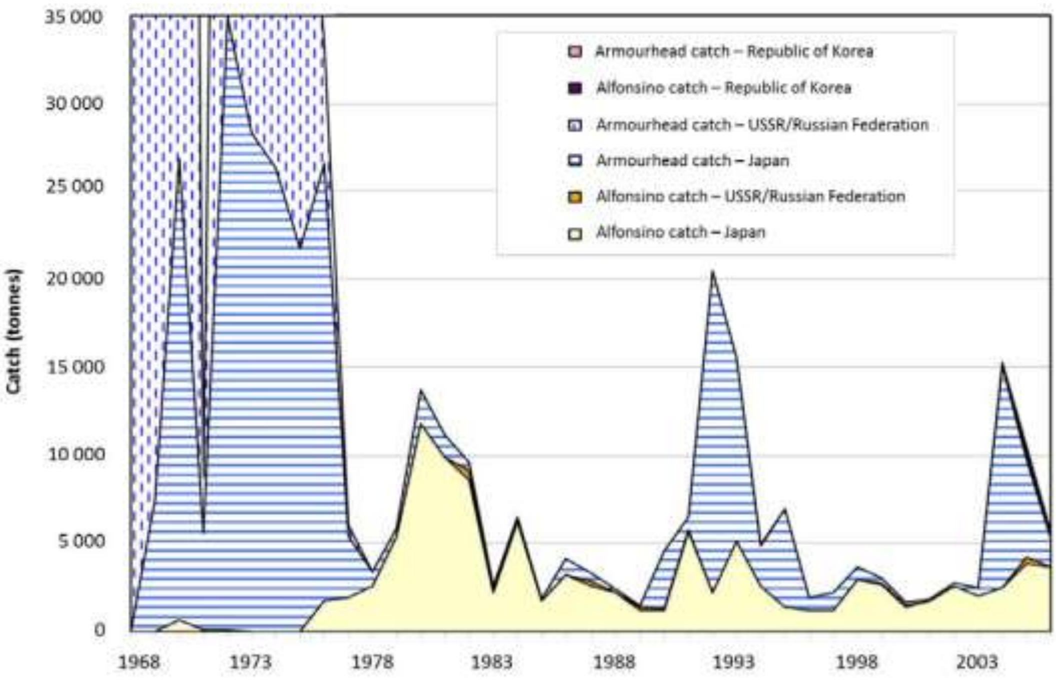
The Japanese commercial trawl fishing for alfonsino is usually carried out at depths of 300-400 m near the flat summits of seafloor features in the SE–NHR where catches are dominated by small individuals of 16–20 cm length (Yanagimoto, 2004; Yanagimoto and Nishimura, 2007). Japanese gillnet fisheries have operated at 300–1 300 m, including slope areas where larger-size individuals (> 30 cm) are abundant (Yanagimoto, 2004). Sasaki (1985) detected a decrease in large-sized alfonsino around the flat summits from the beginning of exploitation of fishing grounds of the SE–NHR. Japanese bottom-gillnet catch statistics are available since 2000 when the Japanese Government implemented a limited–licence system for this fishery (Yanagimoto and Nishimura, 2007). Table 18 summarizes catches from recent fishing grounds of Japan and the Republic of Korea. Figure 16 shows the catch of alfonsino from 1968 to 2003 for the Republic of Korea, the Russian Federation/USSR, and Japan.

TABLE 18
Catch by Japanese trawlers of alfonsino from the Southern Emperor and Northern Hawaii Ridge, 1969–1982

Year	Tonnes
1969	45
1970	600
1971	68
1972	81
1973	12
1974	-
1975	-
1976	1 726
1977	1 941
1978	1 645
1979	5 383
1980	8 632
1981	7 916
1982	8 582

Source: Sasaki (1986)

FIGURE 16
Catch alfonsino by country and fishery for the Southern Emperor and Northern Hawaii Ridge, 1968–2003



Source: modified from NWPRFMO (2008)

3.4.3 Russian Far East fisheries

Russian fisheries targeting alfonsino began following the discovery of large concentrations of armourhead in the SE–NHR region by the Soviet Union in 1967 (Boehlert and Sasaki, 1988; Anon., 2003; Yanagimoto and Nishimura 2007) and as such have only been conducted on the high seas. Some information exists for possible alfonsino catches that were obtained by vessels fishing in the Russian EEZ, mainly around the Kamchatka Peninsula; catches were 477, 120 and 961 tonnes in 2003, 2004 and 2005, respectively. However, uncertainty exists as to the correct species identification, thus these numbers may not be accurate (Baitaliuk and Katugin, 2012).

The USSR/Russian fishery for demersal species on the high seas of the Northwest Pacific began in the late 1960s. Most fisheries were conducted above the seamounts of the SE–NHR, mainly by bottom and midwater trawling. The target species were pelagic armourhead (*Pseudopentaceros wheeleri*). Usually during these fishing operations alfonsino were taken as bycatch (Figure 17). The total USSR (Russian Far East) landings of demersal species decreased from 153 000 to 5 000 tonnes from 1969 to 1971, then increased to 202 000 tonnes in 1972 and 1973 before rapidly declining to less than 2 000 tonnes in 1974–77 (Table 19). No USSR fishery for demersal species in high seas was undertaken after 1977.

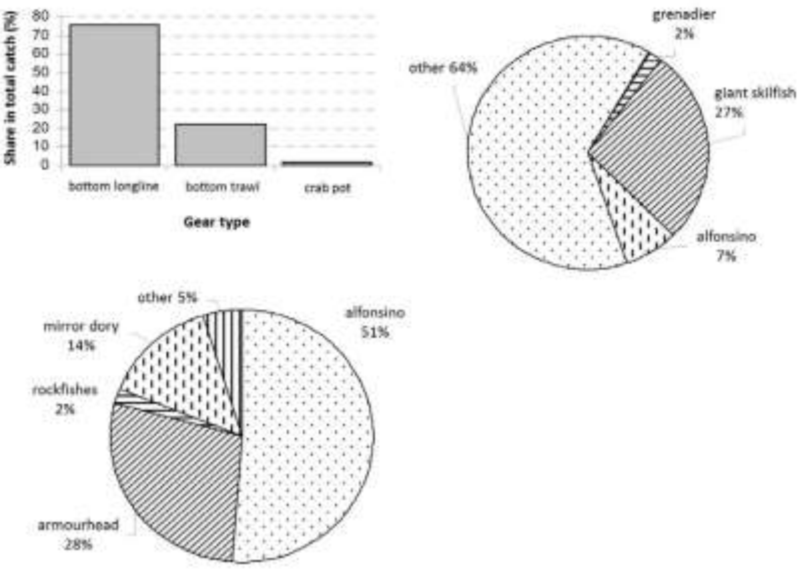
TABLE 19
Reported catch (thousand tonnes), North Pacific deepwater fisheries, 1968–1977

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Total catch	-	153.7	136.2	5.1	88.7	202.1	22.5	33.7	7.2	1.3
Armourhead	46.3	144.9	124.4	3.1	79.3	149.9	19.7	28.7	6.9	0.6
% of bycatch species in total catch	-	6	9	39	11	26	12	15	4	54

Source: Baitaliuk and Katugin (2012)

In the 1960s, armourhead dominated bottom catches accounting for more than 90 percent of total catche while alfonsino accounted for 2–5 percent of the catch. Bluemouth (*Helicolenus avius*), white cardinalfish (*Epigonus denticulatus*) and other fishes made up even less of the total catch. In the 1970s, commercial catches for alfonsino steadily increased reaching 5–19 percent of the total catch in 1977. Catches also increased of blue mouth and white cardinal on the northern seamounts and of caprodon and rubyfish (*Plagiogeneion rubiginosus*) on the southern seamounts. In the late 1970s, the proportion of alfonsino increased to about 19 percent in commercial catches and reached 30 percent, along with an increase in catches of bluemouth and cardinalfish (Table 20).

FIGURE 17
Composition of trawl catches – Russian Far East fishery



Source: modified from Baitaliuk and Katugin (2012)

TABLE 20
Percentage of different species in research and commercial catches from Milwaukee and Kinmei seamounts in the 1960s and 1970s

Species	1960s		1970s	
	Kinmei	Milwaukee	Kinmei	Milwaukee
Armourhead (*Pseudopentaceros wheeleri*)	93.3	97.6	53.5	90.6
Alfonsino (*Beryx splendens*)	4.6	2	19.4	4.9
Mirror dory (*Zenopsis nebulosa*)	0.1	0.1	1.2	1.0
Bluemouth (*Helicolenus avius*)	0.6		17.6	0.6
Cardinalfish (*Epigonus denticulatus*)	0.5		5.7	0.5
Ariomma (*Ariomma lurida*)			< 0.1	
Other	0.5	0.3		2.4

Source: Baitaliuk and Katugin (2012)

Research data from the then Soviet Union suggest that the CPUE increased rapidly during 1981–1983, and then declined over the following few years. Compared with the 1960s and 1970s, the demersal fishing fleet and catch composition have changed considerably in the past decade. Fishing is now mainly by bottom longlines, which account for more than 75 percent of the total catch. Russian trawl and bottom gillnet data have been available on a regular basis since 1999.

Bottom longline catches are dominated by giant skilfish (*Erilepis zonifer*) and alfonsino. Bottom longliners fish mainly on the Jungu and Ojin seamounts, where there were no fisheries before. To the north of these areas skilfish occur less frequently and grenadiers, primarily *Coryphaenoides acrolepis*, become more common in catches. The composition of trawl catches generally corresponds to those of the late 1970s when armourhead abundance was low. Although alfonsino dominated trawl catches the proportions of armourhead and dories were also relatively high.

Total catch of alfonsino by Russian fishing vessels has varied from 10 to 926 tonnes in the past decade as the gear used in the fishery has changed. The highest catch was taken in 2005 when six trawlers operated. Since 2008 no Russian trawl fishery has operated in this area and the catch for alfonsino has been the lowest on record. Most recent Russian alfonsino trawl catches have come from depths of 350-520 m.

3.4.4 Fishery of the Republic of Korea

Republic of Korea trawl fisheries for alfonsino in the North Pacific Ocean occurred mainly from 1998 to 2009 (Seok, 2012). In June–September 2004, the Republic of Korea carried out experimental trawl and longline fishing operations on the SE–NHR seamounts targeting armourhead and alfonsino although the catch of alfonsino was less than one tonne in 2004. The depths of the trawl and long-line fishing grounds of the Republic of Korea are 100–500 m and 250–1 050 m, respectively. The total catch of all alfonsino from the Pacific Ocean from 1998 to 2011 by vessels of the Republic of Korea, all gear types combined, was about 2 721 tonnes (Table 21). The fisheries for alfonsino show that the catches were variable from 4 to 658 tonnes in the period 1998–2011. The catch peaked in 2005 and then gradually declined until 2010.

TABLE 21
Nominal catch (tonnes) of alfonsino by the vessels of the Republic of Korea in the Pacific Ocean, 1998–2011, estimated by distant-water fishery information system of the Republic of Korea

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998
North-west	41	86	88	0	0	305	0	0	0	0	0	0	0	0
West-central	0	0	0	105	237	0	464	0	0	0	0	0	0	0
East-central	0	0	0	0	131	0	0	0	0	0	0	0	0	0

Source: Seok (2012)

3.5 The South Pacific Ocean

3.5.1 Norfolk Ridge

Exploratory fishing by Soviet and Japanese vessels occurred in the mid–1970s on seamounts of the Norfolk Ridge, which runs between New Zealand and New Caledonia. This ridge has a large number of peaks that rise to less than 1 000 m below the surface while towards New Caledonia there are more isolated seamounts and guyots (Clark *et al.* 2007).

In 1980 and 1986, Japanese and French vessels carried out exploratory bottom trawling between 220 and 690 m on the Norfolk Ridge and the Lord Howe Rise. Catches consisted mainly of alfonsino, boarfish (*Pseudopentaceros richardsoni*, and *P. japonicus*), and ruby snapper (*Etelis carbunculus* and *E. coruscans*). The total catch by a Japanese vessel over 14 days was estimated at 140 tonnes (Grandperrin and Richer de Forges, 1988). New Zealand vessels are also reported to have entered this fishery, at least for 2011.

3.5.2 New Caledonia

Five seamounts off New Caledonia, ranging in depth from 500 to 750 m at their summit, were fished by bottom longline between 1988 and 1991. Three vessels were allowed to fish inside the New Caledonian EEZ, although only one vessel operated at any given time. The main target was alfonsino and this constituted 92 percent of the total catch of 1 169 tonnes (Lehodey, Marchal and Grandperrin, 1994; Lehodey and Grandperrin, 1996a,b). Although an active research programme has been carried out in the EEZ, with a focus on deepwater species no further commercial stocks have been found and the alfonsino fishery has not resumed (Clark *et al.* 2007).

3.5.3 Lord Howe Rise

The Lord Howe Rise extends from the northwest margin of the Challenger Plateau, off the west coast of New Zealand, north to Lord Howe Island in the western Tasman Sea. The ridge is mostly in international waters although it extends into both the Australian and New Zealand EEZs (Clark *et al.* 2007).

A major fishery developed on the main ridge top near the southeast end of the Lord Howe Rise in 1988 when a Japanese commercial vessel discovered spawning aggregations of orange roughy (Clark and Tilzey, 1996). The fishery expanded rapidly as vessels from New Zealand, Australia, the Republic of Korean, the then Soviet Union and Norway joined. However, catches declined and the fishery then progressively shifted to small seamounts on the edges of the Northwest Challenger Plateau. Since the early 1990s only New Zealand and Australian operators have fished this area. The total estimated catch from 1988 to 2004 was 13 600 tonnes. The bycatch in the fishery is small although some black cardinalfish (*Epigonus telescopus*) have been taken and bottom trawling directed at alfonsino has occurred on sections of the northern Lord Howe Rise (Clark *et al.* 2007). Sampaklis *et al.* (2007) in Anon. (2009) reports that the Australian catches of alfonsino between 1997 and 2006 amounted to 311 tonnes, mainly from the Lord Howe Rise. New Zealand vessels are also reported to have entered this fishery at least for 2011.

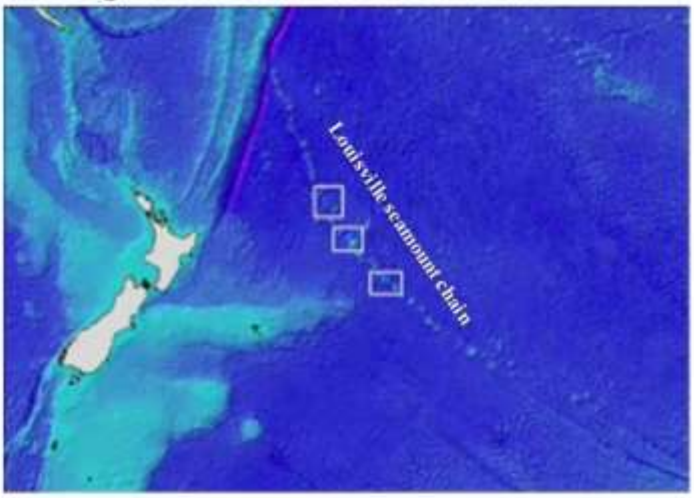
3.5.4 Louisville Ridge

The Louisville ridge (Figure 18) is a chain of seamount and guyot features extending for more than 4 000 km northeast from the North Island of New Zealand. It is a seafloor "hotspot" that comprises more than 60 seamounts, most of which rise to peaks of 200–500 m from the surrounding seafloor at depths of about 4 000 m. The ridge is entirely in international waters (Clark *et al*., 2007).

Exploratory vessels from the then Soviet Union found 14 seamounts with summit depths less than 1 000 m during operations in 1977. Quantities of cardinalfish (*Epigonus pectinifer*, *E. denticulatus* and *E. geracleus*) were found on two of these seamounts with catches between 10 and 50 tonnes per day. A third seamount produced small catches of alfonsino (Polishchuk *et al*., 1989; Boldyrev and Darnitsky, 1991). Exploratory vessels caught a total of 10 000–12 000 tonnes of fish but the Soviet commercial fleet did not fish on this ridge. Japanese commercial vessels are known to have fished on the Louisville Ridge in the 1980s catching alfonsino and bluenose (Clark *et al*., 2007) but no published information is available on these activities.

FIGURE 18

Louisville seamount chain to the east of New Zealand, first detected in 1972. Fishing has concentrated on three regions that contain seven seamounts.



Source: modified from NIWA, New Zealand

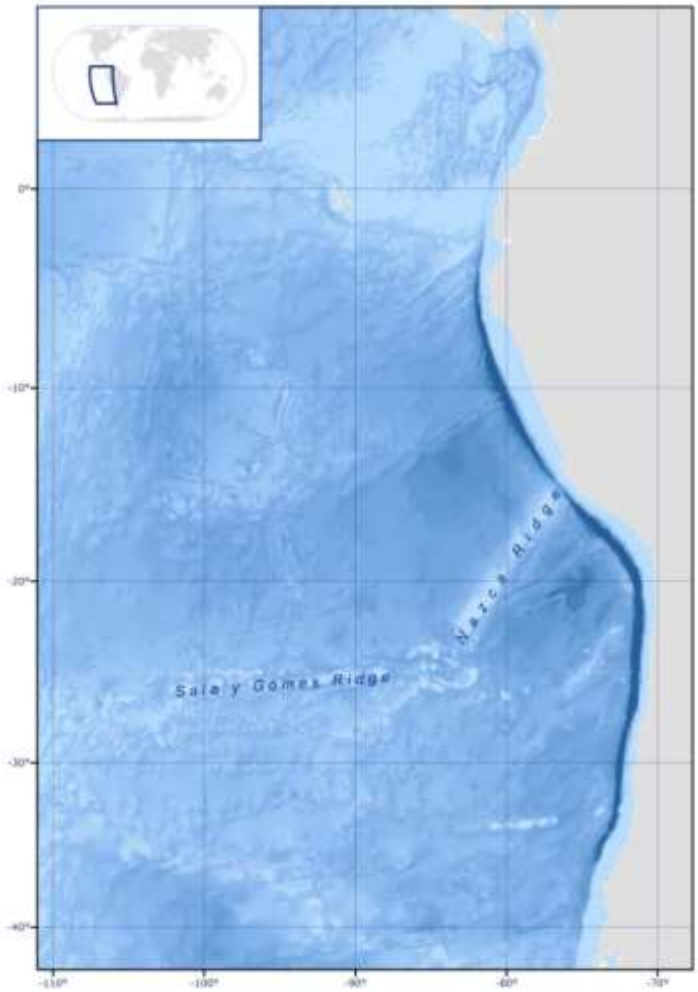
A New Zealand longline commercial fishery began on these seamounts in the early 1990s for species such as alfonsino. A more significant bottom trawl fishery for orange roughy developed in 1993 that saw more than 30 trawlers working the seamounts in 1995, mainly vessels operating out of New Zealand but also including charters or joint-venture operations with countries such as the Republic of Korea, Japan, the Russian Federation and Ukraine. Australian vessels also participated in this fishery (Clark, 2004) but there is apparently no information available as to the alfonsino catch.

3.5.5 Nazca and Sala y Goméz Ridges

The Nazca Ridge is located in the Southeast Pacific between 15-25°S and 76-82°W (Figure 19). Most of the seamonts of the ridge are in international waters and only the northeast part is within the 200-mile EEZ of Peru. In the southwest the Nazca Ridge is joined by the Sala y Goméz Ridge (24-27°S, 84-102°W). There are at least 40 seamounts with a summit depth of less than 1 000 m but the ridges have not been thoroughly explored (Clark *et al.*, 2007).

A fishery for horse mackerel (*Trachurus murphyi*) and redbaits (*Emmelichthys elongates* and *E. nitidus*) was conducted by vessels of the Soviet Union in 1978 and 1979 with catches of 2 100 and 5 100 tonnes, respectively. Concentrations of alfonsino were also found on two seamounts (Anon., 1980, 1985; Dalimaev *et al.*, 1980; Riabikov and Fomin, 1981; Parin, Mironov and Nesis, 1997) but no reliable catch statistics for the area are known. According to data submitted to the SPRFMO Deepwater Working Group, available at www.southpacificrfmo.org, (Anon., 2009) the reported catch of alfonsino taken by vessels of the Soviet Union beyond EEZs in the South Pacific region between 1979 and 1984 was 3 336 tonnes.

FIGURE 19
Map of the Sala y Goméz and Nazca Ridges in the Southeast Pacific

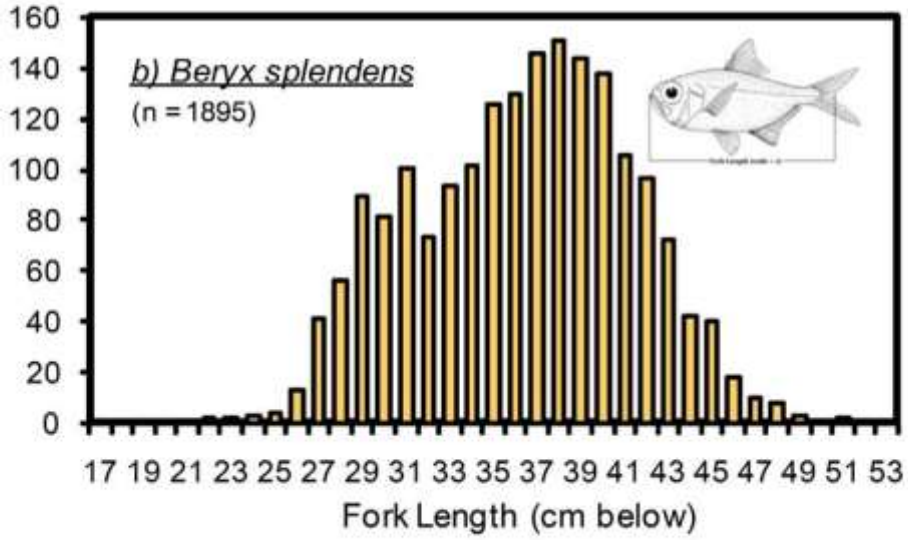


Sources: Map generated by FAO (*sources*: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors)

3.5.6 The New Zealand high seas fishery

Vessels flagged in New Zealand began midwater trawling for the first time in the high seas area north and northwest of New Zealand (North and South Lord Howe Rise, West Norfolk Ridge, Three Kings Rise, Louisville Ridge and NW Challenger Plateau) in 2011 (SWG, 2012a). Three trawlers in 61 tows caught 64 tonnes of alfonsino. The main catch was of southern boarfish (75 tonnes). Alfonsino ranged in length from 21 to 53 cm with an average of 36.2 cm (Figure 20). Between 1991 and 2005 the reported total New Zealand catch of alfonsino taken outside the New Zealand EEZ within the Southwest Pacific region was more than 1 000 tonnes (Anon., 2009).

FIGURE 20
Length distribution of alfonsino caught by the New Zealand high-seas fleet north and northwest of New Zealand in 2011



Source: SWG (2012a)

There was a substantial increase in the catch of alfonsino in 2010 and this was maintained in 2011. Table 22 shows the annual fishing effort and catch of alfonsino in by New Zealand vessels bottom trawling in the convention area of the South Pacific Regional Fisheries Management Organisation (SPRFMO).

3.5.7 Russian Far East South Pacific Fishery

Between 1979 and 1984 the reported catch of alfonsino taken by vessels of the Soviet Union beyond EEZs in the South Pacific region was 3 336 tonnes (Russian data submission to the SPRFMO Deepwater Working Group, available at www.southpacificrfmo.org; Anon., 2009).

3.5.8 The Australian EEZ fishery

Alfonsino is fished in Australia by the East Coast Deepwater Trawl Sector using demersal and midwater trawls (Stobutzki, Rodgers and Pham, 2010). Other bycatch species include blue-eye trevalla (*Hyperoglyphe antarctica*), boarfish (*Pseudopentaceros richardsoni*) and orange roughy. Effort in the east coast deepwater fishery has been low since 2007. A single trip took place in the 2009–10 fishing season, landing 14 tonnes, and there were no trips in the 2010–11 fishing season. Since 2000, 1 298 tonnes of alfonsino have been landed from the East Coast Deepwater Trawl Fishery and 249 tonnes in the Commonwealth Trawl Fishery, which is not covered by quota.

TABLE 22
Annual fishing effort and catch of alfonsino by New Zealand vessels bottom trawling in the SPRFMO area

Fishing year	No. of vessels	No. of tows	Alfonsino (tonnes)
2002	23	2 944	2 578
2003	19	2 928	1 973
2004	17	1 952	1 697
2005	17	2 186	1 597
2006	12	1 135	1 415
2007	8	415	866
2008	4	208	837
2009	6	547	928
2010	7	1 167	1 474
2011	7	1 158	1 079

Source: SWG (2012a)

Sampaklis *et al.* (2007) in Anon. (2009) report that the Australian catches of alfonsino between 1997 and 2006 amounted to 311 tonnes, mainly from Lord Howe Rise. Ward, Roach and Hobsbawn (2012b) report a small Australian catch from the northern area of the Tasman Sea. The target species in this fishery was orange roughy. Catch of *B. decadactylus* showed fluctuations in CPUE over time (Table 23).

TABLE 23
Number of active high seas vessels, effort and annual catch of alfonsino using trawls in the SPRFMO area, 1987–2011
(Catch in tonnes and nominal CPUE in tonnes/trawl h in parentheses)

Year	No. vessels	Effort (trawl h)	*B. decadactylus*
1997	10	396	1 (0)
1998	12	916	1 (0)
1999	10	777	8 (0.01)
2000	12	752	4 (0)
2001	9	307	1 (0)
2002	8	196	3 (0.01)
2003	9	102	2 (0.02)
2004	5	48	1 (0.02)
2005	3	29	81 (2.81)
2006	3	104	209 (2.02)
2007	2	70.7	86 (1.21)
2011	1	91.8	47 (0.51)

Note: No trawl effort or catch were recorded for the SPRFMO area in 2008, 2009 and 2010

3.5.9 The New Zealand EEZ fishery[4]

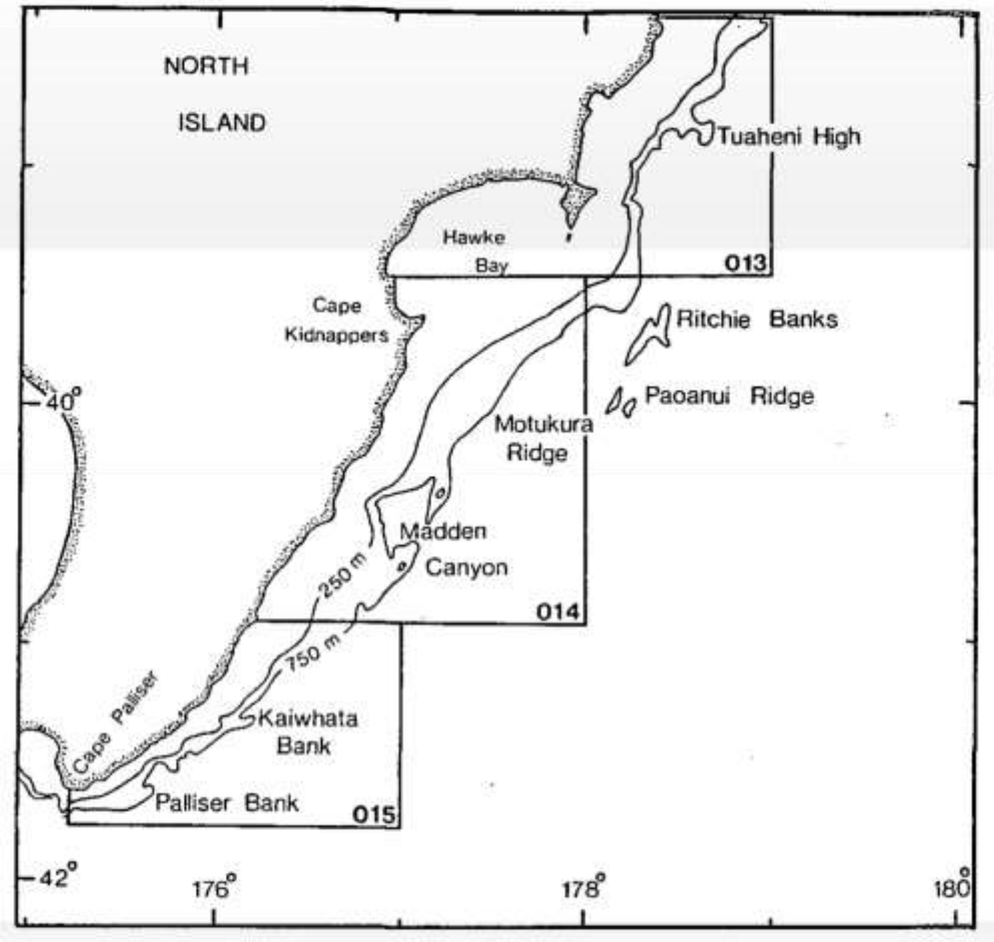
Development of the fishery

The main alfonsino fishery in New Zealand is centred on seamounts or submarine hill complexes along the east coast of the lower North Island (Quota Management Area [QMA] BYX[5] 2 shown in Figure 21) in depths of 300–600 m (Horn and Sutton, 2009; Figure 21 shows the alfonsino QMAs in the New Zealand EEZ). About one-quarter of alfonsino caught is taken as bycatch. Catch data from research trawl surveys show that the species is distributed continuously along the northern edge of Chatham Rise but there is an apparent gap between Mernoo Bank and the southern Wairarapa coast (Anderson *et al.*, 1998), although this may be an artefact of the data based on fewer trawl hauls. A moderate fishery for alfonsino, both targeted and bycatch, occurs in the southern Cook Strait south to the Kaikoura region and extending out to Mernoo Bank.

[4]The FAO species code for *Beryx* spp. Is BYX.

[5]Subsequent to the completion of this document, a comprehensive review of alfonsino fisheries in New Zealand has been produced by MacGibbon (2013). The material in MacGibbon's report has not been reviewed here.

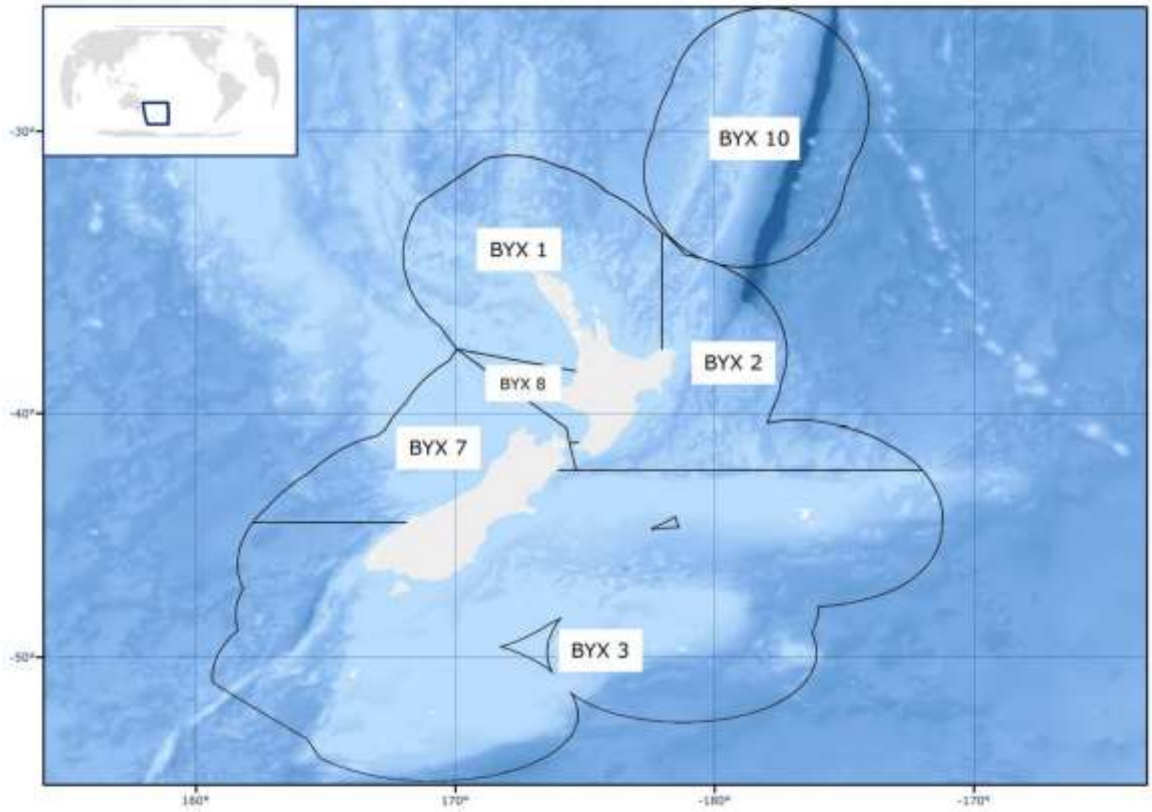
FIGURE 21
Trawl grounds for alfonsino off the lower east coast of the North Island of New Zealand. Fishing return areas 013 – 015 are aslo shown



Source: Horn (1988)

Domestic target fishing using conventional bottom trawls began in 1983 on grounds between Cape Palliser and Cape Kidnappers although commercial quantities of alfonsino have been landed since the late 1970s (Smith and Paul, 2000) by a longline fishery for alfonsino, grouper, and ling to the southeast of the Chatham Islands (Annala, Sullivan and O'Brien, 2000). The major New Zealand fishery for alfonsino in the EEZ has been off the east coast of the North Island in QMA BYX 2 (Figure 22), where the species is taken by a midwater trawl fishery. This fishery was initially concentrated on banks and seamounts between Gisborne and Cape Palliser, but more recently it has concentrated in the northern part of QMA BYX 2. The northern boundary of QMA BYX 2 at Cape Runaway effectively defines the northwest limit of the present fishery, but it may extend westwards to the Bay of Plenty seamounts. In the decade from 1983–84 to 1993–94 the total landings ranged from about 1 500 to 2 000 tonnes and increased to almost 3 000 tonnes in the late 1990s, which exceeded the quota of 2 727 tonnes.

FIGURE 22
Quota Management Areas for alfonsino in the New Zealand EEZ



Source: New Zealand Ministry of Primary Industry

The aimed-trawl alfonsino fishery off the east coast of the South Island of New Zealand has developed relatively recently, particularly to the southeast of the Chatham Islands. In this area fishing was seasonally and spatially segregated with most of the increase in catch between 1996 and 2000 coming from underwater "hill" features to the southeast of the Chatham Islands during the summer (November-February). Bottom trawls took more than 80 percent of the catch; the rest was taken by midwater trawl.

The catch on the Palliser Bank and Motukura Ridge rose rapidly, particularly after the introduction of a semi-pelagic trawl design that enabled fishing over foul ground. In 1985 the Tuaheni High and Paoanui Ridge became important alfonsino grounds and since 1986 significant catches have been taken from the Madden Canyon and Kaiwhata Bank (Horn, 1988).

Fishing methods
Almost all (99.6 percent) of the New Zealand alfonsino catch is taken by semi-pelagic trawl of which 59 percent is by near-bottom bentho–pelagic trawling. The remaining 0.4 percent is bycatch taken on lines and in deepwater set nets. The decline in line catches and increase in set-net catches are correlated with a reduction in line fishing for bluenose in the Central East area and an increase in set netting for bluenose in the Bay of Plenty.

Species taken
Most alfonsino caught are *Beryx splendens*; the rest are *Beryx decadactylus* (red bream in New Zealand). Past *B. decadactylus* catches were higher than recorded landings would indicate because of coding errors, but the catch of this species is still thought to have been small. Most *B. decadactylus* are caught in the Auckland fisheries management area.

A recent development in the trawl fishery since the 1986–87 fishing year has been an apparent increase in the catch of bluenose relative to alfonsino. This has caused appreciable management problems in the fishery. Another recent change in the nature of the fishery has been from mainly day fishing in 1983-84 to almost exclusively night fishing by 1986. This has probably resulted from fishers obtaining a better understanding of alfonsino behaviour. Bycatch of other than alfonsino in this fishery had been 150-200 tonnes per year, of which more than 60 percent was bluenose warehou.

For the period from 1989–1990 to 1998–1999, 68 percent of the alfonsino catch was targeted and of the amount recorded with another target species, 48 percent was recorded as a bycatch of the hoki fishery that also occurred in the same area, 20 percent bycatch of the orange roughy fishery, 11 percent bycatch of the bluenose fishery, 10 percent bycatch of the cardinalfish fishery and 5 percent bycatch of the gemfish (*Rexea solandri*) fisheries. There are differences in the extent of targeting between quota management areas. In QMA BYX 2, 74 percent of the alfonsino catch is targeted, nine percent is a bycatch of the hoki fishery that also occurs in the same area and the remainder is taken about equally when targeting orange roughy, cardinalfish, bluenose and gemfish in that area. Only 42 percent of the alfonsino catch is targeted in QMA BYX 3 with 55 percent being taken as a bycatch in the large Cook Strait hoki fishery of that area. In QMA BYX 4, 67 percent of the alfonsino catch is targeted, 15 percent is bycatch of the orange roughy fishery and 13 percent is bycatch of the hoki fishery on Mernoo Bank.

Monthly catches vary erratically on all grounds. The general absence of landings in July–August results from the diversion of trawlers to other fisheries. Good catches of alfonsino on one ground can influence landings from another. As most vessels involved in this fishery are based in Nelson they search Palliser Bank at the start of a trip and only move to grounds farther north if there are no fish or catches are poor. Hence, peaks in Motukura Ridge catches in April and November 1984 coincide with troughs in Palliser Bank landings. Palliser Bank and Motukura Ridge landings dropped appreciably in 1985 because of an apparent reduction in the amounts of fish on these grounds. Search times appear to have increased, but catches still fell. The overall catch was maintained by increased catches on the Tuaheni High and to a lesser extent from the Paoanui Ridge.

The BYX fishery tends to be most active at the start of the fishing year from October to January, but significant landings can occur in any month. The largest and most consistent catch of alfonsino has been taken from QMA BYX 2. The TAC for QMA BYX 2 has been about 1 570 tonnes since the 1993-94 fishing year. Annual landings have exceeded the total allowable commercial catch (TACC) in all but two years since then, generally by 70–300 tonnes. Landings have fluctuated between 1 262 and 1 868 tonnes per year since 1985–86. The 1 400–1 500 tonnes estimated catch from QMA BYX 2 is less than the 1 500-1 800 tonnes reported by Annala, Sullivan and O’Brien (2000). These amounts are around, or exceed, the TAC, which increased to 1 274–1 575 tonnes over this period. The largest alfonsino catches have been taken from around Ritchie Hills and Madden Bank and lower catches have been taken from the northern part of the Ritchie Hills complex. Consistently high catches have also been taken from the complex of hills off the Wairarapa coast. In 2006–07 significant landings were spread throughout the year, which contrasted with the fisheries from 1998 to 2001 and in 2007–08 when most significant landings occurred at the start of the fishing year.

The annual catch from the QMA BYX 3 fishery was less than 300 tonnes before the 1994–95 fishing year but increased rapidly from the Chatham Rise part of QMA BYX 3 (QMA BYX areas 3, 4, 5 and 6) from 1994–95 and has generally been 200–300 tonnes, reaching 400 tonnes in 1995 and 1996 from the Kaikoura region with small catches on the western Mernoo Bank. Between 1995–96 and 1998–99 the total catch from the QMABYX 3 fishery was close to the TACC of 1 010 tonnes although the annual catch declined to 743 tonnes in 1999–2000 (Annala, Sullivan and O’Brien, 2000).

Catches in QMA BYX 4 reached 200 tonnes in the 1994 and 1995 fishing years, and from 1996 to 1999 were 700–900 tonnes. There were small catches on the eastern Mernoo Bank and along the northern Chatham Rise, but the largest catches have been made east and southeast of the Chatham Islands, mainly since 1996.

Catch by season

In 2006–07 landings were spread throughout the year in contrast to 1998–01 and 2007–08 when most landings occurred at the start of the fishing year. Otherwise, in QMA BYX 2, peak catch was from

September to February because of the relatively large targeted catch for alfonsino and also because of the alfonsino bycatch taken with bluenose, cardinalfish, hoki, and gemfish (*Rexea solandri*). In QMA BYX 3, the targeted alfonsino catch usually peaked in January and February and again in August and October. The alfonsino 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 alfonsino grounds. In QMA BYX 4 the highest catches of alfonsino were consistently taken from September to March and occurred whether alfonsino were targeted or taken as bycatch.

In QMA BYX 2, 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 one of highest catches in spring and/or summer, but with regional and annual variations. The catch in QMA BYX 4, principally taken from east of the Chatham Islands, has a strong pattern of higher spring and/or summer catches.

Catch size composition

Commercial catch size-frequency data of 930 fish caught in 1994–95 showed two strong modes, at 20-21 cm and 25–28 cm fork lengths. A larger time series of length frequency data from the trawl survey data (1991–2000) shows a declining proportion of fish in larger length classes; however, the survey biomass estimates from these data are highly variable.

Horn and Sutton (2009) describe the sampling programme for alfonsino in QMA BYX 2 in the 2006-07 and 2007–08 fishing years and the subsequent estimates of catch-at-age. Sampling of the alfonsino QMA BYX 2 catch occurred in the three fishing years from 1998–99 to 2000–01 (Blackwell *et al*., 2001) and in 2006–07 (Horn, 2009). In 2006–07 fish from 3 to 8 years were abundant in the catch, but with a strong mode at ages 4 and 5. There is a clear difference in the age distributions of the catch from the earlier (1998–2001) and later (2006–08) sampling periods, but it is not clear why. In the earlier samples ages 5-9 dominated the catch. However, consistencies within both the earlier and later sampling periods suggest that the sampling may be producing a reasonable representation of the total catch. Fishing mortality is estimated to have increased over the sampling period from 1998 to 2008.

Male lengths ranged from 21–48 cm; female lengths ranged from 26–50 cm. The male length mode (31–34 cm) is smaller than the female mode (32–36 cm).

The age-frequency distributions from 2006–07 are noticeably different from the three samples taken from 1998–99 to 2000–01 (see Table 24). The dominant age classes in 2006–07 were four and five. In the earlier samples, 5–9 year olds dominated in the catches.

In 2007–08, male lengths ranged from 20 to 44 cm and female lengths from 21 to 49 cm. The male length mode (31–35 cm) was smaller than the female mode (33–36 cm). The most abundant age classes in 2007–08 were the four and five year age classes as in 2006–07; the dominant four-year old fish in 2006-07 appeared to have progressed to the dominant five-year age class in 2007–08. In the earlier samples, age classes 5–9 dominated the catches.

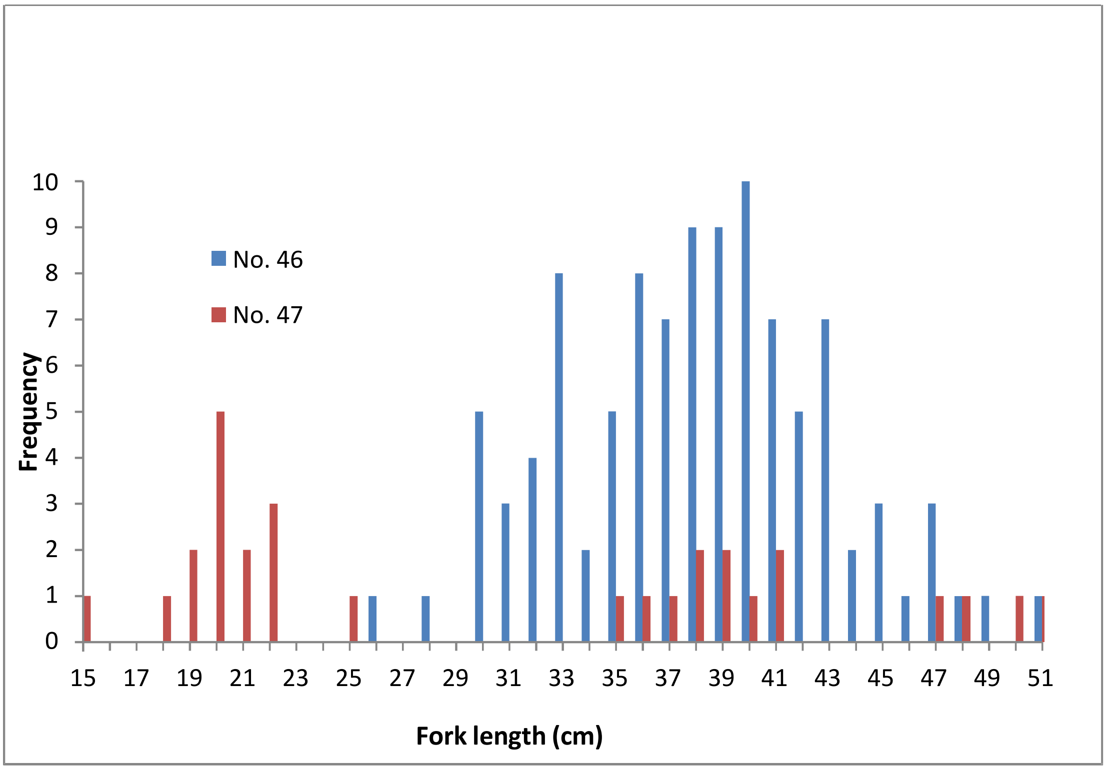
Past investigations of alfonsino landings by Horn and Massey (1989) and Massey and Horn (1990) indicated that length-frequency distributions and thus age-frequency distributions can vary markedly between fishing grounds in the same year. Thus, sampling should consider this potential variability by stratifying for fishing ground. Figure 23 shows the length frequency obtained by the FV *Fukushu Maru* in the Tasman Sea in 1990 (no other information is available).

TABLE 24
Percentage catch-at-age from catch sampling in the New Zealand alfonsino quota management area 2 (QMA–BYX 2) in 2006–07 and 2007–08

	2006–07		2007–08	
Age	**Males**	**Females**	**Males**	**Females**
1	0.2	0.0	0.2	0.2
2	0.4	0.1	2.6	1.0
3	5.4	4.4	7.4	5.0
4	18.5	14.3	11.2	12.0
5	9.1	12.3	14.8	14.2
6	4.8	3.8	6.4	8.0
7	2.0	4.4	3.7	3.4
8	2.5	5.0	1.2	3.1
9	0.9	3.5	0.7	1.7
10	1.0	2.3	0.3	1.9
11	0.3	1.0	0.3	0.3
12	0.2	0.8	0.1	0.1
13	0	0.8	0.0	0.2
14	0	0.4		

Source: Horn and Sutton (2009)

FIGURE 23
Length frequency of alfonsino caught by the FV *Fukushu Maru* in the Tasman Sea, 1990



3.5.10 South Pacific fishery of the Republic of Korea

Table 25 shows reported catches by vessels of the Republic of Korea in the Southwest Pacific Ocean for the period 1998–2011 (Seok, 2012).

TABLE 25
Reported catches by vessels of the Republic of Korea in the Southwest Pacific, 1998–2011

Year	Catch (tonnes)
1998	77
1999	230
2000	0
2001	47
2002	0
2003	0
2004	0
2005	194
2006	0
2007	0
2008	0
2009	50
2010	0
2011	0

Source: Seok (2012)

3.5.11 Southeast Pacific Ocean

In 1998–99, two New Zealand vessels, the FV *Amatal Explorer* and FV *Pakura*, undertook commercial/exploratory fishing programmes of deepwater seafloor features in this area. The former surveyed from New Zealand eastwards to Easter Island and the latter from Easter Island down to latitude 46°S and across a chain of underwater features to just outside the Chilean EEZ and then north up to the Nazca and Goméz Ridge area. Moreover, in a programme with Chilean agencies, one of the FV *Pakura* skippers worked on a programme that continued to the east of San Ambrosia Fellipe Island and out to the edge of the Sala y Goméz Islands ridge area and then southwards to the Juan Fernández Islands inside the Chilean EEZ. Vessels from other countries were also entering the fishery at this time.

The seafloor features in this area were found to range from extremely rough and deep that were nearly impossible to fish to those that were flat-topped and relatively shallow. Although the abundance of orange roughy resources was found to be disappointing in the areas searched at that time of year, abundant stocks of alfonsino and armourhead were encountered. Such alfonsino resources are now under the jurisdiction of the SPRFMO and their future exploitation will be subject to the new fisheries conservation regulations of this regional fisheries management organization.

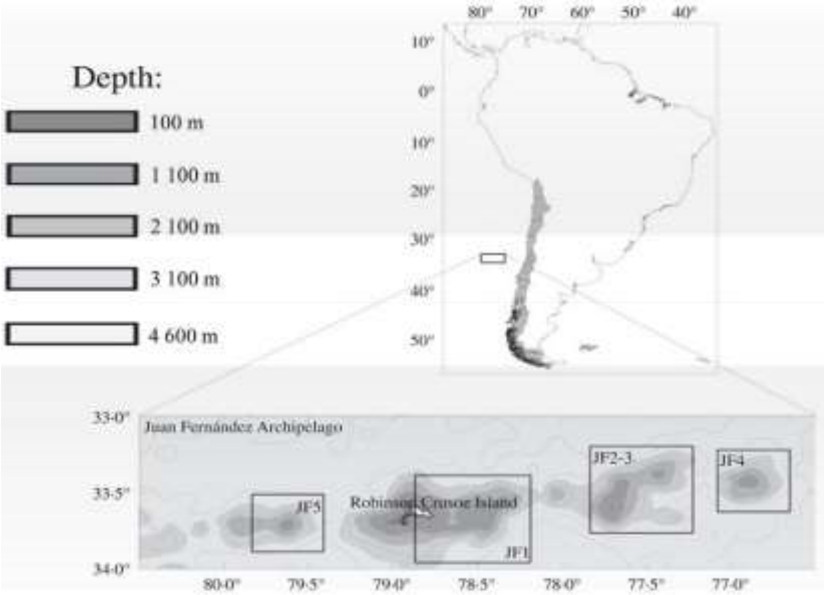
3.5.12 Chilean EEZ

Development of the fishery

Landing records in Chile show that this species was fished principally over the seamounts located in the Juan Fernández Islands and to a lesser extent in the Bajo O’Higgins area and the continental slope between 32°S and 40°S (Figure 24). The fleet consists of a few industrial trawling vessels that operated primarily in depths between 300 and 500 m in 1998. Although this species has been fished since 1989, its landings only became important from 1999 (around 700 tonnes) coinciding with the developing orange roughy fishery. In 2001, landings of alfonsino showed a large increase (up 500 percent) with respect to previous years (Subpesca, 2004).

In 1989, the first registered landings of alfonsino were 30 tonnes from the industrial fleet and 17 tonnes from the artisanal fleet. Until 1997 few alfonsino were landed (e.g. 1 tonne in 1996) but otherwise landings were about 12 tonnes per year. The fishery began in earnest in 1998 when144 tonnes were landed and this increased by 1 300 percent from 1999 to 2003. Fishing was mainly in the area of the Juan Fernández Islands with landings at Talcahuano.

FIGURE 24
Location of the Juan Fernández Islands

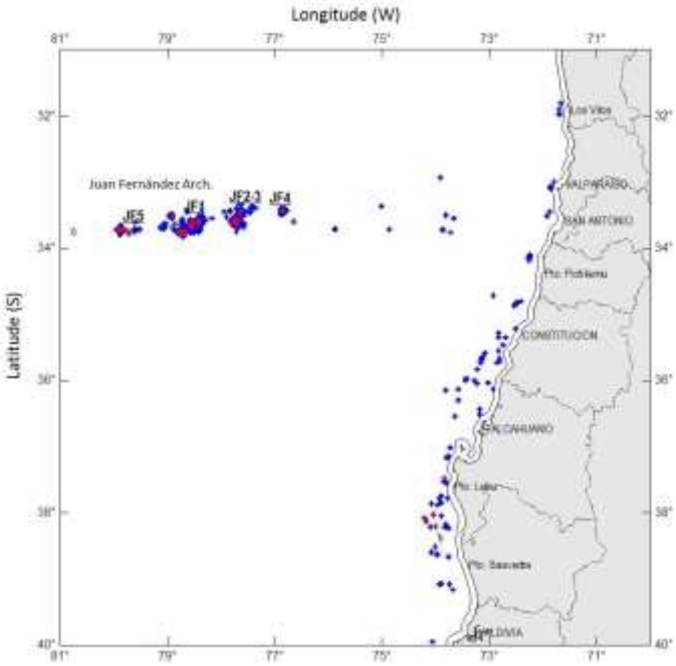


Source: adapted from Flores *et al.* (2012)

Fishing grounds
The major fishing grounds (Figure 25) were traditionally the seamounts of the Juan Fernández Islands – Nazca and Sala y Gomez submarine ridges, although other grounds were also exploited.

Catch rates showed a tendency to fall, and their interpretation typically requires a month for examination. The first period of the fishery was until July 2003, during which period there were no restrictions on operations. The second period started in August 2003, during which there were limits on catches and the fishery followed the "Olympic race" model (Figure 25). In some situations there was a decreasing trend in catch rate particularly in the second period.

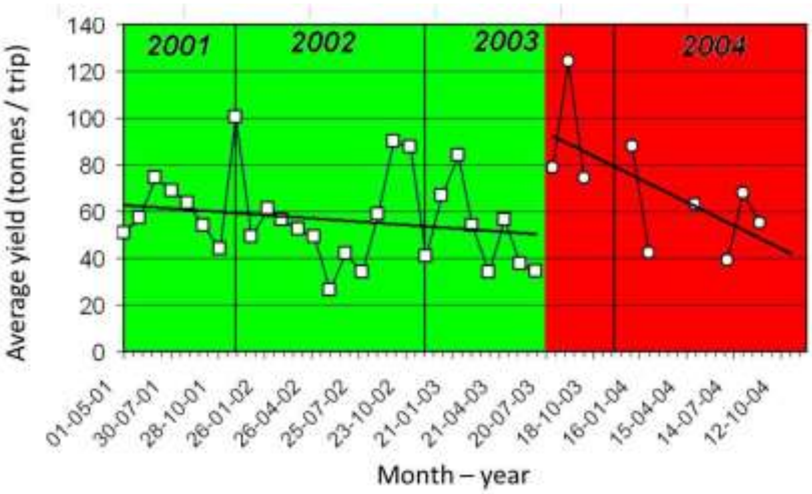
FIGURE 25
Alfonsino fishing grounds, Chile



Source: adapted from Wiff (2012)

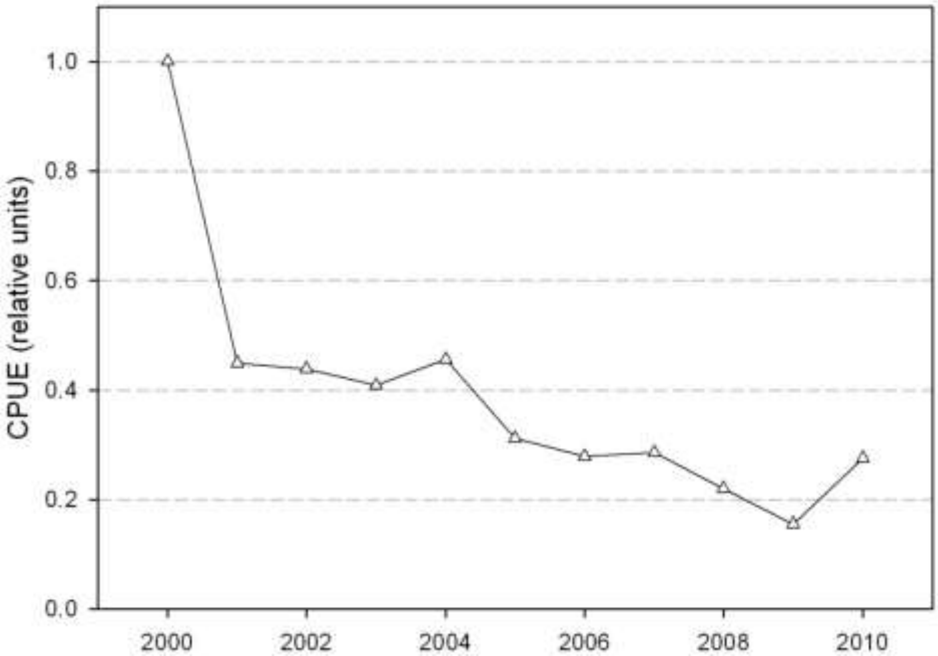
Catch rates and effort
The highest catch rates and landings were reported from the seamounts JF1 and JF2-3 (Figure 26). Both areas have shown a decrease in catch rates, in JF1 from a maximum of 5.5 tonnes per haul in 2003 to 3 tonnes per haul in 2010. In JF2–3 a maximum of 5.5 tonnes per haul was reported in 2001 decreasing to 1.2 tonnes per haul in 2010. Seamounts JF4 and JF5 had lower catch rates and did not show a clear trend over time. Catch rates of the whole Juan Fernández area show a decline from 4 tonnes per haul in 2001 to 2.2 tonnes per haul in 2010. A decrease in the number of vessels targeting this resource has been observed since 2006 and total landings of alfonsino were declared by few vessels at the end of each year. In 2010, the fewest hauls were undertaken since 1998. Landings until August 2004 increased to 664 tonnes, of which 393 tonnes caught during research cruise and the TAC was exceeded by 189 tonnes. Figure 27 shows how the CPUE declined in the period 2000–2012. The annual stock assessment programme done since 2005 indicates that the resource was overfished in 2010 (Wiff, 2012).

FIGURE 26
Trend in catch rates, 2001–04



Source: adapted from Subpesca (2004)

FIGURE 27
Indices of abundance 2000–2012

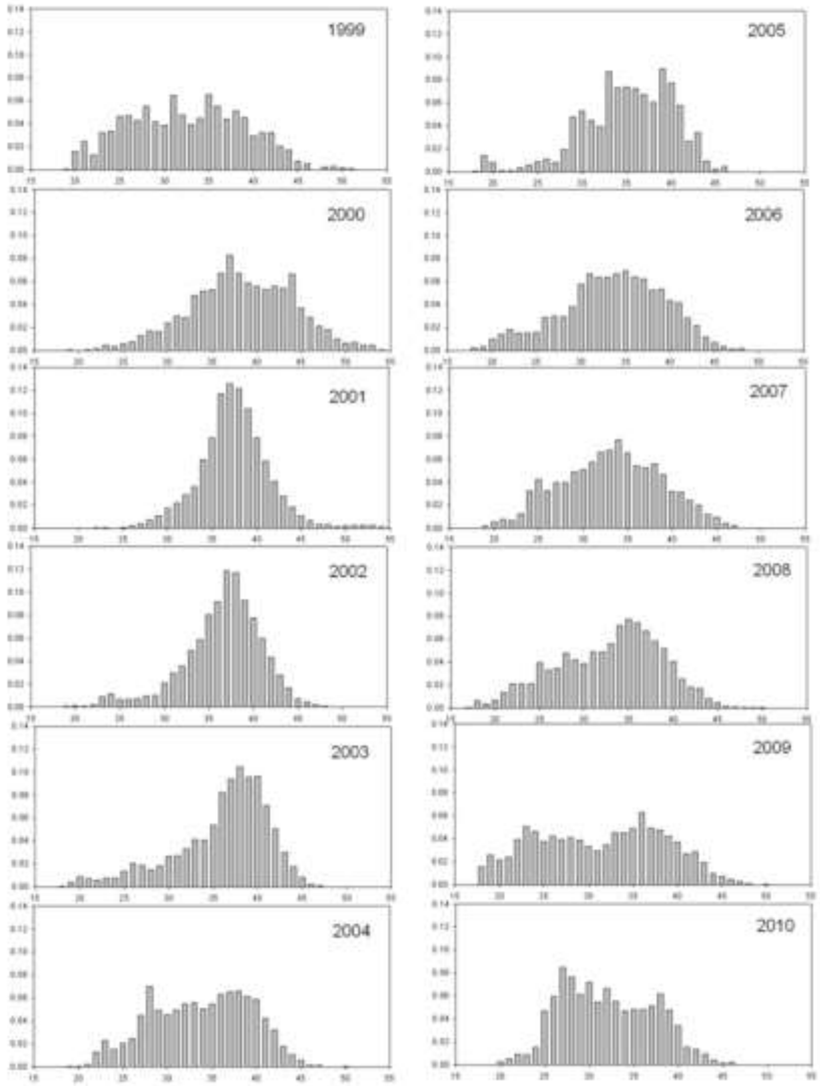


Sources: Wiff (2012)

Length frequency of catch

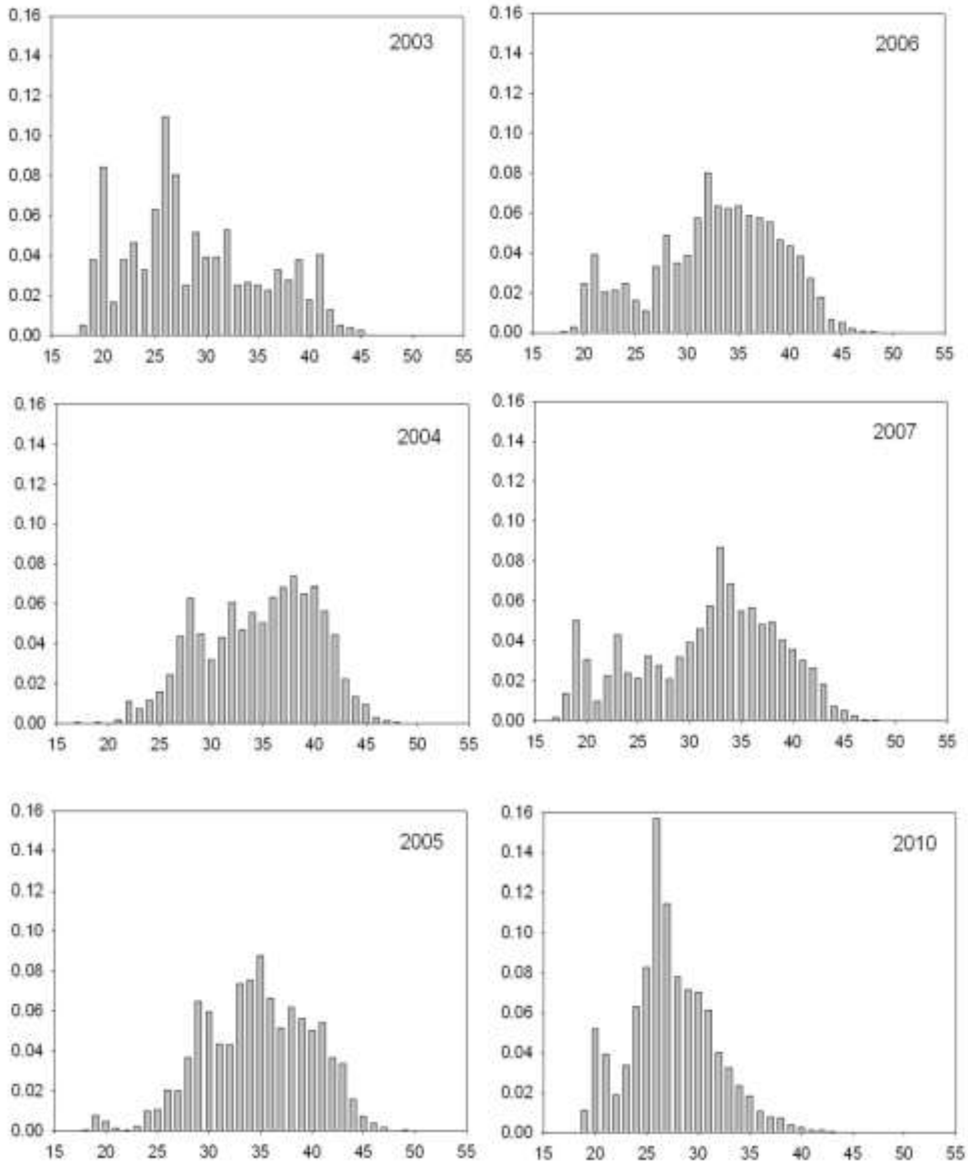
Length distribution of alfonsino from the fishing monitoring programme (Figure 28) and acoustic surveys (Figure 29) show high variability among years. This was unexpected and may have been caused by: (i) merging data from different seamounts; (ii) variation in length/age according to depth; and (iii) variation in fishing tactics such as alternating fishing grounds with time **(**Wiff *et al*., 2012).

FIGURE 28
Alfonsino length frequency distribution of catch from the fishing monitoring programme 1999-2010



Source: Wiff *et al.* (2012)

FIGURE 29
Length frequency distribution of alfonsino caught during acoustic surveys, 1999–2010



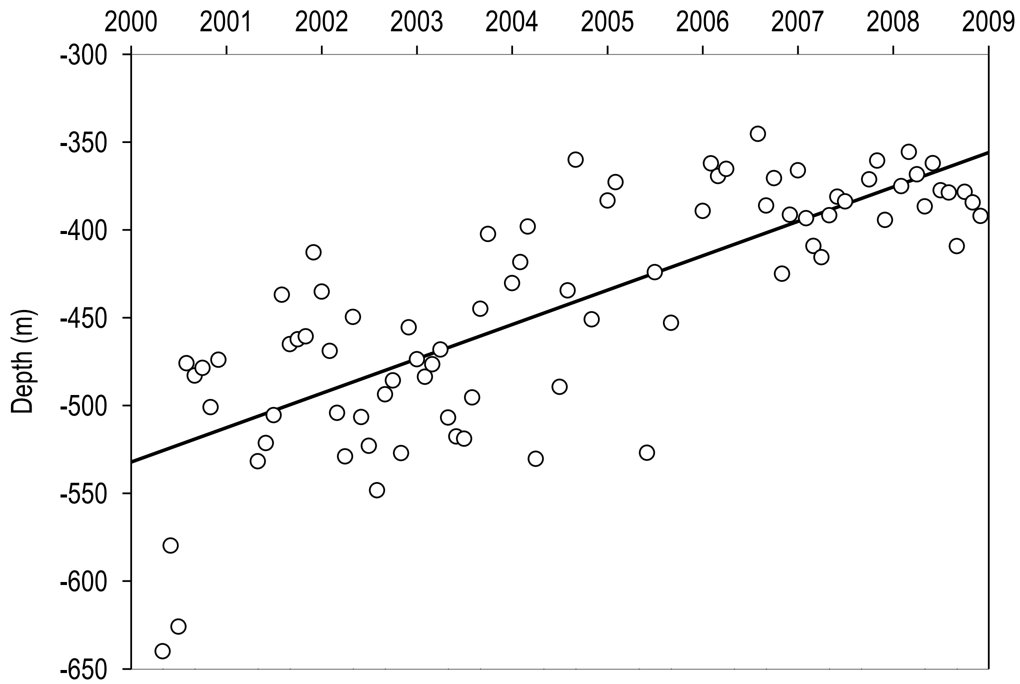
Source: Wiff *et al.* (2012)

Samples of fish lengths taken in 2003 showed a range of 17–49 cm with an average of length of 34.9 cm. The average length of mature females ranged from 18 to 49 cm with a mean of 36 cm while for males the corresponding values were 17-47 cm with an average length of 33.3 cm. Since 2002 there has been a reduction in the mean size of females from 40 to 36 cm with a reduction of 12 cm in the maximum size, from 61 to 49 cm. In all zones a multimodal length-frequency distribution occurred with the principle mode around 38 cm. For males the mode was around 37 cm and for females in the range of 39–41 cm. A second minor mode occurred around 26 cm corresponding to juvenile fish.

Depth of capture

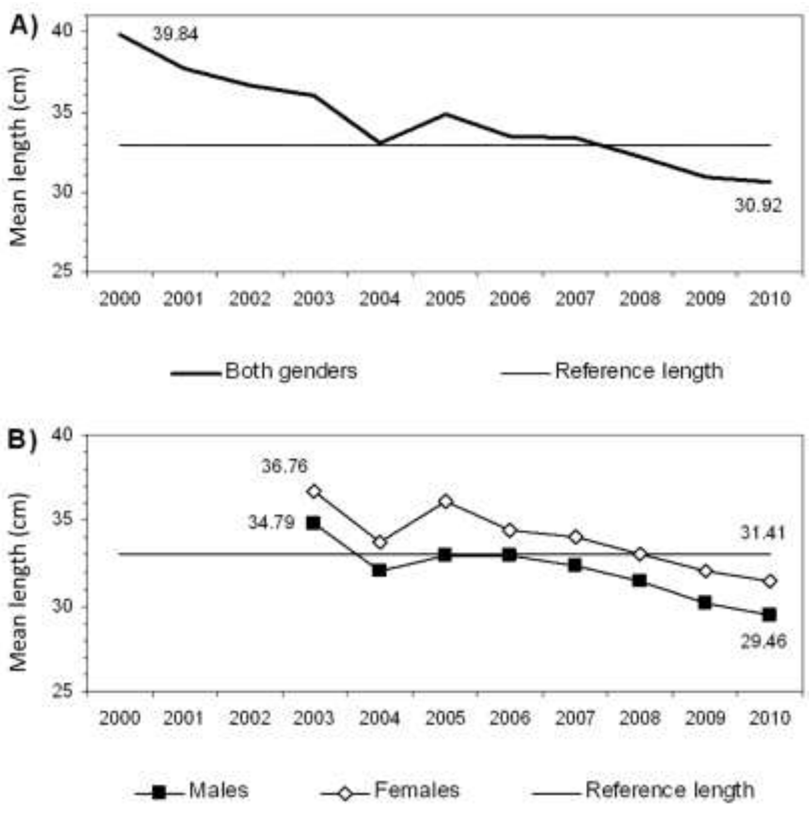
Figure 30 shows the trend in depth of capture for the first decade of 2000. In this period the average depth of capture consistently declined. Figure 31 shows the mean length in the catch. A declining trend in fish length is evident over time.

FIGURE 30
Depth of tows over time



Source: Wiff (2012)

FIGURE 31
Change in length over time in the Chilean fishery



Source: adapted from Wiff (2012)

3.5.13 Summary for the South Pacific Regional Fisheries Management Organisation area

Table 26 lists a summary of alfonsino catches as reported occurring in the SPRFMO management area. No trawl effort or catch were recorded for the SPRFMO area in 2008, 2009 and 2010. Table 27 lists similar data for *B. decadactylus*.

TABLE 26
Annual catch data – *Beryx spp*. (tonnes)

	Australia High Seas	Belize High Seas	Chile FAO 87	EU		New Zealand FAO 81	Russian Federation FAO 81,87	Ukraine[1] FAO 81, 87
				FAO 81	High seas and EEZ			
2013	74			-[2]		169		
2012	16					154		
2011	47					240		
2010	0					244		
2009	0					5		
2008	0		0		1 497	2		
2007	86	61[3]	0		793	2	0	
2006	20	101				28	0	
2005	81	102	5			26	0	
2004	1	229				85	0	
2003	2		11			94	0	11
2002	3		2			17	0	
2001	1		>0.5			22	0	9
2000	4					29	0	
1999	8					39	0	
1998	1		144			464	0	
1997	1					31	0	
1996	0					17	0	
1995	0					18	0	
1994	0					86	0	
1993	0					43	0	
1992	0					23	0	
1991	0						0	
1990	0						0	
1989	0						0	
1988	0						0	
1987	0						0	
1986							0	
1985							0	
1984							467	
1983							633	32
1982							620	
1981							676	1
1980							2 337	33
1979							6 230	4
1978							1 783	
1977							3 491	

[1] Catches made by Ukrainian vessels operating within the New Zealand EEZ are also included within New Zealand annual catch data.
[2] Figure not displayed as data is from less than 3 vessels, and has not yet been made public.
[3] This catch was reported by both Belize and China as an annual total from the same vessel fishing in the same period.

Source: Data submitted to the 3rd Commission meeting of SPRFMO (COMM-03-INF-01)

TABLE 27
Number of active high seas vessels, effort and annual catch of B. decadactylus using trawls in the SPRFMO area, 1987–2011 (Catch in tonnes and nominal CPUE in tonnes/trawl h).

Year	No. vessels	Effort (trawl h)	*B. decadactylus*
1997	10	396.0	1 (0)
1998	12	916.0	1 (0)
1999	10	777.0	8 (0.01)
2000	12	752.0	4 (0)
2001	9	307.0	1 (0)
2002	8	196.0	3 (0.01)
2003	9	102.0	2 (0.02)
2004	5	48.0	1 (0.02)
2005	3	29.0	81 (2.81)
2006	3	104.0	209
2007	2	70.7	86 (1.21)
2011	1	91.8	47 (0.51)

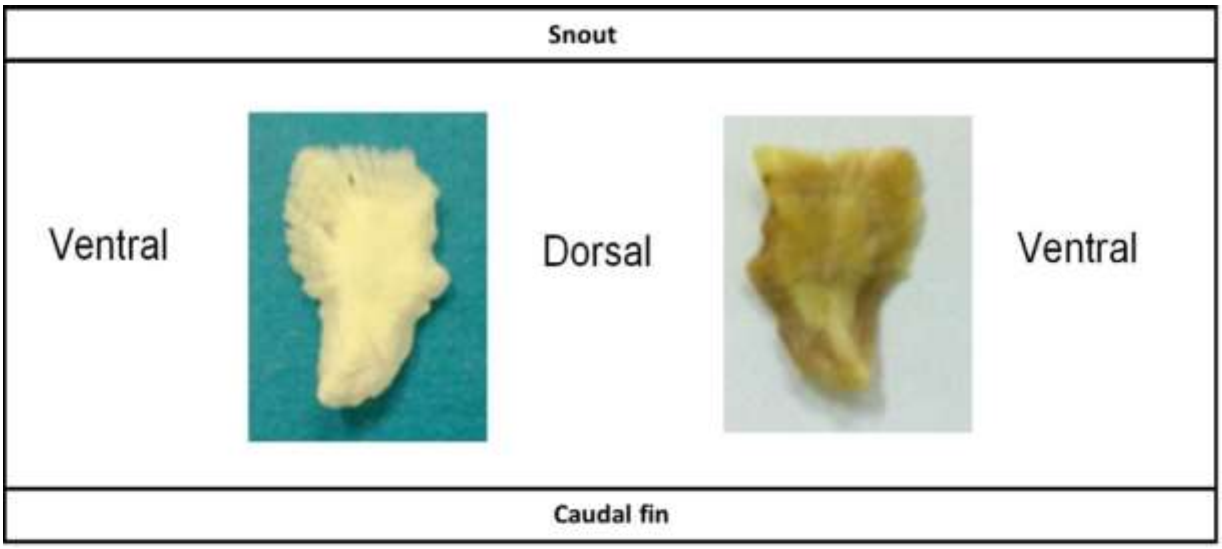
Source: SWG (2012b)

4. AGE, SIZE AND GROWTH

4.1 Determining the age of alfonsino

Otoliths of the alfonsino are thin and in general show clear annual growth rings (Plates 2 and 3). Under conditions in which to read the otoliths the translucent zones appear as dark bands and the opaque bands are white (e.g. Gálvez *et al.*, 2011). Both zones are concentric to the outer edge of the otolith and are more clearly visible anterior to the otolith centre. All studies of alfonsino otoliths have found visible annuli although their interpretation may vary according to investigator.

PLATE 2
Alfonsino otoliths: a non-processed otolith (l); an otolith has been baked in an oven (r).

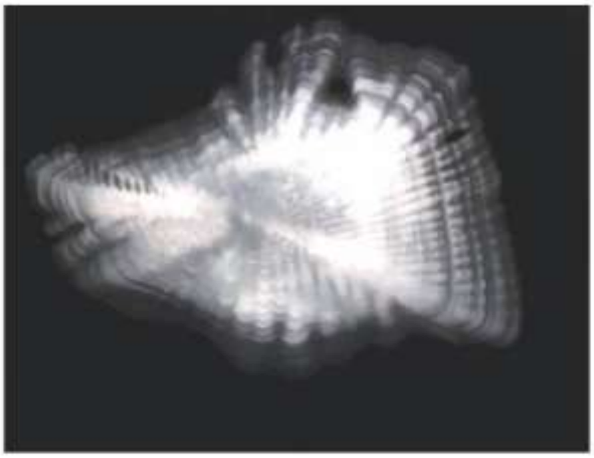


Source: adapted from Gálvez *et al.* (2011)

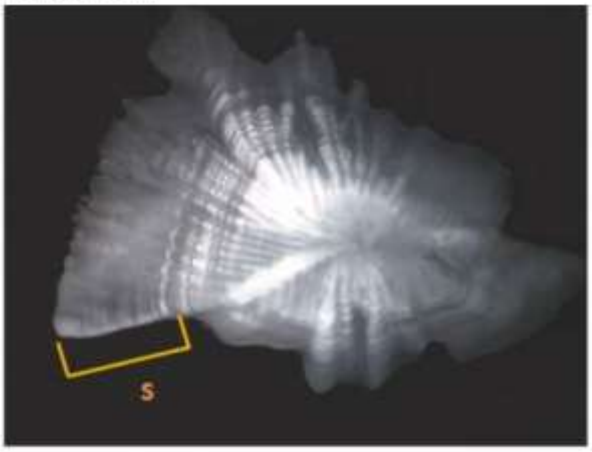
Many studies show that a translucent ring and its adjacent opaque ring are laid down each year on the otoliths, e.g. De Leoân and Malkov (1979) in New England Rise and Corner Rise (Western Central Atlantic); Kotlyar (1987) in Walvis Ridge (Southeast Atlantic) and Naska Ridge (East Pacific); Massey and Horn (1990) in New Zealand; and Lehodey and Grandperrin (1996a) in New Caledonia. However, Ikenouye (1969) concluded that two translucent rings are laid down annually on the otoliths of individuals older than about three years in Japan. Kotlyar (1987) noted that it is necessary to consider the formation of two annual translucent rings for alfonsino caught over the Error Seamount (Northwest Indian Ocean) to obtain growth rate estimates similar to those observed in other regions, although the monsoon could be responsible for this phenomenon. However, Massey and Horn (1990) concluded that this study provided an unsatisfactory basis for this conclusion.In the Macaronesian archipelagos, the opaque ring is formed during the spring and summer months when the temperature of the sea is highest, and the translucent annulus is formed during the autumn and winter months when the temperature of the sea is lowest. Massey and Horn (1990) and Lehodey and Grandperrin (1996b) also found that the translucent ring is formed during the autumn and winter months and the opaque ring during the spring and summer months in the otoliths of alfonsino from New Zealand and New Caledonia, respectively. Ikenouye (1969) concluded that one hyaline ring is formed during the spawning season and the second during the northern winter in the otoliths of alfonsino from Japan that were older than about three years.Lehodey and Grandperrin (1996a) found that 73.6 percent of the otoliths were read with “no doubt or little doubt about zone count.” The fast-growth zone was found to begin in October; the slow-growth zone being between March and June (which they took as the beginning of May). They found their results to be remarkably similar to those of Massy and Horn (1990) and that growth seemed to be similar to that in the Atlantic and Pacific Oceans.

PLATE 3

Otoliths of an alfonsino 28 cm fork length (A) and 51 cm (B and C). S refers to sector length.



B: Lpez: 51 cm



C: Enlargement of segment

Source: adapted from Gálvez *et al.* (2011).

In contrast, Gauldie (1995) found problems of age determination of alfonsino using otoliths. According to him, the complexity of the opaque banding results in an increased number of bands with increasing magnification. He regards the otolith nucleus as the first broad opaque zone although he found minor opaque zones within this region. In Gauldie’s view bands that are observed are caused by surface sculpturing and there is no evidence to support an assumption of a linear relation between age and the number of annuli observed from alfonsino otoliths. This is a contrary view to all other workers examining alfonsino otoliths.

Both Massy and Horn (1990) and Rico *et al.* (2001) have also validated the relation between ring formation in alfonsino otoliths and age and Kotlyar (1987) is also of the view that there is a linear relation between the number of otolith rings and age. Anabil *et al.* (1998) found a good relation between otolith radius and ring counts and ring counts and fork length that reinforces the view that ring counts as an accurate indicator of alfonsino age. Ivanin and Rebyk (2012) note that the change in otolith marks occurs during spawning when energy expended on reproduction is 40–60 times that expended on growth. Ivanin and Rebyk (2012) note that Russian workers have used scales to determine the age of alfonsino.

Santamaría and colleagues (2006) sampled alfonsino from Walters Shoals and the Sapmer seamount. The sample contained 107 males, ranging in size from15.5 cm to 42.5 cm, and 85 females, ranging in size from 17.8 cm to 43.5 cm. Three of the alfonsino sampled were of indeterminate sex with sizes ranging from 17.2 cm to 19.3 cm. The samples were aged using the sagittal otoliths, of which 195 of the readings were staged and two were rejected. The study concluded that there was a reliable and direct relation between the number of otolith rings observed and age in years.

4.2 Growth

The growth of juveniles is probably rapid. It is estimated that alfonsino reach a fork length of about 15–20 cm in their first year by which time they attain about 50 percent of their maximum length. After the first year, the growth rate drops rapidly. Alfonsino have an average fork length of about 25 cm after three years and about 40 cm after 10 years. Juveniles live in the pelagic environment where food is more abundant. They then settle on the bottom and growth slows after which they move to deeper depths with age and enter the commercial fishery. Lehodey, Marchal and Grandperrin (1994) found that length of alfonsino increased steadily with increasing depth.

In the Canary Islands the oldest fish examined were 9 years old (38 cm); in the Azores, 11 years (40 cm); and in Madeira 12 years old (41 cm). Rico *et al.* (2001) believe that differences between ages are related to differences in the length of the largest fish sampled in the respective studies. On the New Year and Corner Rise seafloor features these species may attain an age of 9 and 11 years (41 and 48 cm), respectively (De Leoân and Malkov, 1979). Kotlyar (1987) found that alfonsino may attain ages of 5, 6 and 8 years and lengths of 28, 34 and 41 cm on the Kit Range, Naska Range and Error Seamount, respectively. Anabil *et al.* (1998), Kotlyar (1987) and unpublished reports by ICES found that alfonsino grew to about 18–19 cm in their first year, declining to about 2.5 cm/year in later life. On the Corner Rise in the North Atlantic the growth rate during the first years of life was found to be relatively high with mean length-at-age of 1, 2 and 3 year old fish being 8, 15 and 22 cm, respectively (Vinnichenko, Gorchinsky and Shibanov, 1994; Vinnichenko, 1996a, 1996b, 1997a, 2012). In the North Atlantic, fish caught ranged from 2 to 14 years of age (Vinnichenko, 2012).

On the SWIR Ivanin and Rebyk (2012) found the maximum standard length of alfonsino to be 55 cm (= 60.4 cm fork length) and the maximum weight to be 6 260 g. Fastest growth occurred in the first year in which a length of 16.8 cm was attained. Lehodey and Grandperrin (1996b) recorded fish up to 15 years old (52 cm) in New Caledonia but estimated L_∞ as less than 50 cm. Massey and Horn (1990) recorded fish up to 16 years old (57 cm) in New Zealand. They derived a possible length of 56.7 cm for females from analysis of otoliths.

Rico *et al.* (2001) examined age and growth of alfonsino caught off the Canary Islands, Madeira and the Azores using otoliths. Fish sampled were 1–9 years of age and 18.2–38.9 cm fork length off the Canary Islands, 0–12 years (15.2–41.0 cm) off Madeira, and 0–11 years (15.3–43.0 cm) off the Azores. No significant differences in the growth parameters were found between males and females. Rico *et al.* (2001) found no significant differences between males and females in the growth parameters (analysis of covariance [ANCOVA], $P > 0.05$) for fish aged 1–9 years. Table 28 shows age at length for alfonsino from the Macaronesian archipelagos.

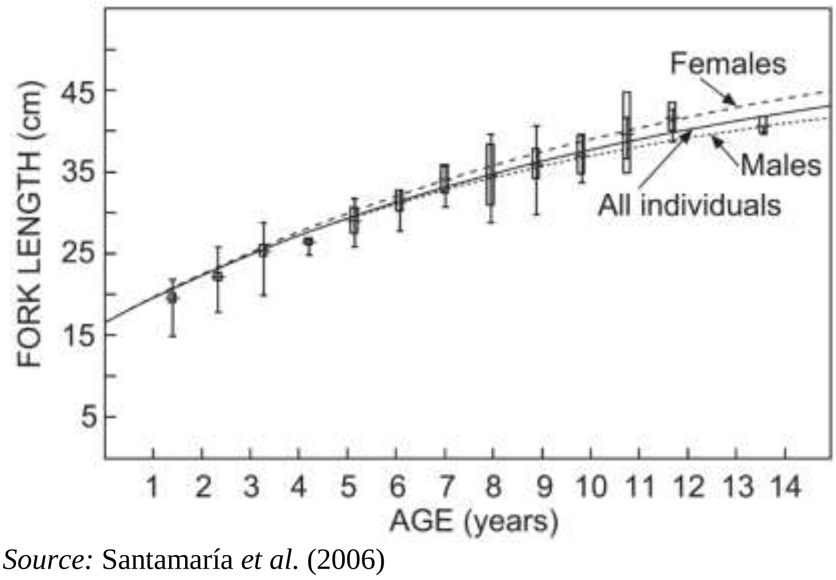
TABLE 28
Age–length key measurements of alfonsino for all individuals taken at Azores, Madeira and Canaries Islands

	Mean length (FL - cm)		
Age	**Azores**	**Madeira**	**Canaries**
0	18.5	17.2	
1	20.7	19.7	19.5
2	24.3	21.6	25.0
3	27.0	24.3	27.4
4	30.6	26.5	30.1
5	32.4	27.9	31.6
6	32.8	29.6	33.6
7	35.2	31.3	35.3
8	36.9	33.5	36.5
9	35.2	34.5	36.3
10	37.5	33.5	
11	40.5	37.5	
12		40.5	

Source: Rico *et al.* (2001)

Santamaría *et al.* (2006) estimated growth paramters for alfonsino in the South-west Indian Ocean. These were in the range of those obtained in the Atlantic and Pacific oceans (see Table 31). For males, females, and all individuals aggregated, the coefficients of determination (r^2) were high: 0.89, 0.92, and 0.90, respectively. The growth curves, confidence intervals and length ranges for males, females, and for all individuals combined are shown in Figure 32. Santamaría *et al.* (2006) found no significant differences in growth between sex or significant differences in growth either for male or female alfonsino between New Caledonian and those from the South-west Indian ocean. Growth of males was similar between alfonsino from the Izu Islands, Japan, and those in the current study. However, growth differed considerably, particularly for males, between New Zealand and the South-west Indian Ocean stocks.

FIGURE 32
Von Bertalanffy growth curve for males, females, and all individuals of *B. splendens* combined. Vertical lines represent length range and bars indicate mean ± 2 standard deviations.

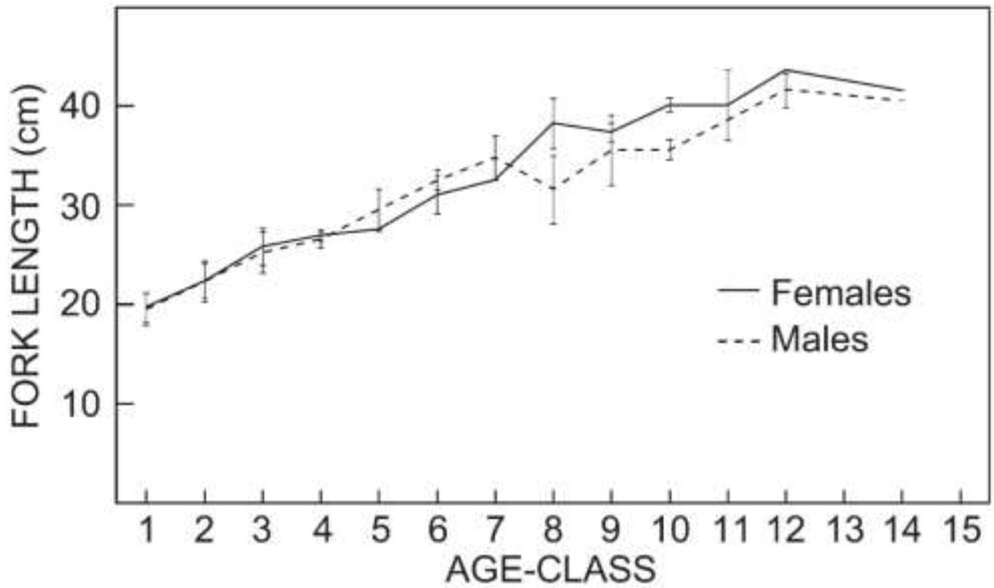


Source: Santamaría *et al.* (2006)

Santamaría and colleagues (2006) determined the mean length-at-age for alfonsino from Walter Shoals and Sapmer seamount (Figure 33). The ages of the individuals studied ranged between one and 14 years.

Juveniles (age 0) were absent in the collections, which the authors believed was most likely because of their benthopelagic behavior and thus made them unavailable to bottom trawls. Males aged 11 years and 13 years, and females aged 13 years were absent in the collection.

FIGURE 33
Mean length-at-age for alfonsino from Walter Shoals and Sapmer seamount



Source: Santamaría *et al.* (2006)

Lehodey and Grandperrin (1996a) found a highly significant difference in the rate of growth of males and females. Their growth rates were similar to other investigators for females but slower than those found by Massey and Horn (1990) for males. The coefficients of determination of the parameters they determined were all high. They note that the results of other investigators compare "reasonably well" with those from New Caledonia with the exception of Ikenouye (1969), who obtained a smaller value for L_∞. However, Anabil *et al.* (1998) and Kotlyar (1987) were unable to confirm differences in growth rates between the two sexes. Lehodey and Grandperrin (1996b) note that other studies did not consider the affects of sexual dimorphism on length at age; did not validate the interpretation of the otoliths and were often based on small samples from various size ranges.

Lehodey and Grandperrin (1996a) correlated the mean temperature of the 0–500 m water layer with the Southern Oscillation Index after seasonal cycles were removed. They found that the interannual fluctuations of temperature are influenced by El Niño Southern Oscillation (ENSO) events with a time lag of several months. They found that the growth rate of alfonsino derived from annuli on sagittal otoliths was strongly related to temperature fluctuations in intermediate-depth water masses and, consequently, ENSO events, which appear farther north at low latitudes in the equatorial Pacific, even though this fish lives in deep waters far from the equator where ENSO events arise. El Niño events would increase growth rates, and La Niña events would decrease them.

Ivanin (1987) found several small alfonsino 5.4–9.7 cm at 50–210 m over depths of 2 000 m. Lehodey and Grandperrin (1996b) caught 22 small alfonsino (13–15 cm with mean age 8 months) by bottom trawl in 390 m off New Caledonia. Over the same seamount, the same trawl caught 17 alfonsino of ages 10–12 months and 2–2.5 years (22 cm) at 500–700 m.

Growth appears to be similar in other areas, i.e. the East and West Atlantic, and North and South Pacific (Lehodey and Grandperrin, 1996b; Rico *et al.*, 2001; Gili *et al*., 2002). Massey and Horn (1990) found no evidence of asymptotic growth, i.e. their results indicate that alfonsino keep growing. Honda (2012) reports that growth of alfonsino on the SE–NHR is slightly faster than in Japanese waters for both sexes (Table 29). Massey and Horn (1990) found growth of alfonsino appeared to be similar in Japan and New Zealand.

Figure 32 shows the size distribution of alfonsino in Tokyo Prefecture (Honda, personal communication, 2012). This plot shows evidence of modal progression. Table 30 shows length-at-age values from various studies.

TABLE 29

Length (cm) at age of splendid alfonsino in the SE–NHR and Japanese waters

Reference / area	Sex	Age							
		1	2	3	4	5	6	10	15
Yanagimoto (2004) SE–NHR	M	19.0	23.4	27.0	30.1				
	F	18.6	23.0	27.0	30.5				
Adachi *et al.* (2000) Japan	M	19.7	22.8	25.4	27.8	29.8	31.6	36.9	40.5
	F	16.6	20.6	24.0	26.9	29.4	31.6	37.7	41.5
Myojin & Ura (2002), cited in Yanagimoto (2004) Japan	M	17.8	22.0	25.6	28.6	31.2	33.3	39.3	42.9
	F	17.6	21.7	25.1	28.0	30.4	32.4	37.6	40.6

Sources: Honda (2012); Yanagimoto (2004)

Ikenouye and Masuzawa (1968) examined alfonsino growth and estimated von Bertalanffy parameters from a tagging experiment in Sagami Bay, Japan, but they considered the three methods they used to be unsatisfactory. Ikenouye (1969) examined 209 alfonsino from fishing grounds near Sagami Bay to estimate growth parameters from fish of 17–36 cm length. He concluded that the equation probably only described the growth of younger fish adequately and that the L_∞ value was probably too low as fish of 38–45 cm were frequently caught in the study area. Masuzawa, Kurata and Onishi (1975) reported two growth studies using scales. He estimated von Bertalanffy parameters for alfonsino from the Sagami Bight and nearby Zunan Sea area but did not state what size range of fish were sampled. In a study by de Leon and Malkov (1979) von Bertalanffy growth curves were obtained for alfonsino from the West Central Atlantic using fish of 32–48 cm and 19–41 cm from the Corner Rise and New Year Rise seafloor features, respectively. Massey and Horn (1990) tentatively report that comparison of age–length relationships indicates that growth was slower on the New Zealand grounds they studied than was the case in Japanese waters and the Western Central Atlantic.

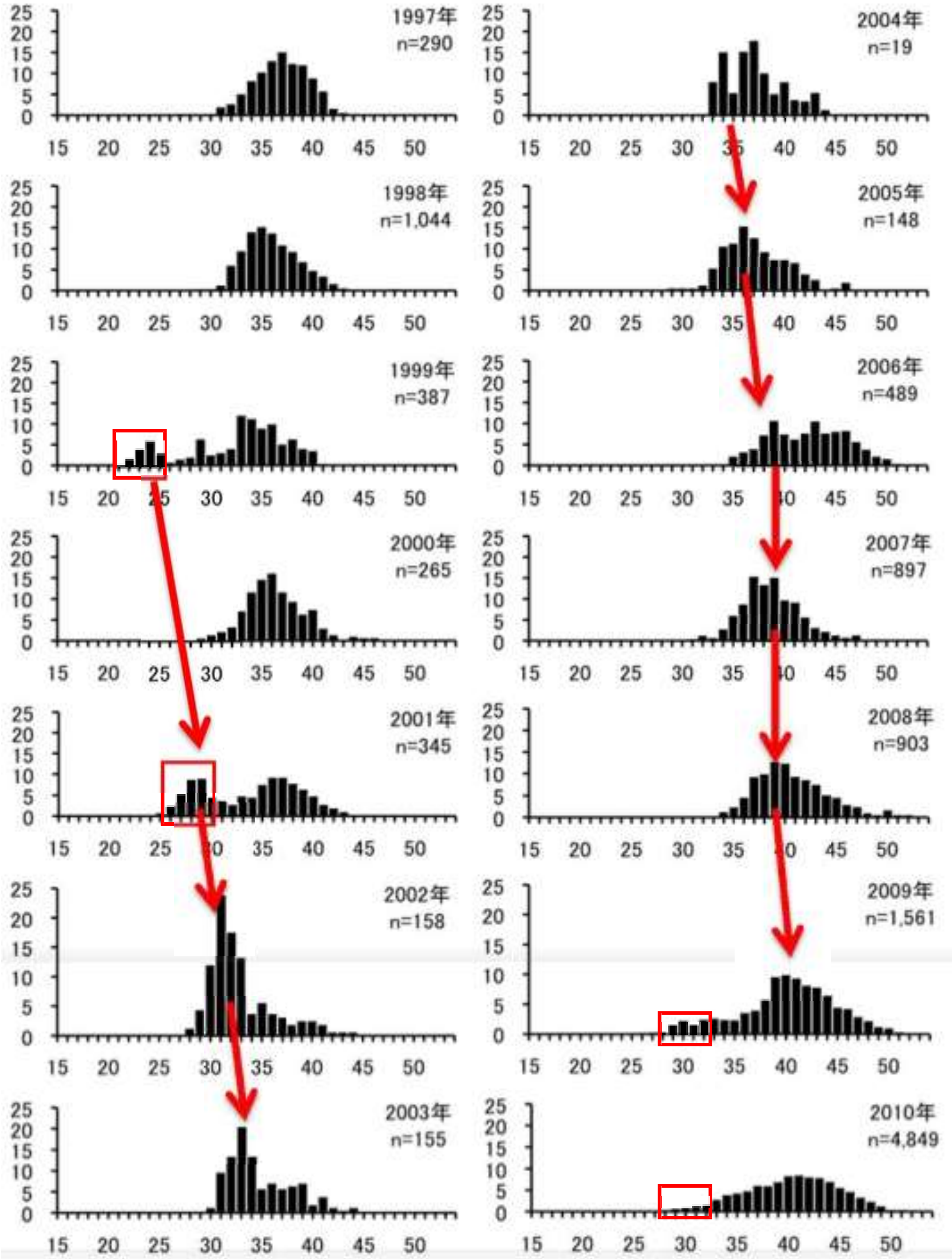
Massey and Horn (1990) note that the instantaneous growth rates are best described by the following equations:

$$G_{male} = 0.444 - 0.154 \ln(\text{age}),\ r = 0.992$$

$$G_{female} = 0.441 - 0.144 \ln(\text{age}),\ r = 0.990$$

In Chile, Gili *et al.* (2002) reported on the ageing of 681 male and 706 female sagittal otoliths between 1999 and 2001 corresponding to lengths from 17 to 57 cm. Ages that were determined ranged from 1 to 15 years for males and from 1 to 19 years for females. A linear back-calculation method was used to generate age at length for small fish that had low probability of being sampled. The von Bertalanffy function was fitted using a maximum likelihood method. A significant difference was found between sexes (p < 0:05). Growth of alfonsino estimated by otolith analysis for the SE–NHR region is slightly faster than in Japanese waters for both sexes. Table 31 summarizes growth-related parameter values that have been determined for alfonsino. Table 32 summarizes the results of Massey and Horn (1990).

FIGURE 32
Size distribution of alfonsino from Tokyo Prefecture



Source: Honda (personal communication, 2012)

TABLE 30
Alfonsino length at age

	Age (years)															
Area	**3**		**4**		**5**		**6**		**7**		**8**		**9**		**10**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
New Caledonia	24.5	24.9	27.3	28.2	29.7	31.0	31.6	33.5	33.6	35.7	35.2	37.6	36.6	39.3	37.7	40.7
M&F	24.7		27.7		30.3		32.7		34.8		36.6		38.3		39.7	
New Zealand																
Paonui Ridge	24.5		27.8		30.7		33.1		35.3		37.1		38.7		40.1	
Palliser Bay	26.3	26.7	28.9	29.3	31.2	31.7	33.2	33.9	35.1	35.9	36.8	37.7	38.3	39.3	39.6	40.9
Tuaheni High	27.1	28.7	29.5	30.7	31.8	32.6	33.8	34.3	35.7	36.1	37.4	37.7	38.9	39.3	40.4	40.8
Japan M&F																
Sagami Bight	29.6		34.1		37.3		39.7		41.4		42.6		43.5		44.1	
Zunan Sea	23.2		28.4		32.7		36.3		39.3		41.8		43.9		45.6	
Sagami Bay	25.7		30.0		32.8		34.6		35.7		36.5		36.9		37.2	
Atlantic																
Corner Rise	29.9		32.8		35.2		37.3		39.1		40.5		41.8		42.8	
New England Rise	25.0		28.8		31.8		34.3		36.3		37.9		39.2		40.4	

Sources: Derived from Lehodey and Grandperrin (1996b), lists length at age for various workers: New Caledonia – Lehodey and Grandperrin (1996b); Japan – Masuzawa, Kurata and Onishi (1975) and Ikenouye (1969); Atlantic – Kotlyar (1987); New Zealand – Massy and Horn (1986)

TABLE 31
Growth-related parameter values for alfonsino

Area	Authors	L∞ (cm)		W∞ (g)	K (per year)		t_0	
		M	F		M	F	M	F
Canary	Rico *et al.* (2001)	44.51			0.15			3.41
Madeira		58.71			0.06			5.71
Azores		43.10			0.17			2.80
Southern Indian Ocean	Santamaría *et al.* (2006)	49.1	57.1		0.099	0.081	-4.11	-4.16
		53.5			0.085		-4.33	
New Caledonia: Norfolk–Loyalty Ridges	Lehodey & Grandperrin (1996b)	45.2	50.8		0.146	0.134	2.34	2.00
	Males & females (M&F)	51.3			0.119		0.005	
Southern Indian Ocean	Ivanin & Rebyk (2012)[1] – M&F	66.8		10 570	0.0823		-2.60	
Azores	Anabil *et al.* (1998)	45.3	53.7		0.133	0.085	-2.74	-4.02
	Anabil *et al.* (1998): M&F	46.1			0.120		-3.18	
	FishBase (2012)		>50					
North Pacific Ocean	Yanagimoto & Nishimura (2007)	46.48	58.17		0.1725	0.1193	-2.046	-2.230
New Zealand	Massey & Horn (1990)							
Palliser Bay		51.1	57.5		0.11	0.088	-3.56	-4.1
Tuaheni		54.9	76.3		0.093	0.042	-4.3	-8.25
Paoanui		49.1	-		0.144	-	1.81	-
Japan								
Sagami Bay	Ikenouye (1969)	37.8			0.439			
Sagami Bight	Masuzawa, Kurata and Onishi (1975)	45.8			0.323		-0.2228	
Zunan Sea		54.4			0.1813		-0.0757	
Atlantic								
Corner Rise	de Leon & Malkov (1979)	48.5			0.181		-2.63	
New England Rise		44.8			0.209		-0.89	
Chile								
Juan Fernández Islands	Gili *et al.* (2002)	58.5	63.6		0.095			
		63.4			0.093		-2.567	
Chile	Niklitschek & Toledo (2011)	49.3			0.12		-2.0	

[1] This relation is for standard length, where SL = 0.91 FL

TABLE 32
Estimates and 95 percent confidence intervals of von Bertalanffy parameters for alfonsino from the Palliser Bank, Tuaheni High, and Paoanui Ridge

	L_∞ (cm)		K		t_0 (years)	
Sample	**M**	**F**	**M**	**F**	**M**	**F**
Palliser						
Observed	51.1 ± 2.1	57.5 ± 2.5	0.110 ± 0.016	0.088 ± 0.012	–3.56 ± 0.79	–4.10 ± 0.72
Back-Calculated	49.6 ± 2.6	57.9 ± 2.6	0.116 ± 0.023	0.087 ± 0.012	–3.67 ± 0.96	–4.7 ± 0.65
Tuaheni						
Male	54.9 ± 11.9	76.3 ± 22.5	0.093 ± 0.069	0.042 ± 0.026	–4.30 ± 4.02	–8.25 ± 3.34
Paoanui						
Male	49.1 ± 3.0		0.144 ± 0.038		–1.81 ± 1.25	

Source: Massey and Horn (1990)

Male and female length-at-age relationships were significantly different in all comparisons of the lengths at age 5, 8 and 11 years from all grounds. The differences became more significant with increasing age; females on the Palliser Bank were about 0.7, 1.0 and 2.5 cm longer than males at 5, 10 and 15 years, respectively. Maximum sizes recorded from all grounds were 49 cm for males and 57 cm for females.

The most notable feature of Massy and Horn's (1990) analysis of all age-length curves was that the growth data show no evidence of an asymptote. They concluded that, unless large fish were not being sampled by the trawl gear, fish grow through their entire life and continue to do so until they die of old age. Ikenouye (1969), Masuzawa, Kurata and Onishi (1975), and de Leon and Malkov (1979) also report L_∞ values that are larger than maximum observed alfonsino sizes.

Niklitschek and Toledo (2011) investigated three growth models, that of Gompertz, von Bertalanffy and Schnute. According to the Schnute model, length at age 1 would be 17.9 cm and at age 14, 42.3 cm. Females had a tendency to grow faster than males, e.g. length was estimated at 17.7 cm at age one and 43.1 cm at age 14, while for males, the corresponding values were 17.6 and 40.0 cm. Table 33 shows the growth parameters obtained.

TABLE 33
Estimates of growth parameters by Niklitschek and Toledo (2011)

Model	**Parameters**	
Von Bertalanffy	L_∞	49.3
	K	0.12
	t_0	-2
Gompertz	L_∞	54.0
	G_t	0.13
	t_0	1.97
Schnute	A	0.36
	B	-2.94
	L_1	17.9
	L_2	42.3

Source: Niklitschek and Toledo (2011)

Deepwater species in the ICES area ranked according to longevity and growth rate, summarized from Anon. (2001) are given in Table 34.

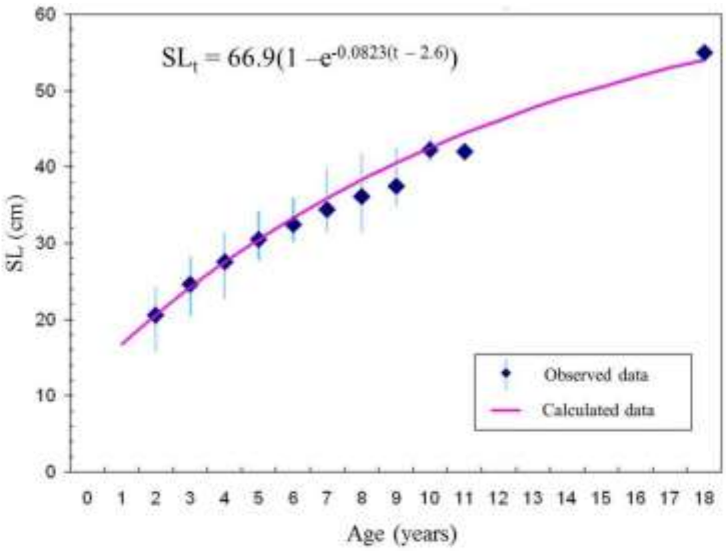
TABLE 34
ICES estimates of longevity and growth rate

	Longevity (years)	Growth rate (k) per year
Beryx decadactylus	13 (5)	0.11–0.17
Beryx splendens	11 (5)	0.13–0.14

Source: ICES (2001a)

Figure 33 shows the length-age dependence of alfonsino on the SWIR banks for data collected in the period 1980–1988 (Ivanin and Rebyk, 2012). Lehodey and Grandperrin (1996b) report a maximum age of 20 years.

FIGURE 33
Length-age dependence of *Beryx splendens* on South West Indian Ridge banks, 1980–88



Source: adapted from Ivanin and Rebyk (2012)

Beryx decadactylus
Krug, Carvalho and González (2011) studied age and growth of *B. decadactylus* from the Azores, Madeira and Canary Islands based on otolith readings. In general, otoliths of *B. decadactylus* showed clear annual growth rings that were concentric to the outer edge of the otolith and most visible on the anterior part of the otolith. Specimens ranged in length from 21.0 to 50.0 cm (aged 2–10 years) in the Azores, from 20.0 to 45.0 cm (1–11 years) in Madeira, and from 21.0–44.0 cm (0–9 years) in the Canary Islands.

Krug, Carvalho and González (2011) used covariance analysis and found no significant differences (ANCOVA, $P > 0.05$) in the regression coefficients of length versus ln (age) between males and females in three regions around the Azores. Overall, growth of *B. decadactylus* from the Macaronesian archipelagos was found to be relatively slow with males and females having similar growth rates. The results obtained for age and growth of *B. decadactylus* in the Azores, Madeira and Canary Islands were in good agreement with length and age ranges observed among the three archipelagos. Isidro (1996) determined a slightly lower asymptotic length ($L_\infty = 56.3$ cm) for this species in the Azores than the present study. However, his estimate of K (0.107 per year) was similar. Table 35 shows the results obtained by Krug, Carvalho and González (2011). Fish between 0 and 9 years were represented in the sample of 105 otoliths.

TABLE 35
Growth parameters for *B. decadactylus*

	L_∞	K	t_0	Maximum age (year – cm)	Length at maximum age (cm)
Azores	68.40	0.11	1.90	10	50
Madeira	70.10	0.07	4.83	11	45
Canary Islands	58.11	0.11	4.70	9	44

Source: Krug, Carvalho and González (2011)

4.3 Maximum age[4]

The maximum estimated age for alfonsino (*B. splendens*) was 10 years (50 cm) in the Azores, 11 years (45 cm) in Madeira and 9 years (44 cm) in the Canaries. Apparent differences in the von Bertalanffy growth parameters between the Azores and the Canaries and between the Azores and Madeira were not statistically significant. The higher growth parameter estimates obtained for the Azores could be partially explained by the greater lengths found in the region and/or due to smaller sample sizes of older and young individuals from the other two regions. Isidro (1996) determined a slightly lower asymptotic length (L_∞ = 56.3 cm) for this species in the Azores than the present study. The K value (0.107 per year) was similar.

Ivanin and Rebyk (2012) conclude that longevity of female alfonsino is greater than males on the SWIR. Maximum age of males was estimated to be nine years (length 36.7 cm and 1 556 g) while for females it was 18 years (55 cm and 6 260 g).

Examination of the catch taken by Japanese vessels fishing in the Atlantic showed the alfonsino to have an average maximum life span of 17 years (Nishida, 2012).

4.4 Weight–length relation

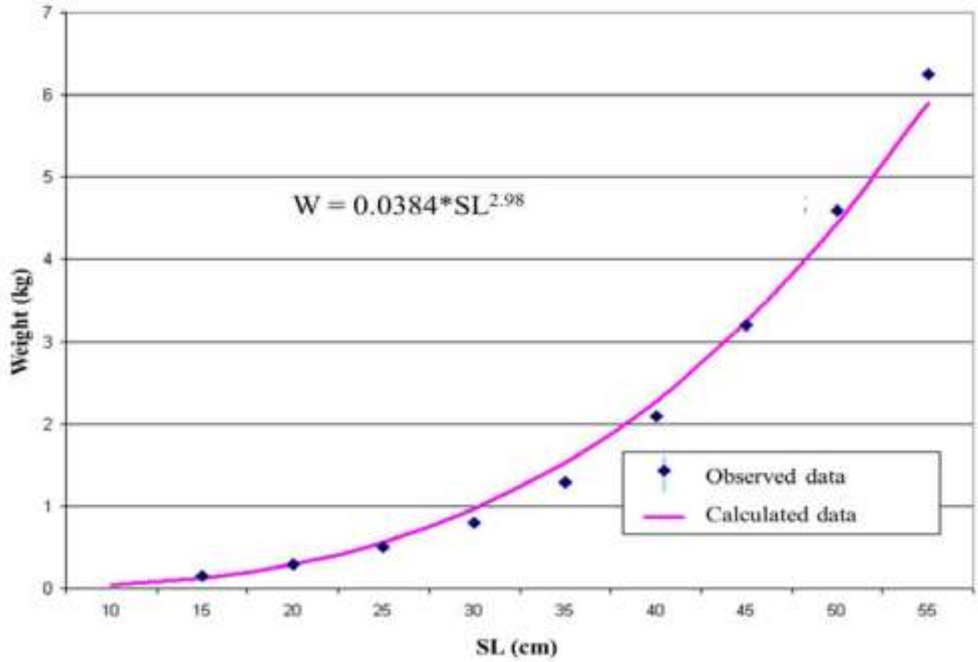
Table 36 lists parameters for the weight–length relation $W = aL^b$, weight in grams, length in centimetres. Figure 34 shows the weight–length relation for alfonsino samples on the SWIR banks, 1980–88 (Ivanin and Rebyk, 2012). De Leon and Malkov (1979) calculated weight–length equations for alfonsino from the Corner Rise (c. 35°N, 50°W) and New Year Rise (c. 15°N, 54°W) in the Western Central Atlantic. Ivanin and Rebyk (2012) also determined a relation but their equation was derived from much smaller fish (17-36 cm) than those used by Massey and Horn (1990) and de Leon and Malkov (1979).

[4] See also Section 7, Estimates of Mortality.

TABLE 36
Weight–length relation ($W = aL^b$): weight in grams, length in centimetres

Author	Length	A	B	Period
Ivanin & Rebyk (2012)	Standard	0.0384	2.98	
Massey & Horn (1990) New Zealand	10L	1.877×10^{-5}	3.061	Male, October–May
		1.966×10^{-5}	3.061	Male, June and September
		1.857×10^{-5}	3.061	Female, October–May
		1.913×10^{-5}	3.061	Female, June, and September
Stocker & Blackwell (1991) New Zealand		0.0225	3.018	
de Leon & Malkov (1979)				
Corner Rise		1.01×10^{-5}	3.0245	
New Year Rise		1.21×10^{-5}	3.1538	
Azores		0.0178	3.0755	
Ikenouye (1969)		2.42×10^{-5}	2.979	
Niklitschek & Toledo		0.0156	3.107	
Females		0.0147	3.122	
B. decadactylus				
Azores (same for both sexes)		0.021	3.0375	

FIGURE 34
Weight–length dependence of alfonsino on SWIR banks, 1980–88



Source: adapted from Ivanin and Rebyk (2012)

The weights of the New Zealand alfonsino (male–female mean for November–May) at 30, 40 and 45 cm were 0.62, 1.50 and 1.98 kg, respectively, compared with 0.55 (0.55), 1.37 (1.37) and 1.98 (2.00) for the New Year Rise (and Angular Rise). The result of Ikenouye (1969) was derived from much smaller fish (17–36 cm) than those used by Massey and Horn (1990) and de Leon and Malkov (1979).

5. MATURITY

5.1 Gonad structure

The gonads of alfonsino consist of two triangular lobes held in the abdominal cavity by a mesovarium. They join to form an oviduct that opens into the urogenital pore. The testes are paired, elongated and multilobed. In immature fish the gonads are thin, elongated and not easy to differentiate. As alfonsino mature the gonads elongate to fill the entire posterior abdominal cavity (Lehodey, Grandperrin and Marchal 1977).

5.2 Maturation indices

For the Azores, Pereira and Pinho (2012) recorded the sex and stage of maturity of specimens by macroscopic examination of the gonads, which were weighed to the nearest 0.01 g. A macroscopic scale of six stages was used to classify the different stages of maturity: 0: Immature; I: Resting; II: Developing; III: Ripe; IV: Spawning; V: Spent. One problem with quantifying the stage of maturity of alfonsino gonads is that a variety of classification systems exist (Table 37). These various systems need to be clarified and a single system agreed upon.

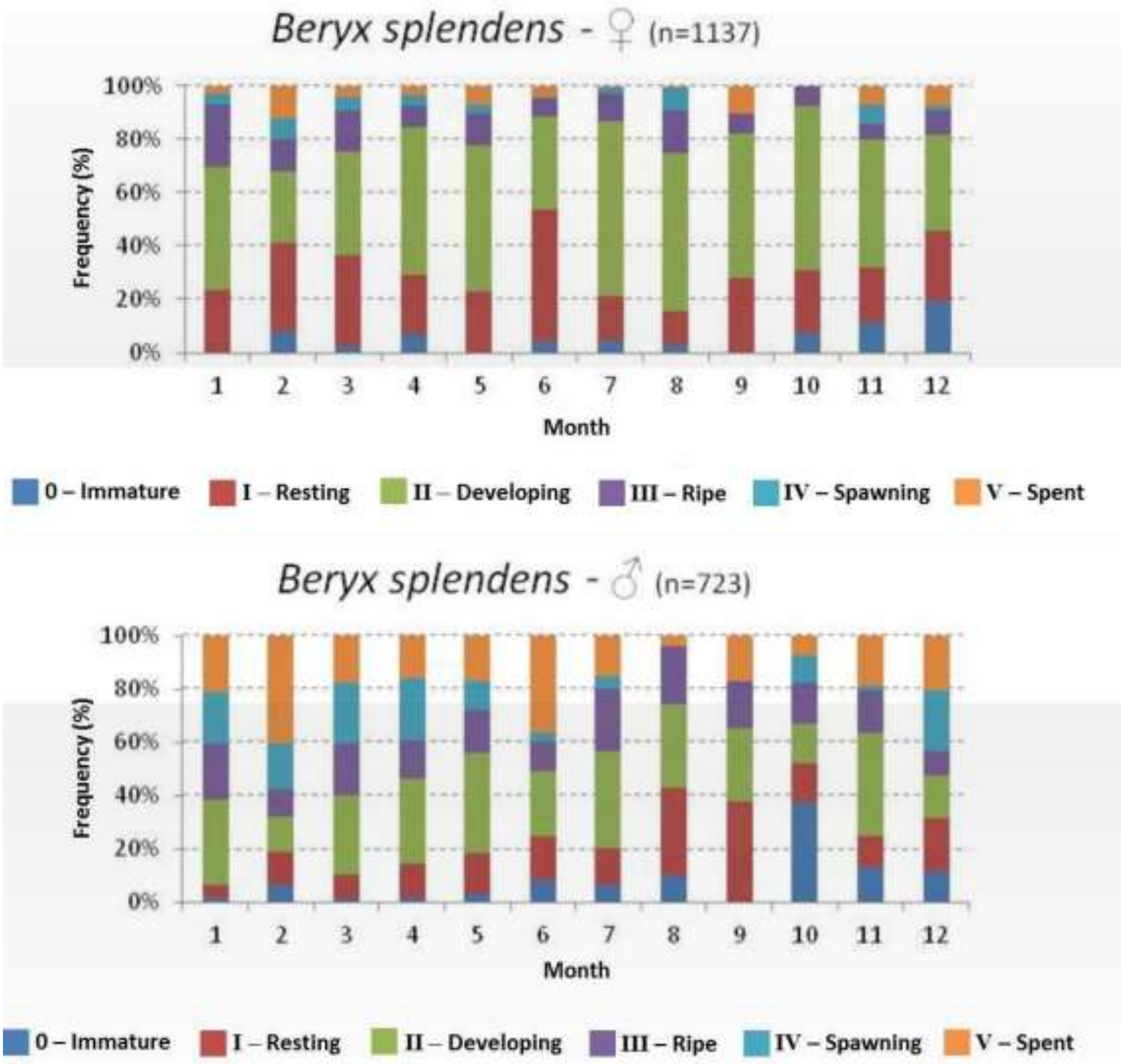
TABLE 37
Descriptions of gonad stages obtained by different researchers

Stage	Pereira & Pinho (2012)	Adapted from Isidro (1989), Krug (1990), Isidro (1996) (females)	Adapted from Krug (1990), White, Wyanski & Sedberry (1998), Lehodey, Grandperrin &Marchal (1997) (males)	Lehodey, Grandperrin & Marchal (1997) (females)	Lehodey, Grandperrin & Marchal (1997) (males)
0	Immature	Gonads small, translucent. Primary or previtellogenic oocytes only.	Immature. Gonads small and translucent. Small transverse cross-section compared with resting male. Spermatogonia and little or no spermatocyte development; sperm ducts and main sperm duct not as evident as in resting stage.		
I	Resting			Immature, sex difficult to distinguish.	
II	Developing	Gonads opaque consistent with some vascularization; oocytes scarcely visible with yellow/orange colours. Oocytes yolked undergoing vitellogenesis; yolk granules on the cytoplasm.	Gonads large, consistent and white. Development of cysts containing spermatogonia in mitosis, spermatocytes and spermatids.	Ovaries small, translucent, reddish colour but due to strong vascularization?	Testes small, elongated, whitish – to pinkish in colour.
III		Pre-spawning. Gonads opaque consistent with well-developed vascularization; oocytes well visible; oocytes with yellow/orange colours. Oocytes in final maturation usually with a migratory nucleus and coalescence of yolk material.	Pre-spawning. Gonads consistent, well developed, white with visible sperm. Gonads contain cysts in all stages of development, spermatozoa in sperm ducts and main sperm duct.		

Stage	Pereira & Pinho (2012)	Adapted from Isidro (1989), Krug (1990), Isidro (1996) (females)	Adapted from Krug (1990), White, Wyanski & Sedberry (1998), Lehodey, Grandperrin &Marchal (1997) (males)	Lehodey, Grandperrin & Marchal (1997) (females)	Lehodey, Grandperrin & Marchal (1997) (males)
III	Ripe	Gonads opaque, uniform with well-developed vascularization. Hydrated oocytes clearly visible, forming a gelatinous matrix. Orange/reddish colours. Hyaline oocytes or evidence of hyaline oocytes.		Ovaries larger, orange colour, oocytes visible to naked eye.	Testes larger but still flattened; whitish colour.
IV	Spawning	Gonads opaque consistent with well-developed vascularization, hydrated oocytes easily visible forming a visible gelatinous matrix; Orange/reddish colours. Hyaline oocytes or evidence of them.	Spawning. Gonads whitish with very visible sperm that run when abdomen is pressed. Predominance of spermatozoa in sperm ducts and in main spermatic duct, little or no spermatogenesis.	Ovaries well developed, orange colour, transparent membrane with visible oocytes.	Testes thicker, well developed, whitish colour but no milt expressible.
V	Spent	Gonads opaque, flaccid, with some vascularization; sometimes some residual oocytes visible; reddish colour. Atretic oocytes.	Spent. Gonads opaque, flaccid with "bloody aspect", some sperm. Some residual sperm in sperm ducts and main sperm duct, occurrence of spermatogonia and development of connective tissue.	Ovaries occupy half of body cavity, orange colour. Oocytes well visible; thin and granular walls.	Stage IV but testes larger.
I/VI		I Resting. Gonads opaque consistent with some vascularization; oocytes not visible; yellow/orange colour. Primary and unyolked oocytes usually at the start of yolk vesicle accumulation.	Resting. Gonads opaque, uniform with some vascularization. Oocytes not visible; yellow/orange colours. Primary and unyolked oocytes usually at the start of yolk vesicle accumulation.	Spawning eggs flow freely when handled.	Testes fill more than half the body cavity; milt run when abdomen pressed.
VII				Post-spawning ovaries flaccid and "bloody".	Testes "bloody, no milt expressible when pressed.

Figure 35 shows the monthly frequencies of occurrence of the various maturity stages of male and female gonads in alfonsino. Females in spawning condition (stage IV) were observed from February to July and from October to December with a peak in March and April. A similar situation was observed for males. This was also confirmed by the development of the gonadosomatic index[5] (GSI). The GSI for females on a monthly basis showed an increase from February to June with a peak in June; highest GSI values occurred in larger fish.

FIGURE 35
Monthly changes in the maturity stages of gonads of alfonsino in the Azores



Source: modified from Pereira and Pinho (2012)

5.3 Age and size at maturity

Kotlyar (1987) found that alfonsino in the Atlantic Ocean began to mature in their second year at a standard length of 19–20 cm and that most fish were mature by their fifth or sixth year. On Corner Rise, sexual maturation was found to begin in the second year at a mean length of 18 cm and at an age of 5-6 years, length 25–30 cm, all fish were mature (Pshenichny, Kotlyar and Glukhov, 1986; Kotlyar 1996). Vinnichenko (2012) reported that sexual maturation of alfonsino in the North Atlantic began in their second year at a mean length of 18 cm, and at 5–6 years, length 25–30 cm, all fish were mature. Table 38 lists the various $L_{50\%}$ maturity estimates obtained by different authors.

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[5] Gonadosomatic index = 100 × gonad weight / total fish weight.

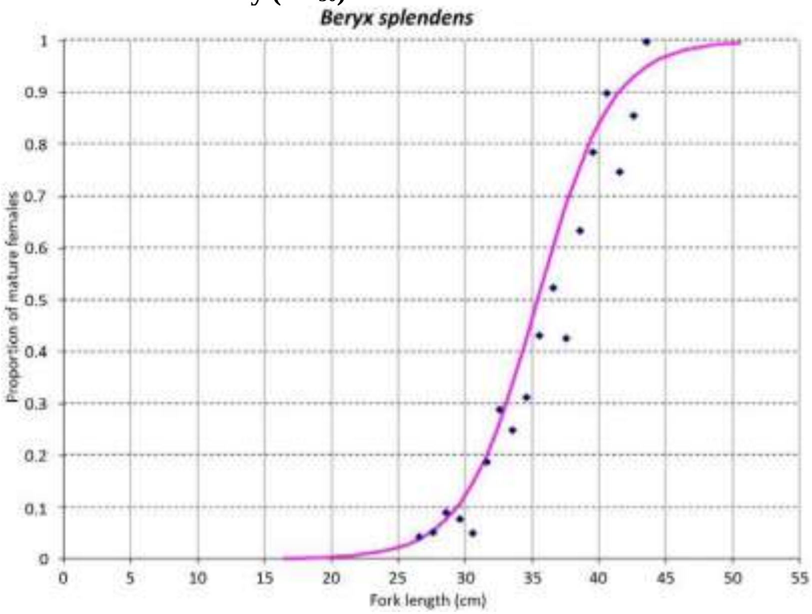
TABLE 38
Estimates of alfonsino $L_{50\%}$ obtained by different researchers

Source	Age (50%)	Size (cm)		Comment
		M	F	
	4–6	~ 35		Australia
Masuzawa, Kurata & Onishi (1975)		> 34 cm		
Azores Pereira & Pinho (2012)			35.5	Azores
Azores González *et al.* (2003)		23	23	"Length at maturity"
Canary Islands González *et al.* (2003)		29.9	31.3	"Length at maturity"
Madeira González *et al.* (2003)		30.3	34.6	"Length at maturity"
Lehodey *et al.* (1977) New Caledonia	7.5 (M) 5.9 (F)	34.5	33.2	
Guerrero & Arana (2009)		34.3	33.1	October 2001 to May 2003, logistic fit based on macroscopic analysis
Niklitschek & Toledo (2011) Chile		33.8		Histological analysis
Flores *et al.* (2012) Chile	7.4 (F)	39.7	36.9	January 2006 to October 2009. Logistic fit. Macroscopic analysis.
Flores *et al.* (2012) Chile	9.6 (F)		43.7	May to December 2001; logistic fit, histological examination
Gili *et al.* (2002) Chile			40.4	November; logistic fit; histological examination

Pereira and Pinho (2012) estimated mean lengths at first maturity ($L_{m50\%}$) using a logistic function. Fish were considered sexually mature if they were in gonad stages III, IV or V. This gave a mean length at $L_{m50\%}$ at 35.5 cm fork length (Figure 36).

Shotton (2014b) provides a recent review of age and size information of alfonsino in the context of management of alfonsino fisheries in the Southern Indian Ocean.

FIGURE 36
Size at sexual maturity (FL_{50}) for alfonsino from the Azores



Source: Pereira and Pinho (2012)

The estimated size at sexual maturity at Madeira and the Canary Islands is similar at 32 and 30 cm, respectively, while for the Azores it is 23 cm. Table 39 summarizes the information González *et al.* (2003).

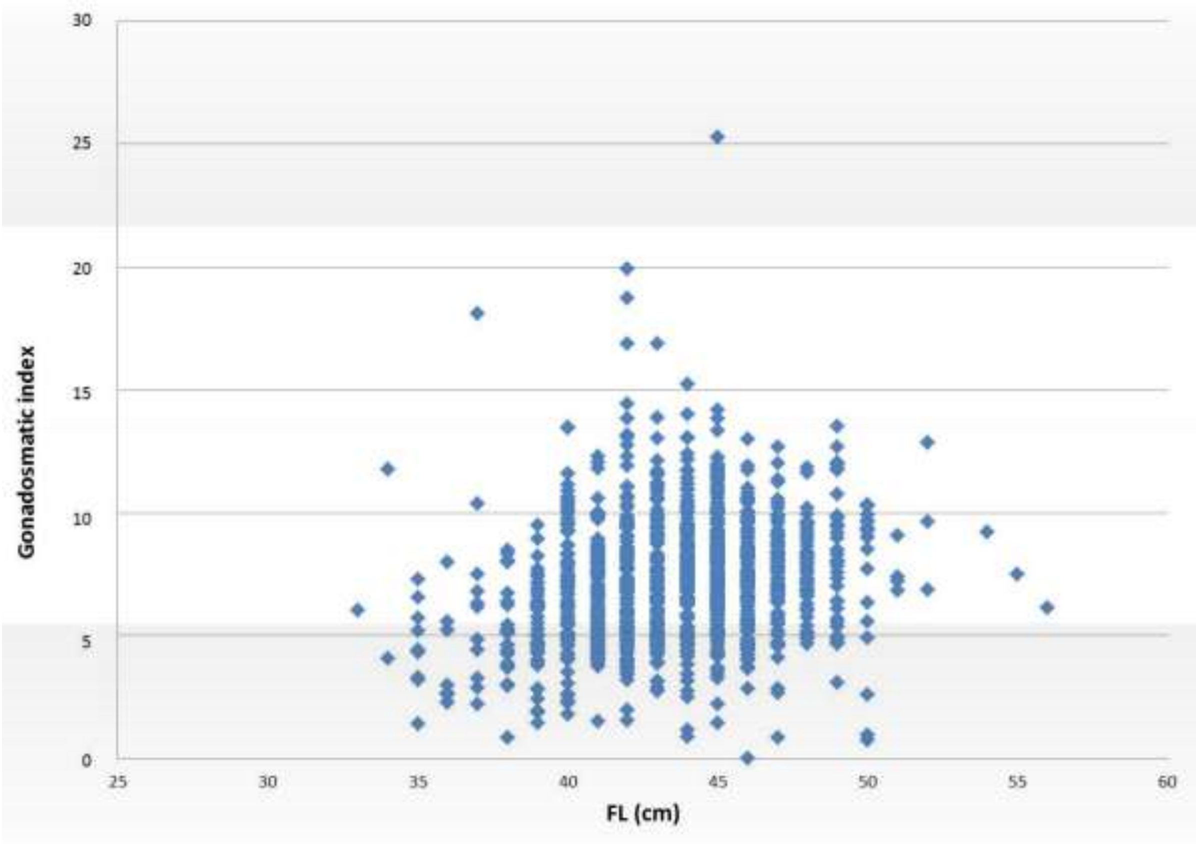
TABLE 39
Summary of maturity information for alfonsino

Location	Percentage mature (females)	Time	$L_{50\%}$ at maturity
Azores	54.8	Aug–March, peak in Dec	23.0 both sexes
Madeira	53.0	March–June, peak Apr–May	M / F 30.3 / 34.6
Canary Islands	64.4	Feb–Nov, peak July	M / F 29.9 / 31.3

Source: González *et al.* (2003)

The smallest size at sexual maturity was observed in the Azores where the fishing intensity is the highest, while the largest size at sexual maturity was found in Madeira where the fishing pressure is the lowest. However, Pereira and Pinho (2012) estimated an $L_{50\%}$ of 35.5 cm for females using commercial samples collected from 1998 to 2011, which suggests that the estimate of González *et al.* (2003) may be biased. Figure 37 shows the relation between the GSI for alfonsino in the Southwest Indian Ocean and length of females.

FIGURE 37
Relation between the GSI for alfonsino in the Southwest Indian Ocean and length of females



Source: adapted from G. Patchell, Southern Indian Ocean Deepsea Fishers Association (personal communication)

In Japan, alfonsino begin to mature in their second year and most fish are mature at 5–6 years (Matsuzawa, Kurata and Onishi, 1975). Honda *et al.* (2004) note that sexual maturation starts at age three or four and at a length about 28–32 cm in Japanese waters.

Lehodey, Grandperrin and Marchal (1997) calculated $L_{50\%}$ using a non-linear regression to fit a logistic function to the fish length and maturity using:

$$Y = \frac{1}{1 + A\,(e^{-BX})}$$

Where:

Y	= proportion of mature adults	
X	= fork length	
A, B	= model constants	

For: $Y_{0.5}$, $\hat{X}_{0.5} = \frac{-\log A}{B}$

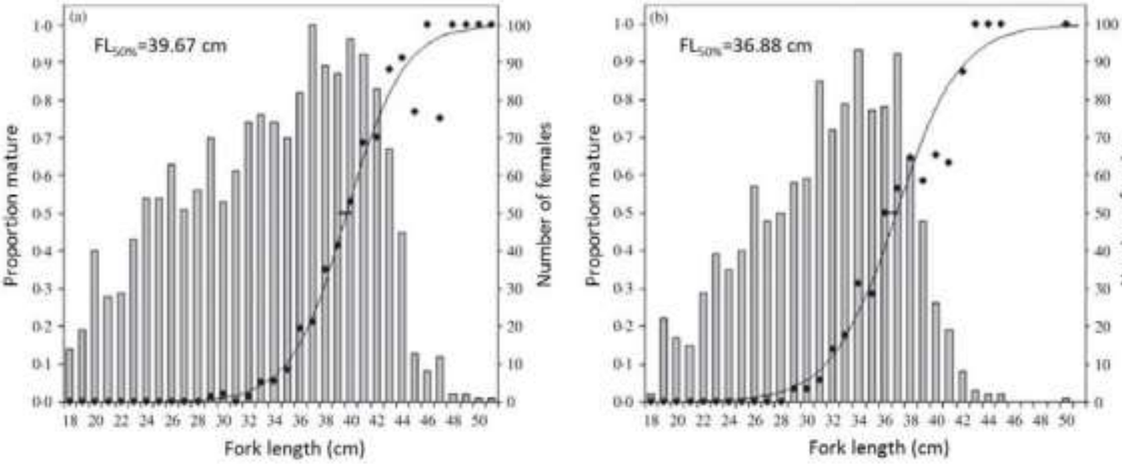
$\hat{X}_{0.5}$ = length at which 50 percent of population are mature

Discrepancy in age at 50 percent maturity could result in substantial bias in the estimates of spawning biomass obtained from stock assessment models.

Using a macroscopic maturity scale, Guerrero and Arana (2009) estimated L50 as 33.1 cm for females and 34.3 cm for males. For the same area, based on the histological analysis of the females' gonads, Niklitschek and Toledo (2011) reported $L_{50\%}$ as 33.8 cm. These previous studies also used specimens caught by commercial vessels and, thus, the differences in L50 estimates are not thought to be caused by differences in the sampling protocols. The discrepancies found in the $L_{50\%}$ maturity ogives for the Juan Fernández area are mostly related with the visual assignment of maturity stages in the macroscopic analysis. In addition, Guerrero and Arana (2009) and Niklitschek and Toledo (2011) used the macroscopic maturity scale of Lehodey, Grandperrin and Marchal (1997) in which fish are considered mature in stage IV or above. Flores *et al.* (2012) considered stage III as the cut-off for maturity based on recent studies. In fact, preliminary histological analysis of females of *B. splendens* by Roa, Niklitschek and Lamilla (2008) suggested that the macroscopic scale of Lehodey, Grandperrin and Marchal (1997) does not apply for alfonsino in Chile, and they estimated $L_{50\%}$ as 40 cm. This estimate is similar to the present results from the histological analysis. This similarity highlights the importance of histological analyses in determining maturity stages in the alfonsino inhabiting the Juan Fernández Islands.

Flores *et al.* (2012) presented two maturity ogives for alfonsino sampled from Chilean seas (Figure 38). Few females were mature before reaching a length of 30 cm, and the $FL_{50\%}$ was 39.67 cm (Figure 38a). The $FL_{50\%}$ for males was almost 3 cm shorter than for females with few fish mature before a length of about 26 cm (Figue 38b).

FIGURE 38
Maturity ogives for alfonsino sampled from Chilean seas (a: females, b: males)



Source: modified from Flores *et al.* (2012)

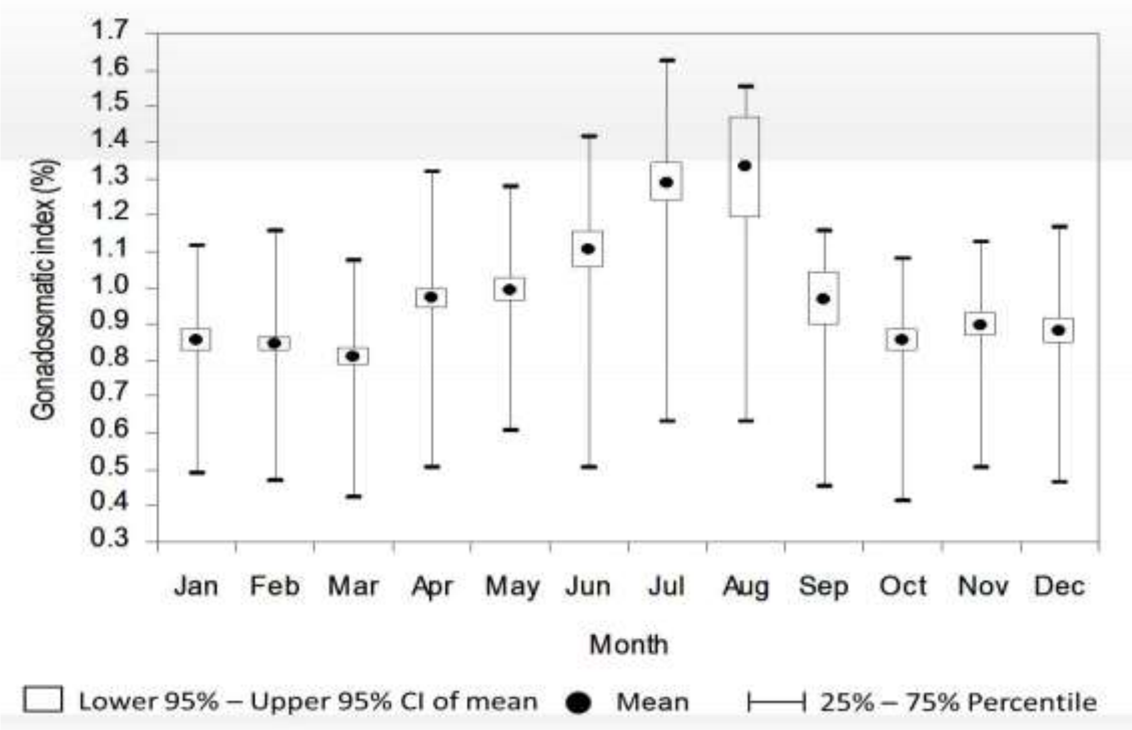
In their study of alfonsino on seamounts off New Caledonia, Lehodey, Grandperrin and Marchal (1997) found that the smallest size at which the sex could be determined was 20 cm for females and 18 cm for males. The spawning stage (stage VI according to these authors) was reached at 28 cm for females and 30 cm for males. Lehodey, Grandperrin and Marchal (1997) found that sexual maturity could only be determined for fish collected between September and April. The $F_{50\%}$ was 33.2 cm for females and 34.5 cm for males. Minimum size at pre-maturation (stage III) was 21 cm. The smallest pre-spawning size (stage V) was 26 cm for females and 30 cm for males.

In the Pacific Ocean, Kotlyar (1987) found females began to mature in the first year at a standard length of 16.2 cm; males matured in their second year at a standard length of 16.3 cm. All fish were mature by their sixth year. In Japan, Masuzawa, Kurata and Onishi (1975) found that most alfonsino are mature by age 5-6 years.

Flores *et al.* (2012) reported that estimates of $L_{50\%}$ for the Juan Fernández Islands showed significant differences between sexes in both the macroscopic and histological analyses. Females matured at larger sizes and had a longer life span in comparison with males (Gili *et al.*, 2002). Estimates of $L_{50\%}$ reported by Flores *et al.* (2012) were 39.67 cm for females and 36.88 cm for males based on the macroscopic analysis of the gonads. In addition, an even higher $L_{50\%}$ estimate of 43.7 cm for females was obtained using histological data, probably owing to more accurate classification of maturity stage. An important factor is the average fish age at 50 percent maturity. The average age for females at 50 percent maturity was estimated as 7.4 years using macroscopic analysis and 9.6 years using histology and based on a deterministic transformation of the von Bertalanffy equation specifically parameterized for female *B. splendens* around the Juan Fernández Islands (Gili *et al.*, 2002).

Wiff (2012) (Figure 39) shows how the GSI varies through an annual cycle for alfonsino sampled from Chilean waters. From a low in March, the GSI increases until August and then declines rapidly until October, remaining stable until the following March. However, a wide range in GSI values occurs throughout the year with individuals with values up to 1.1 always present in the sampled population.

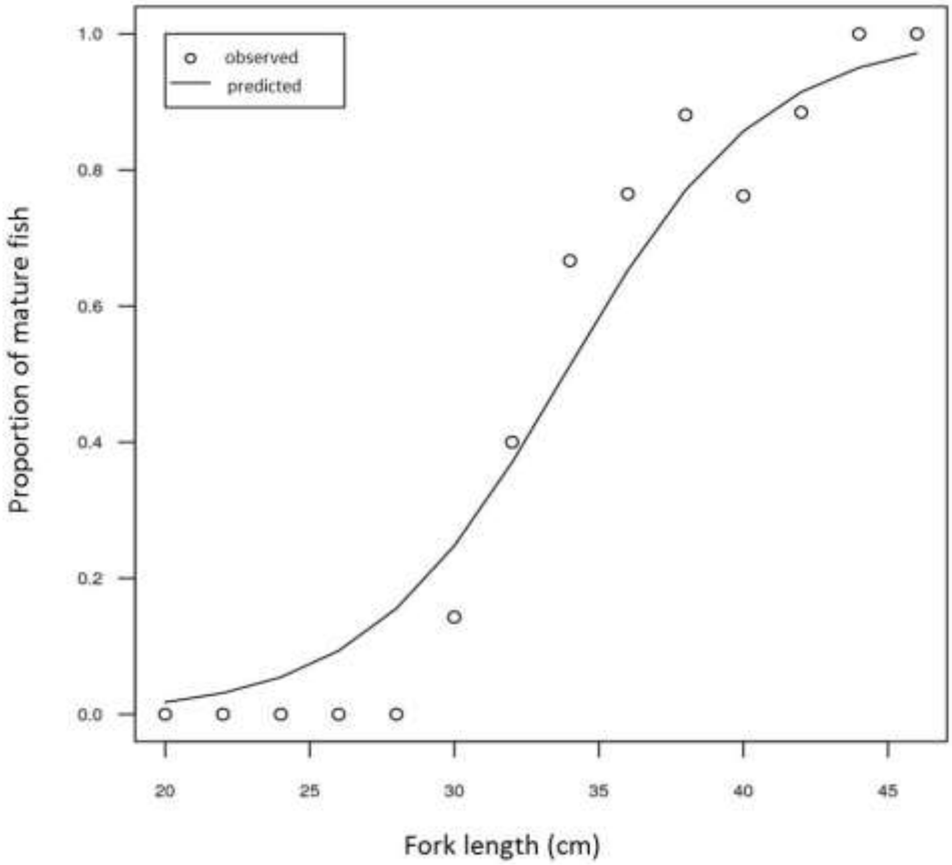
FIGURE 39
GSI as a function of month



Source: adapted from Wiff (2012)

Niklitschek and Toledo (2011) report that individuals greater than 35 cm were mature. The size at which 50 percent of females were mature, 33.8 cm, corresponded to an age of 7 years (Figure 40).

FIGURE 40
Logistic ogive of maturity versus length, females, 2010



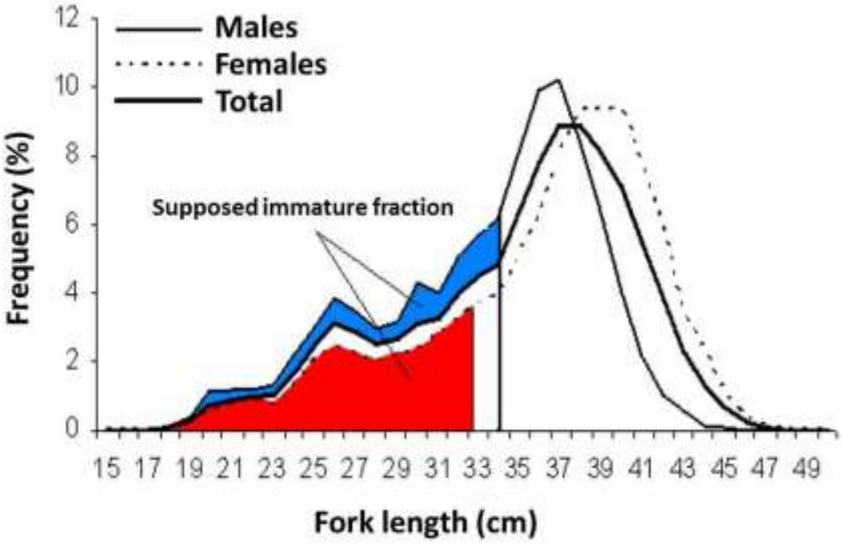
Source: Niklitschek and Toledo (2011)

Related research studies conducted on alfonsino in the area of the Juan Fernández Islands showed evidence of spawning in the spring season (Lamilla and Roa-Ureta 2008, *In* Roa-Ureta *et al.* 2008). The average size at sexual maturity of this species was estimated at 40 cm and about 7–8 years old (Roa–Ureta, 2008).

Figure 41 shows the size distribution of the Chilean alfonsino catch with the fraction of immature fish (Subpesca, 2004) disaggregated by seamount. Figure 42 shows the size frequency distribution of alfonsino catch by seamount in 2003.

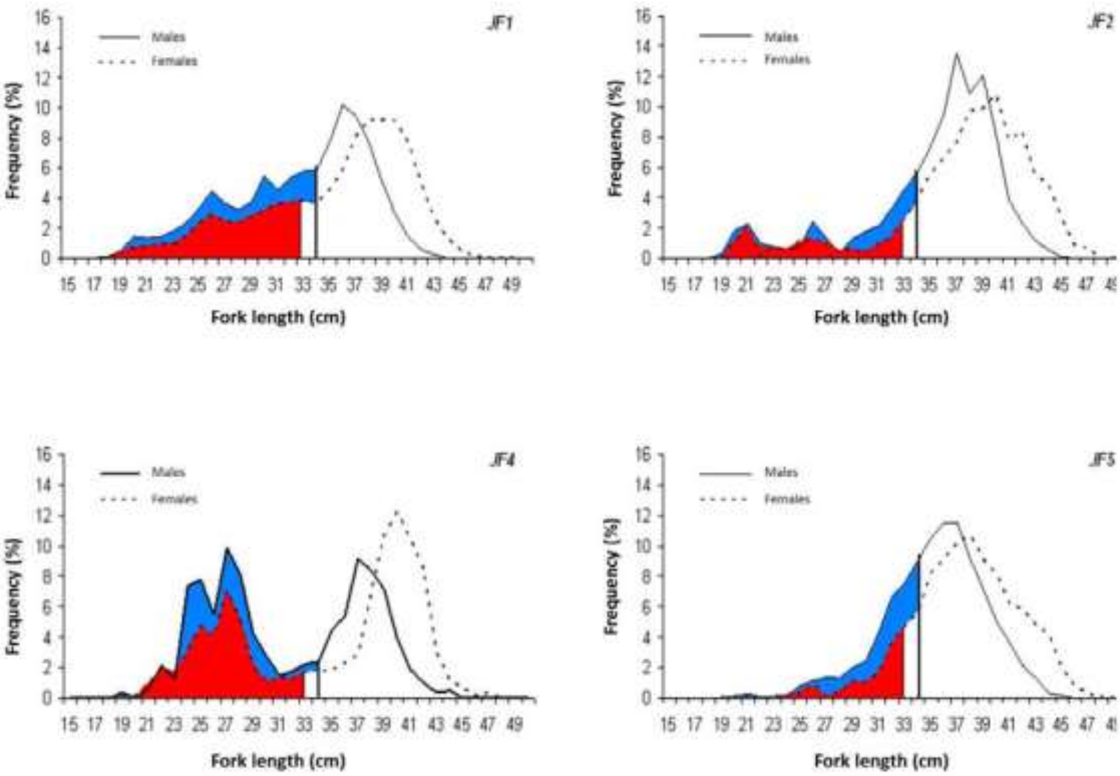
Beryx decadactylus
Estácio *et al.* (2001) determined the size at first maturity of *B. decadactylus* in the Azores at 32 cm (4 years). Pereira and Pinho (2012) confirmed that in the evolution of the gonadosomatic index of *B. decadactylus* the average for both sexes stayed at a low level throughout the year in the EEZ of the Azores (Figure 43).

FIGURE 41
Size distribution of the catch of alfonsino in 2003 showing the fraction of immature fish in the catch



Source: modified from Subpesca (2004)

FIGURE 42
Size frequency distribution of alfonsino catch by seamount in 2003

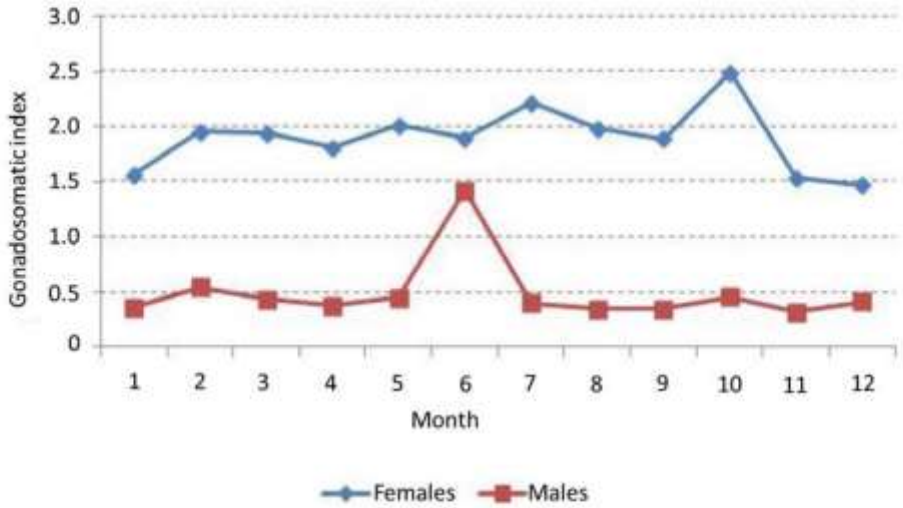


Source: modified from Subpesca (2004)

5.4 Fecundity

Individual fecundity of alfonsino in the North Atlantic ranged from 800 000 to more than 2 million eggs. Masuzawa, Kurata and Onishi (1975) found that fecundity increased with size of fish: those of about 40 cm length had 300 000–500 000 eggs. Lehodey, Grandperrin and Marchal (1997) found that the number of oocytes per gram of gonad was not correlated with length: the mean was 10 431 oocytes/g.

FIGURE 43
Monthly evolution of the average gonadosomatic index for *B. decadactylus* from the Azores



Source: adapted from Pereira and Pinho (2012)

The number of oocytes was proportional to the size of the ovaries, which in turn was a function of fish length. Therefore, the evolution of fecundity in relation to fish length should be well described by an allometric function, i.e. $Fecundity = aL^b$. Fecundity in relation to ovary weight is well described by a linear function, with an intercept value not different to zero at $P < 0.05$. The regression of fecundity on fish length gave oocyte numbers ranging from 270 000 to 2 500 000 for fish between 32 and 33 cm (6 years old at first maturity) and a length of 50–51 cm.

Niklitschek and Toledo (2011) report that, from a survey of alfonsino in the Juan Fernández Islands, the potential fecundity determined by microscope averaged 164 000 oocytes per female with a range of 69 080 to 287 700. This represented a potential fecundity of 99 000 oocytes per gram, which is lower than is usually reported and probably reflects the lack of development of the individuals that were examined.

5.5 Spawning

Alfonsino on the Corner Rise were observed to spawn from May–June to August–September (Alekseeva and Alekseev, 1984) while Alekseev *et al.* (1986) report that spawning peaks in July–August on the Corner Rise in the North Atlantic and in January–March in the South Atlantic. Only mature fish were found above the Corner Rise. Sherstyukov and Nostov (1986) note that spawning occurs from June to October in the Northeast Atlantic. Alekseev *et al.* (1986) reported alfonsino to have about 10-12 spawning events separated by about four days. Young alfonsino 3–10 cm in length are caught in September–October above Corner Rise seamounts to depths of 600 m. The spawning duration in the North Atlantic was estimated to be up to two months (Vinnichenko, 2012). Peak boreal spawning is in July–August, and in January–March in the Southern Hemisphere.

Alekseeva (1983) found spawning of alfonsino was intermittent. Individual fecundity is high, from 810 000 to 2 350 000 eggs. The duration of the individual spawning period was estimated to be up to two months. Young alfonsino 25–98 mm in length were caught on the Corner Rise by fry-sampling trawl in the 0-600 m water layers in autumn, where water temperatures were 14-26 °C (Sherstyukov and Noskov, 1986). Massive spawning occurred around the Azores in July–August. Catches off Northwest Africa were exclusively of immature fish. On Vavilov Ridge, only mature fish were caught while off the Southwest African coast only immature fish were encountered. Alekseev *et al.* (1986) concluded that spatial separation based on size and physiological condition occurred in both the North and South Atlantic.

Analyses of alfonsino from Madeira, the Azores and the Canary Islands found distinct spawning seasons in each location (González *et al*., 2003). On the north Azores seamounts no specimens with running gonads were caught, but there are reasons to suggest that spawning occurs in this area in summer–autumn (Kemenov *et al*., 1979; Vinnichenko, 1996a).

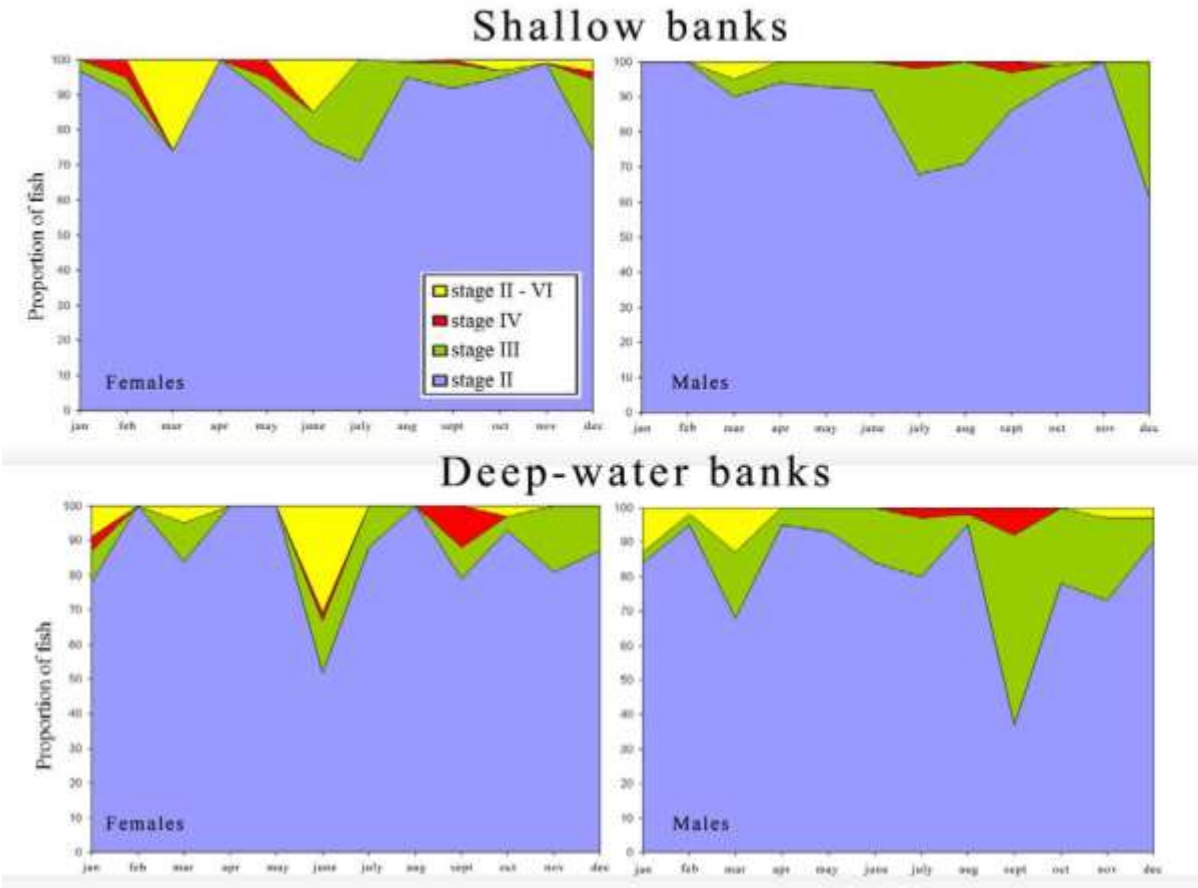
During a longline survey in Azorean waters Menezes *et al.* (2009) found one unusual and localized spawning aggregations of alfonsino and *E. telescopus* on the Sedlo seamount summit in September. Several authors have suggested a spawning season for *B. splendens* in summer/autumn (e.g. Vinnichenko, 1997b; González *et al*., 2003), which appears to agree with the results (obtained in September) of Menezes *et al.* (2009). Menezes (2003) found other spawning aggregations in November over the Nova Holanda seamount in the Cabo Verde archipelago. Previous surveys and reproductive studies of alfonsino in the Azores were not conclusive and did not reveal any defined seasonal pattern at a population level (e.g. Isidro, 1996; Menezes *et al.* 2001). For the New Caledonia area, Lehodey, Grandperrin and Marchal (1997) proposed a complex life cycle and reproductive strategy of alfonsino linked to the predominant local gyre circulation system involving different seamounts in the path. They proposed the existence of “vegetative zones” where juveniles grow until they reach maturity and reproductive zones inhabited by mature individuals. In the Atlantic the reproductive strategy of alfonsino and *E. telescopus* remains poorly understood (Menezes *et al*., 2009). Whether these reproductive aggregations occur periodically in the area and how long they persist should be further investigated.

The reproductive period of alfonsino is in the summer and early autumn and extends over four months. In temperate zones (35–50°N and 35–50°S) the spawning season occurs during autumn–winter. If a prolonged breeding season is generally characteristic of fish living in variable and unstable and/or highly productive environments; this would explain the four-month spawning period. The long breeding season for alfonsino is probably promoted by the favourable water temperature (González *et al*., 2003). Galaktionov (1984), Lehodey and Grandperrin (1996b), and Lehodey, Grandperrin and Marchal (1997) in relation to water temperature found that alfonsino rises into the upper water layer at night and, thus, is subjected to warming by the upper water layer. This might be the main factor inducing maturation and spawning.

Ivanin and Rebyk (2012) note the spawning of alfonsino on the banks of the SWIR (Figure 44), presumably in benthic layers along slopes, where the water temperature is 10–13° C. Post-spawning females are present in January, March and June and in pre-spawning stages in September, indicating that spawning of alfonsino extends year round. However, mass reproduction on shallow banks probably occurs in February–May and on deepwater banks in June–September. They believe that year-round spawning through 10–12 spawning events is instrumental in maintaining the population.

Spawning in Japanese seas occurs from June to October (Masuzawa, Kurata and Onishi, 1975) and northwest of Hawaii (Uchida and Uchiyama, 1986) and varies in Japanese seas among spawning locations (Honda *et al*., 2004).

FIGURE 44
Periods of ripening of gonads of alfonsino – SWIR, 1980–88



Source: adapted from Ivanin and Rebyk (2012)

Alfonsino spawn over the seamounts they inhabit and thus, no spawning migrations are involved (Masuzawa, Kurata and Onishi, 1975; Alekseev *et al.* 1986). Clear differences exist in the habitat by age. Nursery zones are inhabited by juvenile alfonsino and are in areas where adults reproduce. Lehodey, Grandperrin and Marchal (1997) noted that spawning evidently occurred in the southern summer. Spawning (stage VI) of females commenced in November–December and this stage dominated in January (81 percent of the females observed during that month) and February (78 percent). Post-spawning (stage VII) individuals dominated in March (60.5 percent) and in April, when stages II and VII accounted for 91 percent of the observations. Development was more difficult to follow for males as their macroscopic stages of maturation are less easy to identify. However, spawning (stage VI) males were observed in the warm season between November and April. Moreover, stage II and VII males (which are easiest to identify because of their high vascularization) as for females, were dominant in April, 49 percent of all males recorded in this month.

Flores *et al.* (2012) indicate that in the Southern Hemisphere the main reproductive season takes place in the southern winter and spring (June–November). Males also showed a substantial presence of mature individuals in the southern summer although with low values of the GSI.

Lehodey, Grandperrin and Marchal (1997) calculated a GSI by:

$$GSI = \frac{W_{gonads}}{L^3} \times 10^4$$

Where W is the gonad wet weight of the fish in grams, and L is fork length in centimetres. Regressions of the GSI on alfonsino size as a function of maturity stage revealed no correlation between these two variables, i.e. the GSI was independent of body size. Consequently, this index constitutes a good marker for sexual maturation. For New Caledonia, Lehodey, Grandperrin and Marchal (1997) summarize the reproductive cycle as follows:

- gonad maturation begins around September
- spawning commences in November, with a peak between December and February
- until April, the alfonsino are in the post-spawning stage when they enter a resting period until the beginning of the next maturation cycle.

Differentiation of mature and immature fish is possible only during the breeding period. The $FL_{50\%}$ was therefore estimated from data collected between September and April. It was further considered that fish that had not reached at least stage IV of the macroscopic scale of gonad maturation during this period would not spawn and they were consequently not considered in calculating the $FL_{50\%}$. However, the $FL_{50\%}$ obtained for males depended on identifying macroscopic stages III and IV, which was difficult.

Lehodey *et al.* (1997) found a rapid increase in the GSI in November with a peak in December continuing at a high level in January and falling to a minimum in March. Lehodey *et al.* (1997) found maximum potential fecundity to be between 270 000 and 675 000 eggs for fish between 34 and 40 cm. Lehodey (1994) found spawning peaked during December- January in New Caledonia.

Lehodey, Grandperrin and Marchal (1997) observed both female and male alfonsino in the spawning stage on seamounts where they are fished year round. They concluded that reproduction does not involve large migrations and that alfonsino reproduce in the areas they inhabit (also Masuzawa, Kurata and Onishi, 1975; Alekseev *et al*., 1986). However, the length-frequency distribution varied between fishing grounds and with depth (Masuzawa, Kurata and Onishi, 1975; Humphreys, Tagami and Seki, 1984; Horn and Massey, 1989; Massey and Horn, 1990; Lehodey, Marchal and Grandperrin, 1994). There appears to be a clear habitat difference in the zones inhabited by juveniles and those inhabited by mature alfonsino. Movement between these zones could occur either by migration or by drifting with currents.

Smith and Paul (2000) summarize that in the western North Atlantic the peak spawning period occurs between July and September (Sherstyukov and Nostov, 1986; Vinnichenko, 1997a, 1998), similarly in the North Pacific Ocean (Masuzawa, Kurata and Onishi, 1975; Uchida and Uchiyama, 1986). In the Southern Hemisphere, they note that spawning occurs between November and March, with a peak in December and January around New Caledonia (Lehodey, Grandperrin and Marchal, 1997) and between January and March in the Southeast Atlantic (Galaktionov, 1984; Alekseev *et al*., 1986).

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, Grandperrin and Marchal, 1997) where fish grow until near maturity and then move to spawn. In other regions spawning fish have been caught on seamounts where there are year-round fisheries and there does not appear to be an extensive adult migration to spawning areas (Alekseev *et al*., 1986, Lehodey, Grandperrin and Marchal, 1997). Smith and Paul (2000) believe that it is intuitively unlikely that these fish migrate long distances to spawn. Limited tagging studies on Japanese populations also indicate that adult alfonsino do not migrate over wide distances and long- distance spawning migrations have not been reported in other areas (Masuzawa, Kurata and Onishi, 1975; Lehodey, Grandperrin and Marchal, 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 the selectivity of fishing gear (Horn and Massey, 1989). No eggs or larvae have been observed in the Chilean EEZ (Lamilla and Roa-Ureta, 2008, in Roa-Ureta *et al*., 2008).

Beryx decadactylus

Spawning of *B. decadactylus* generally occurs over a period of four months but this period probably depends on climatic variation. Estácio *et al.* (2001) determined the size at first maturity of *B. decadactylus* in the Azores at 32 cm and age 4 years.

5.6 Post-spawning development

As alfonsino roe are small larvae are presumed to develop from epipelagic freely floating eggs. It is assumed that eggs are in the benthic layers of water and rise as development occurs. In any event, alfonsino larvae have been caught in epipelagic waters both near seamounts and in open ocean waters. Mundy (1990) presented the first complete ontogenetic description of *Beryx* species. Large larvae and small juveniles of *B. splendens* are compared to those of *B. decadactylus* and developmental features of *Beryx* pertinent to future phylogenetic studies of the Beryciformes are reviewed. The larval development of the alfonsinos, *Beryx* spp. is described from specimens collected from the central North Pacific Ocean (29°N, 179°E) in July 1984, primarily in the upper 50 m.

Alekseev *et al.* (1986) note that no descriptions of drifting eggs or larvae exist although they believe that they are evidently epipelagic because of the small size of the eggs. They report that alfonsino fry (4–10 cm) were common in the epipelagic zone above the Angolan trough and above the continental slopes of the Southeast Atlantic. In September–October 1983 young alfonsino were caught to depths of 600 m over the Corner Rise seamounts area. Young alfonsino of 25–98 mm in length were caught on the Corner Rise at a depth of less than 600 m in autumn, where water temperatures were 14–26 °C (Vinnichenko, 2012).

Alekseev *et al.* (1986) suggest that the vegetative and reproductive zones of the alfonsino populations in the Atlantic Ocean are located inside large oceanic eddy systems where the currents carry the eggs and larvae from the reproductive to the vegetative zone and finally return the first-maturing fish to the reproductive zone.

Ivanin (1987) caught juveniles 54–96 mm long at depths of 50–210 m in the Indian Ocean. The juveniles were captured where water depths exceeded 2 000 m and at considerable distances from the continental slope and seamounts indicating a wide dispersal of pelagic juveniles. Such dispersal would promote gene flow among 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).

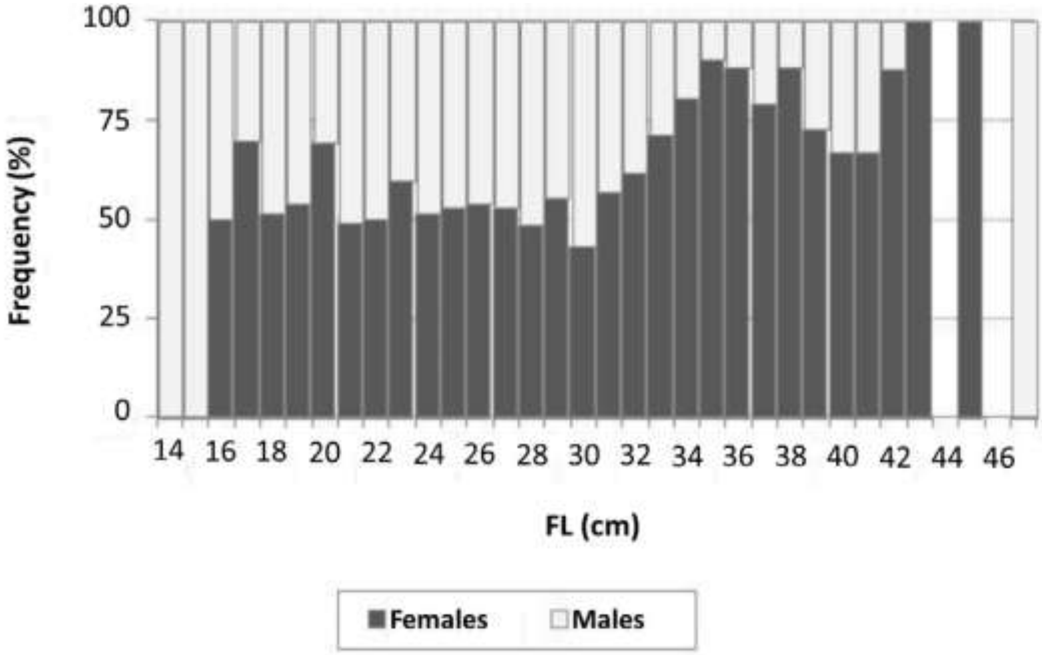
Lehodey and Grandperrin (1996a), Lehodey, Marchal and Grandperrin (1994), and Lehodey, Grandperrin and Marchal (1997) have described a model of larval and juvenile recruitment in an eddy system south of New Caledonia. Here, the reproductive zone corresponds to the fishing grounds located on the seamounts of the Norfolk and Loyalty Ridges, about 200 nm south and southeast of the main island respectively. The life cycle is contained within a large eddy system in this area that is centred between the Norfolk and Loyalty Islands ridges (23.5–25.5°S and 167.5–171°E) and recorded to be as deep as 700 m. This eddy moves pelagic eggs and larvae from the reproductive zone to the vegetative zone and then the first maturing fish back to the reproductive zone. Alfonsino caught on these seamounts, whose summit depths were between 500 and 750 m, were always > 17 cm. As the smallest alfonsino, consisting of immature juveniles of 13 cm in length with an estimated age of 8 months, were caught in October on seamounts with shallow summits (390 m) south of the main island this area could be their vegetative zone. Lehodey, Grandperrin and Marchal (1997) note that while few observations exist and cite studies showing that the eggs are pelagic for about four months before settling on shallow seamounts. A similar picture of small immature fish in shallower water with larger spawning fish above offshore seamounts was produced for alfonsino off Japan (Masuzawa, Kurata and Onishi, 1975) and for three populations of alfonsino in the central Atlantic Ocean (Alekseev *et al*., 1986).

Chikuni (1971) notes that alfonsino eggs are buoyant and hatch after 1–8 days. The pelagic larvae can be widely distributed by surface currents until they adopt a demersal existence, probably when they are about one year old. No eggs of alfonsino have been collected from the SE–NHR area (Yanagimoto, 2004) but larvae and juveniles were collected from the Southern Emperor Hancock seamount at the depths of 0–200 m in July by Mundy (1990), and two 2 cm juveniles were sampled from the summit of Kanmu seamount in November (Yanagimoto, 2004). In Japanese waters, juveniles are reported from near the Izu islands at the depths of 0–300 m and offshore of the Kuroshio Current (Anon., 2004).

Lehodey and Grandperrin (1996a) note that alfonsino rise at night from depths where light and temperature are relatively stable all year round into shallower waters where seasonal temperature fluctuations would occur and which could provide the stimulus for maturation of eggs and sperm. Indeed, these authors concluded that alfonsino are sensitive to interannual oceanographic variations, and their abundance has been affected by ENSO events.

5.7 Sex ratio
5.7.1 Alfonsino
A sample by Pereira and Pinho (2012) of 2 019 alfonsino taken in the Azores showed 40.1 percent were males and 59.9 percent were females, a ratio of 1:1.50 that was significantly different from 1:1. The sex ratio by length classes also showed an increasing proportion of females for sizes over 32 cm. This could indicate a differential growth or a natural mortality between sexes as no signs of hermaphroditism were observed even for the smaller sizes (Figure 45) (Pereira and Pinho, 2012).

FIGURE 45
Sex ratio of alfonsino in the Azores



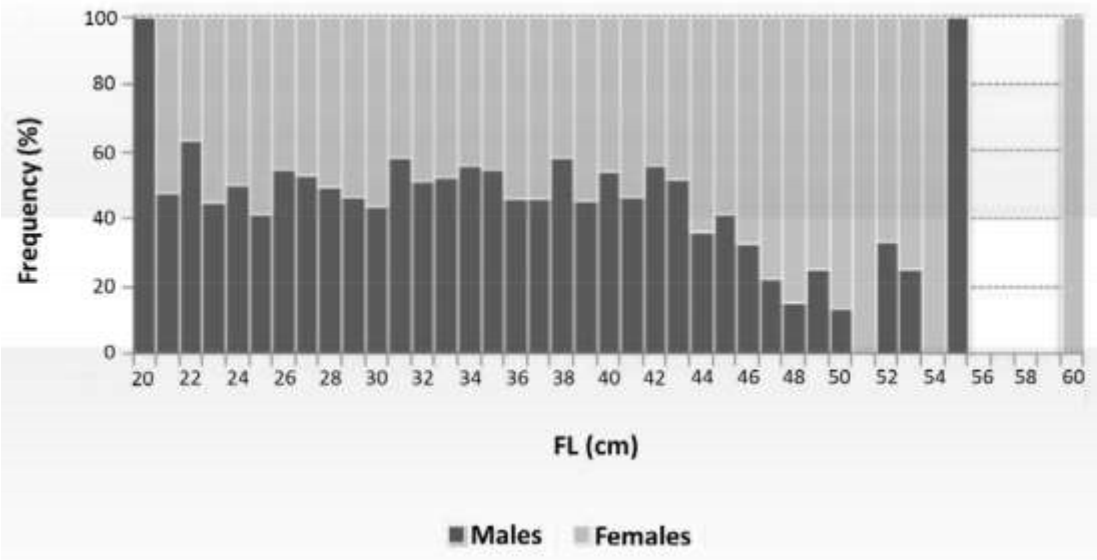
Source: adapted from Pereira and Pinho (2012)

Lehodey, Grandperrin and Marchal (1997) found that males predominated in fish smaller than 36 cm and females in sizes larger than this, although the sex ratio for the whole sampled population was close to 1:1. This, they thought, could arise from sampling over a small range in depth, the higher growth rate of female alfonsino and the increase in size of alfonsino with depth sampled. They concluded that alfonsino is not protandric but typically gonochoric. McKoy *et al*. (2009) report that, of 157 alfonsino caught during two surveys in the Arabian Sea in 2013, 45 were male, 105 were female and 7 were unidentified as to sex.

5.7.2 *Beryx decadactylus*
A sample of 705 *B. decadactylus* taken in the Azores showed 345 to be males (48.9 percent) and 360 to be females (51.1 percent), a ratio of males to females of 1:1.04, which was significantly different to 1:1 (Pereira and Pinho, 2012). For lengths of more than 42 cm, the sex ratio by size classes shows an increasing proportion of females; for lengths greater than 50 cm no males were observed. This could

indicate a differential growth rate or natural mortality between the sexes. Figure 46 shows the observed sex ratio of *B. decadactylus* by size class.

FIGURE 46
The observed sex ratio of *B. decadactylus* by size class



Source: adapted from Pereira and Pinho (2012)

6. POPULATION STRUCTURE[6]

6.1 Atlantic Ocean

Alekseev *et al*. (1986) believe that a North Atlantic population of alfonsino inhabit the North Atlantic subtropical eddy, with larvae drifting to nursery areas and settling on seafloor features. Based on studies after 1976 and in 1984 of spatial differentiation by size composition, physiological condition and the frequency of locus E^{st} – II, these authors concluded that at least three populations of alfonsino exist in the Atlantic Ocean, one in the north and two in the south, localized in macroscale, subtropical and tropical cyclonic eddies. 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 recalculate allele frequencies and re-analyse the data.

The range of these populations is divided into "vegetative" and reproductive regions related to geographically isolated thalasso-bathyal and benthopelagial zones of the continental shelves. Alekseev *et al.* (1986) believe that the currents that divide these populations serve as effective interpopulation barriers. The authors note that inadequate data were available and further studies are required. In the South Atlantic, Alekseev *et al.* (1986) note that alfonsino smaller that 15 cm were reported absent from the catches of juvenile fishes, and they hypothesized the existence of two populations: one living in the south tropical cyclonic eddy and the other in the Walvis Ridge area. They hypothesize that the smaller fish stay in the epipelagic zone. Kakora (2005) proposed that there are several populations or reproductive groups on the Southwest Atlantic seamounts.

The hypothesis that alfonsino migrate between Corner Rise and the Azores seamounts and that there is a single population in that area (Alekseev *et al*., 1986) appears doubtful, as it appears to be largely based on non-representative data on length–age composition of alfonsino on the Corner Rise and in the Azores area, which suggest that only large mature fish inhabit the Corner Rise whereas the Azores area is inhabited

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[6] A comprehensive and well-expressed summary of this topic is given by Smith and Paul (2000) from whom much material in this chapter has been taken directly.

mostly by small immature fish (nursery part of the range). However, data from several research and exploratory cruises suggest that both older and younger alfonsino permanently inhabit the Corner Rise and the Azores seamounts (Sherstyukov and Noskov, 1986; Vinnichenko, Gorchinsky and Shibanov, 1994; Vinnichenko, 1996a, 1996b; Menezes *et al*., 2009). Moreover, there are no reports of mature alfonsino migrations in the high seas (Kotlyar, 1996).

Many Russian investigators believe that the stock structure of alfonsino in the Atlantic consists of independent populations on each separate seamount that do not migrate long distances during any stages of their life cycle. This view is supported by the genetic investigations of Titova (1981) and by the absence of alfonsino aggregations on seamounts for long periods (several years) caused by heavy fishing (Klimenko, 1983; Melnikov, Ivanin and Piotrovsky, 1993; Vinnichenko, 1995, 1998).

6.2 The Azores

The exact geographic distribution of alfonsino in this area is uncertain and may be more extensive than the survey or regional catch areas (ICES, 2006, 2010a; Isidro, 1996; Pinho, 2003; Vinnichenko, 2002). Thus, generalizations about population structure based on the analysis of survey abundance trends should be interpreted carefully as the species may have been inadequately sampled by the surveys that were undertaken (Pinho, 2003).

Pinho (2012) notes that there is little information about the stock structure of these species and ICES has assumed the existence of a single stock for both species in the North Atlantic (ICES, 2004, 2010a). Although some hypotheses suggest genetic homogeneity at interoceanic scale for alfonsino (Hoarau and Borsa, 2000) geographical genetic population differences were detected for the Macaronesian archipelagos (Canary Islands, Madeira and the Azores) suggesting limited genetic flow between them. Thus, alfonsino should be considered as independent management units for management purposes (Schönhuth *et al*., 2005). However, high mobility for these species was also observed during an intensive fishing experiment on a seamount within the Azores area of Portugal's EEZ (Silva and Menezes, 1996).

The species spawns on the Azores and all phases of its life cycle occur in the fishing and survey area (Rico *et al*., 2001; ICES, 2010a). Little is known about movements of alfonsino between the Azores area of Portugal's EEZ and the seamounts on the Mid-Atlantic Ridge, but it has been suggested that those seamounts may support independent management units as no recovery was observed after the depletion of the seamounts (see Vinnichenko, 2002).

Schönhuth *et al.* (2005) used polymerase chain reaction (PCR) amplifications of mitochondrial gene fragments corresponding to cytochrome *b*, rRNA 16S and a control region. Morphometric and meristic variables were used to identify potential stocks occurring in the Azores, Madeira and Canaries archipelagos. For each fish, fork length, precaudal length, cephalic length, interorbitary distance and body depth were measured, and the number of spines in the dorsal fin, number of soft rays in the dorsal fin, number of spines in the anal fin, number of soft rays in the anal fin, and number of vertebrae were counted. Morphometric and meristic variations between specimens from the Canaries and Madeira archipelagos were analysed to identify possible morphological groups and the influence of the different variables on their separation.

Alignment of rRNA 16S sequences allowed the clear identification of alfonsino from the Azores as they showed a distinctive haplotype to the Canarian and Madeiran individuals, which in turn showed no differences between them in this mitochondrial fragment. Analysis of cytochrome *b* sequences permitted the unequivocal detection of alfonsino from Madeira. The haplotypes identified by 16S rRNA and cytochrome *b* served to establish a composite haplotype for the identification of each population from the Azores, Canaries and Madeira (Schönhuth *et al*., 2005).

Phylogenetic analyses inferred from partial cytochrome *b* sequences included all alfonsino from the Macaronesian archipelagos within the Clade A of Hoarau and Borsa (2000). According to the mitochondrial fragments analysed, it was possible to distinguish individual specimens from each archipelago. The morphological features of alfonsino observed were consistent with their genetic data, and comparison of the Canary Islands and Madeira morphometric and meristic data confirmed these observations.

The agreement between morphological and genetic data suggests the possibility of differentiating stocks and confirms that both analyses serve to discriminate populations of *B. splendens* from the three island groups. The A and W mitochondrial lineages were identified for populations of *B. splendens* and their findings indicate that the Macaronesian populations of *B. splendens* should be assigned to Clade A.

Schönhuth *et al.* (2005) note that their findings are consistent with the recent evolutionary history of Clade A proposed by Hoarau and Borsa (2000). However, the differentiation observed between populations from the Canary Islands, Madeira and the Azores suggests a role for oceanic currents as geographical barriers among the respective archipelagos, preserving distinctive haplotypes. This area has complex and dynamic mesoscale circulation with meanders and eddies. This includes the Azores current, an eastward permanent shallow, almost zonal, subtropical jet, and to the north, a smaller westward-flowing, eddy-driven subsurface Azores counter-current with flow at depths of 200–500 m. North of the Azores there is an easterly flow of the North Atlantic current. Madeira lies within the main eastward flow of the Azores current, and the Azores is bracketed to the south by this current and to the north by the North Atlantic current.

Findings indicate that the differential haplotypes detected in the study area may have been generated by effective dispersal filters such as local currents. This differentiation of populations appears to be consistent with the hypothesis of retention of the pelagic stage and recruitment of adults to specific habitats, reducing long-distance dispersal despite extended pelagic periods as previously suggested by other researchers. The results of Schönhuth *et al.* (2005) for Macaronesian populations of *B. splendens* are similar to those obtained for the New Caledonian populations but showed genetic differentiation among the three populations, suggesting stable currents in the area promoting the genetic differences.

The mitochondrial control region (421 bp) and cytochrome *b* (273 bp) were sequenced from individuals captured in Azores, Madeira and Cabo Verde archipelagos. *Beryx splendens* showed no significant population structure, indicating that it forms a panmictic population in the Northeast Atlantic. In contrast, strong evidence for isolation of the Cabo Verde population from Madeira and the Azores was detected for *B. decadactylus* (Amboim, 2005). A more detailed analysis performed at a finer-scale analysis on *B. decadactylus* analysing samples from Peniche (mainland Portugal) and subdividing the Azores archipelago into several different sampling groups, confirmed the differentiation between Cabo Verde population and all the other samples and also detected a significant although moderate differentiation between Peniche and one of the Azores subsamples (Central Group) (Amboim, 2005). Mismatch distribution analysis suggested a demographic history that included a sudden bottleneck/expansion about one million years before the present for *B. splendens* for the entire Northeast Atlantic population. For *B. decadactylus*, no evidence of past population expansions or bottlenecks were found (Amboim, 2005). The contrast in the genetic population structure of two closely related deep-sea fish, regarded as having similar life-history characteristics, is striking, especially as both species are often treated together in fisheries statistics as *Beryx* spp. Implementation of management strategies for these two species in multispecies deepwater fisheries must take into account genetic evidence of panmixia in *B. splendens* and particularly the presence of discrete genetic stocks in *B. decadactylus* (Amboim, 2005).

Beryx decadactylus

Mitochondrial DNA studies of *B. decadactylus* also suggest contradictory results, with no differences between the Azores and areas on the western North Atlantic (off the southeast coast of the United States of America) (Friess and Sedberry, 2011a), but with some evidence for localized genetically-different populations between Azores and areas on the Eastern Atlantic (Amboim 2005). Friess and Sedberry (2011b) found larger, mature individuals of *B. decadactylus* off the southern areas of the United States of America, which suggests a migration of adults from western areas similar to the one observed for other deepwater species. Their analysis of the mitochondrial control region sequences of 141 alfonsino (*B. decadactylus)* sampled off the coast of South Carolina, the United States, and 164 sequences from *B. decadactylus* collected in the Azores showed that all of the genetic variation was found within populations, indicating an absence of population structure. Their research suggested that *B. decadactylus* in the North Atlantic Ocean had undergone population expansion and the results may indicate that transatlantic gene flow occurs, possibly through passive drift of larvae or adult migration. Almost no sexually mature individuals were caught in the Azores region, and aggregations have not been reported to date (Isidro, 1996; ICES, 2010a; Pereira and Pinho, 2012).

6.3 Southern Indian Ocean

Ivanin (1989) examined the intraspecific population structure by comparative morphometric analyses of 97 alfonsino from the SWIR and 85 alfonsino from Ninety East Ridge in the Southern Indian Ocean caught in 1983–84. In the case of the southern end of Ninety East Ridge Ivanin (1989) does not provide the location of the samples and the spatial scale of the sampling could be more than seven degrees of latitude. Fish were caught during the period of feeding and when gonads were at stages II and III of maturity. No significant differences[7] were detected at the Ninety East Ridge. In the SWIR region males and females were differentiated only by the length of nose (Ivanin, 1989) and there were no significant differences in external measurements between the sexes.

Ivanin (1989) notes further that in regard to growth of alfonsino the proportions of their body were found to change. Fish from the SWIR region had positive allometry of the preventral and prepectoral distances and the distance between the eyes diminished. In the Northern Equatorial Ridge region the preventral and prepectoral distances and the length of the head increases. The relative distance between eyes and length of nose in ontogenesis is characterized by negative allometry. The change with age of these measures was statistically significant.

The differences between individuals from the two distinct ridges were found to be statistically significant were for: (i) the number of prickly rays of the dorsal fin; (ii) the preventral and pectoventral distances; (iii) the length of dorsal and pectoral fin bases; (iv) the height of the anal fin; and (v) the eye diameter. From these statistically significant differences of separate morphometric measurements, Ivanin concludes that there are two groups of this species. He notes that cases are known of the catch of alfonsino fry in open oceans (Sherstyukov and Noskov, 1986; Ivanin, 1987) and it is possible that the Ninety East Ridge alfonsino population recruits from the SWIR alfonsino population. However, Ivanin states that adults do not execute migrations over the open ocean, which indicates the existence of some reproductive isolation of the two groups of alfonsino.

6.4 North Pacific

A comparison by Masuzawa, Kurata and Onishi (1975) of samples from three fishing grounds exploited by the Japanese fleet to the east of Japan found no differences in the meristic characters of fin-ray counts, lateral-line scale count and vertebral count, but differences in morphometric characters. 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 from 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". 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°11'E) they concluded that the stocks were independent.

Yanagimoto (1996) examined both meristic and morphometric characters of alfonsino collected from the SE–NHR, Japan (Izu Islands) and New Zealand. The morphometric data that were examined were:

- dorsal fin spine and soft ray
- anal fin spine and soft ray
- pectoral fin soft ray
- pelvic fin spine and fin soft ray
- upper and lower gill-rakers

[7] Based on special criteria M-difference = $(M1 - M2) / \sqrt{[(M1)^2 + (M2)^2]}$ where M = arithmetic average; M = diff differentiation of series. If M-diff > 3.0 differences between series, e.g. a morphemic measure from alfonsino from SWIR and Ninety East Ridge, is statistically significant (Pravdin, 1966).

Samples were analysed from the Koko, Yuryaku, Kammu, Colahan and C-Hancock seamounts in the Northwest Pacific and from the Tasman Sea and eastern New Zealand. An analysis of covariance of two factors was done between body parts and body length. Correctness percentages ranged between 38.9 and 75.0. Discriminant analysis of morphometric data for samples from the Northwest Pacific and New Zealand were 86.7 and 89.2 percent, respectively. No statistical differences within the SE-NHR were detected but there were statistically significant differences among the three separated regions. These data suggest that alfonsino of the SE–NHR forms a single population, which may form a meta- population with the Japanese stock.

Yanagimoto (1996) also reported on PCR restriction fragment length polymorphism (RFLP) analyses of mitochondrial DNA (mtDNA) of fish from the above three regions. This analysis revealed no statistically significant differences within the Japanese waters and mtDNA analyses and tag-recapture data suggest that alfonsino in the Japanese waters form a single population (Yanagimoto, 2004). Chikuni (1971) and Yanagimoto (2004) proposed a meta-population hypothesis for the North Pacific alfonsino, as: (i) there is no genetic differentiation; (ii) larvae can be drifted from the Japanese waters to the SE-NHR via the Kuroshio Current and Kuroshio Extension; and (iii) morphological characters can be affected by local environmental conditions.

6.5 New Caledonia

The New Caledonia alfonsino stock is contained within an eddy system between 23.5–25.5°S and 167.5-171°E that 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, Grandperrin and Marchal, 1997).

Hoarau and Borsa (2000) examined the gene composition of 250 alfonsino sampled from seamounts and continental margins in New Caledonia, New Zealand and southeast Australia and from the Northeast Atlantic. Two major single-strand DNA (single-strand conformation polymorphism [SSCP]) haplotypes[8] were observed in New Caledonia, *a* and *w*, whose frequencies were negatively correlated along a north-to-south cline. The analysis showed that *a* and *w* belonged to two distinct mitochondrial clades. An analysis of 30 individuals from New Caledonia showed that their DNA fingerprint was strongly bimodal. The larger similarity values all corresponded to comparisons within a clade (A or W) while the lower values were all between clades. These results indicate the existence of two biological/sibling species (sp. A and sp. W) within the current taxon *B. splendens* (Hoarau and Borsa, 2000). Hoarau and Borsa note that a remarkable result is that the three cytochrome *b* haplotypes of Northeast Atlantic *B.* cf. *splendens* sp. A were also the three most common in the Southwest Pacific populations. Such a level of homogeneity in the distribution of haplotypes suggests there is, or recently has been, gene flow on an interoceanic scale. This finding puts into question the current systematics and taxonomy of the genus *Beryx*.

The sympatric presence of two phylogenetically-distant mitochondrial lineages lead Hoarau and Borsa to propose two hypotheses:

- recent secondary contact of populations that have been geographically separated for a long period; or
- there is an admixture in the samples of two sibling species.

The first hypothesis implies that only one alfonsino species is present around New Caledonia and that the dichotomy in the mitochondrial phylogeny reflects recent secondary contact of two lineages that have diverged by geographic isolation. Hoarau and Borsa (2000) conclude that the first of these hypotheses is unlikely for several reasons and note that the cline of haplotype frequencies in alfonsino would reflect the admixture in variable proportion of two reproductively isolated entities: *B.* cf. *splendens* sp. A, and *B.* cf. *splendens* sp. W. This cline may correspond to a simple contact between species, or perhaps to a hybrid zone.

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[8] A combination of alleles (for different genes) that are located closely together on the same chromosome and that tend to be inherited together.

Under the second hypothesis (sibling species), nuclear genotypes are expected to be heterogeneously distributed among mtDNA (A or W) classes of individuals and heterozygotes between the species specific alleles should be rare or absent. Hoarau and Borsa (2000) concluded that the significant correlation between direct amplification of length polymorphism (DALP) fingerprint and mitochondrial clade and arbitrary-primed PCR fingerprints confirms that the mitochondrial clades A and W characterize individuals of different species. Species W was sampled in New Caledonia only, mostly in the north of the area sampled; species A was sampled in New Caledonia, on the Chatham Rise off New Zealand, off southeast Australia, and on the Galicia Bank in the Northeast Atlantic. No heterogeneity in the distribution of haplotype frequencies was observed within either *Beryx* cf. *splendens* species A or W at the scale of New Caledonia. The presence of the same SSCP haplotypes (*a*, *h*, *i*) in both the Northeast Atlantic and the Southwest Pacific suggests that *B* cf. *splendens* sp. A populations share a recent evolutionary history at the worldwide scale, which in turn implies interoceanic gene flow. For deep-sea species such as *B. splendens,* gene flow can be due to recent or present stepwise migration along oceanic ridges and continental margins or to transoceanic expansion of the species' range.

According to current taxonomy the genus *Beryx,* Cuvier includes two species, *B. decadactylus* Cuvier and *B. splendens* Lowe, both with worldwide distribution. As *Beryx* is known for its extreme morphological conservatism, Hoarau and Borsa (2000) hypothesize that morphological characters are not powerful enough for full systematic resolution, thus explaining why *B. splendens* has to date been considered as monotypic. The molecular identification of two species within the current taxon *B. splendens* will have consequences on the understanding of what are the systematics and the taxonomy of the genus.

Lehodey, Grandperrin and Marchal (1997) found the smallest alfonsino, 8 months and length 13 cm, on a seamount of depth 390 m. These authors posit that they were carried by currents to reproductive zones. These authors note that, if true, it would support the hypothesis of a single population/stock, which would have important implications for management.

6.6 New Zealand[9]

There are four potential stock models for alfonsino in the QMA BYX 2 and QMA BYX 3:

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 owing 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 different models are produced by differences in movement patterns of both larvae and juveniles and/or adults.

The biological data on global populations of alfonsino indicate that models 3 and 4, with extensive adult movement are the least likely stock structures for QMA BYX 2 and QMA BYX 3 alfonsino. 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 based on the presence of alfonsino on Louisville Ridge seamounts.

9 This section is taken from Smith and Paul (2000).

6.7 Potential stock discrimination techniques for alfonsino

6.7.1 Otolith composition analysis

Smith and Paul (2000) believe that microchemical analyses of otoliths would be inappropriate for alfonsino for technical and theoretical reasons. Otoliths to be used for microchemistry analyses are unsuitable if inappropriate handling procedures, such as alcohol storage, have been used. Freshly collected and dried otoliths could be used for microchemical analyses. However, recent reviews of the microchemical techniques of stock separation suggest that it is inappropriate for oceanic fishes that occupy a relatively homogeneous saline environment. Moreover, 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 in otoliths and are only just above the detection limit. For marine fish in general the small differences reported between sites have not been confirmed with repeat samples. 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 the approach is not useful for stock discrimination in this species and other oceanic species have shown no regional differentiation in elemental concentrations. It has been concluded that the science of analysis of otolith composition is still developing and major methodological issues still need to be resolved. Smith and Paul (2000) conclude that microchemical analyses of dried otoliths is not recommended as a tool for stock discrimination of alfonsino.

6.7.2 Genetic analysis

An allozyme analysis of alfonsino samples from the Atlantic Ocean showed regional population structure with one esterase marker (Alekseev *et al*., 1986) and the authors concluded that their genetic data supported a three-stock hypothesis based on the esterase allele frequencies, distribution of adults and juveniles and oceanic circulation patterns. Alekseev *et al.* (1986) appear 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.

Studies based on DNA analysis of small samples of alfonsino showed no genetic differentiation between Chatham Rise, Australia, New Caledonia and the North Atlantic Ocean (Hoarau and Borsa, 2000; 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. 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 relatively small spatial scales.

6.7.3 Tagging

Tagging experiments off Japan released 3 925 alfonsino between 1957 and 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 (about 140 km) (Masuzawa, Kurata and Onishi, 1975). Hook tagging of alfonsino has not been successful in New Zealand (Horn, 1989).

6.7.4 Phenotypic characters: morphometries

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 North 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, Kurata and Onishi, 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°11'E (Masuzawa, Kurata and Onishi, 1975). In the Indian Ocean, samples were taken from SWIR and Ninety East Ridge, which are separated by as much as seven degrees of latitude (Ivanin, 1989).

6.7.5 Phenotypic characters: meristics

Samples of adult alfonsino from the West Indian and East Indian ridges of the Southern Indian Ocean differed in one of eight meristic characters - the number of dorsal spines (Ivanin, 1989). Samples from three fishing grounds in the North Pacific Ocean to the east of Japan had no differences in three meristic characters (fin ray, lateral-line scale and vertebral counts), but there were differences in morphometric characters (Masuzawa, Kurata and Onishi, 1975). The number of dorsal spines, the only meristic character to differentiate alfonsino stocks in the Indian Ocean (Ivanin, 1989), should be included in any testing of morphometric characters.

Results of examinations of meristic and morphometric characters of alfonsino collected from the SE-NHR, Japan (Izu Islands), and New Zealand (Yanagimoto, 1995, 1996) showed:

- no statistical differences within SE–NHR
- statistically significant differences among the three separated regions

However, it was noted that morphological characters can be affected by local environmental conditions.

7. ESTIMATES OF NATURAL MORTALITY

Gili *et al.* (2002) estimated natural mortality (M) using five empirical methods: those of Rikhter and Efanov (1976), Alagaraja (1984), Alverson and Carney (1975), Roff (1988) and Taylor (1958) (Table 40).

Massey and Horn (1990) noted a steep decline in the age–frequency composition from catches on the Palliser Bank, and different age structures on the two fishing grounds. Both indicate that some age-specific migration is occurring between different seamounts along the east coast. Consequently, mortality rates cannot be estimated from age–frequency data at present. Masuzawa, Kurata and Onishi, (1975) reached a similar conclusion based on the discrepancy between mortality estimates obtained from age–frequency and tagging data. Horn and Sutton (2009) were of the view that there were no reliable estimates of instantaneous natural mortality for any population of alfonsino in New Zealand or elsewhere. They estimated M using Hoenig's (1983) equation of:

$$M = -(\log_e 0.01)/A$$

where, 0.01 = proportion of the population that reaches age A or older.

TABLE 40
Estimates of natural mortality for alfonsino in Chile

	Rikhter & Evanov (1976)	**Alagaraja (1984)**	**Alverson & Carney (1975)**	**Roff (1988)**	**Taylor (1958)**
Males	0.148	0.178	0.323	0.199	0.116
	(0.136,0.160)	(0.158,0.198)	(0.286,0.359)	(0.212,0.187)	(0.103,0.129)
Females	0.136	0.158	0.287	0.211	0.103
	(0.129,0.143)	(0.147,0.170)	(0.265,0.307)	(0.203,0.218)	(0.096,0.111)
Both sexes	0.134 (0.128,0.141)	0.155 (0.145,0.165)	0.281 (0.263,0.299)	0.213 (0.207,0.220)	0.101 (0.095,0.108)
Model: $M =$	$\frac{1.521}{t_m^{0.720}} - 0.155$	$\frac{-\ln 0.01}{t_\infty}$	$\frac{3k}{e^{t_\infty 0.025k} - 1}$	$\frac{3ke^{-kt_p}}{1 - e^{-kt_p}}$	$t_0 - \frac{\ln(0.05)}{k}$

Note: 95% confidence intervals in parentheses
Source: Numerical estimates from Gili *et al.* (2002)

Ageing studies of alfonsino from various locations in the North and South Pacific Ocean have indicated that the maximum age for this species is probably about 20 years (e.g. Lehodey and Grandperrin, 1996a). The oldest alfonsino aged from New Zealand waters was 18 years (Massey and Horn, 1990; National

Institute of Water and Atmospheric Research, unpublished data). Using *A* = 18 in the above equation gives an estimate of M of 0.26; using A = 20 gives an M of 0.23. None of the ageing studies has examined unexploited populations, so there is a possibility that the true A is slightly more than 20 years. Massey and Horn (1990) assume that M is in the range 0.20 to 0.26.

Massey and Horn (1990) estimated total (instantaneous) mortality, Z, from the age structure of the catch using the method of Chapman and Robson (1960) and the R1 regression model of Dunn *et al.* (1999) (Table 41). Estimates, by sex, were made for each of the fishing years from data for QMA BYX 2 (Figure 22 shows the New Zealand QMAs). Estimated ranges of fishing mortality in the years for which data were available were derived after subtracting the range of M (0.20–0.26) from total mortality.

TABLE 41
Estimates of instantaneous total mortality and the resulting estimated ranges of instantaneous fishing mortality assuming M ranges from 0.20 to 0.26, by sex, for each sampled year

Sample year	Chapman–Robson		R1–Regression		Range	
	Male	Female	Male	Female	Male	Female
1998–99	0.37	0.35	0.39	0.34	0.11–0.19	0.08–0.14
1999–2000	0.47	0.38	0.42	0.35	0.16–0.27	0.09–0.19
2000–01	0.49	0.41	0.48	0.35	0.22–0.29	0.09–0.21
2006–07	0.56	0.37	0.53	0.34	0.27–0.36	0.08–0.17
2007–08	0.77	0.55	0.69	0.57	0.43–0.57	0.29–0.37

Source: Massey and Horn (1990)

A comparison of the 2007–08 and 2006–07 catch-at-age distributions indicated the progression of a relatively strong 2003 year class (i.e. 5 years old in 2007–08). Estimates of F for alfonsino in the five sampled years were determined assuming that M for this species was in the range 0.20–0.26. The results indicated that F increased over the sampled period, being (for males) probably less than M from 1999 to 2001, but greater than M in 2007 and 2008. The value of F was estimated to be consistently lower for females than males. However, if the true M for females is lower than that for males, then the real difference will be less than that indicated in Table 41. If the trend of an increasing F over time is real then it is indicative of a declining stock size as annual landings since 1990 have been relatively constant at 1 400–1 800 tonnes.

8. STOCK ASSESSMENT

8.1 North Atlantic

Vinnichenko (2012) notes that there is no explicit estimate of alfonsino stock size for the North Atlantic high seas. Nonetheless, retrospective data from Russian research, exploratory and fishing cruises suggest comparatively small stock sizes on the seamounts in this area. It was calculated that biomass of alfonsino both on Corner Rise and North Azores area in 1976–1995 had been about 17 000-27 000 tonnes. There is no information on stock status or advice for management of the alfonsino fishery from the Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO).

Advice from ICES in 2010 also notes that there is no knowledge of alfonsino stock status in the Northeast Atlantic. Landings data for 2008 and 2009 did not change the perception of the status of the stock. Therefore, the advice for the fishery from 2008 was still appropriate: “Due to their spatial distribution associated with seamounts, their life history and their aggregation behavior, alfonsino are easily overexploited by trawl fishing; they can only sustain low rates of exploitation. Fisheries on such species should not be allowed to expand above current levels unless it can be shown that such expansion is sustainable. In the light of the vulnerability of deep-sea species a reduction should be considered until such time there is sufficient scientific information to prove the fishery is sustainable.” (ICES, 2010a).

In the assessment of the current status of alfonsino stocks in the North Atlantic, the following information was considered:

- Compared with other deepwater fishes, alfonsino has a relatively short life, high growth/reproductive rates and high individual fecundity. These biological peculiarities determine relative resilience of alfonsino to heavy fishing on seamounts. In the absence of fishery, recovery of the stock to the level allowing for profitable fishery would take 4–5 years.
- Vulnerability to capture and pulse fishing for alfonsino, as a result of their aggregating behaviour and small population sizes on seamounts can result in rapid depletion of stocks.
- There has been no fishery targeting alfonsino in the North Azores area in the past decade. The fishery on the Corner Rise has been occasionally prosecuted by Spanish vessels since 2004 with limited annual catches.

Analysis of the above information gives grounds to believe that alfonsino stocks in the open North Atlantic have recovered to some extent compared with the situation in the 1990s.

8.2 Azores

8.2.1 Survey method

In the Azores archipelago, the use of trawl and acoustic stock assessment methods is not possible because the sea bottom is rough and the behaviour of alfonsino is not ideal for these types of surveys. However, the Department of Oceanography and Fisheries of the University of the Azores has conducted an annual longline survey since 1995. The annual Azorean bottom-stratified longline survey in ICES Area Xa2 has usually been done from March/April to June. Strata are divided into 50 m depth intervals for abundance estimation purposes, with one random station within each subarea always extended to deeper strata (601–1 200 m) for exploratory and ecological purposes. A maximum of 60 days (corresponding approximately to 30 sets) was imposed by ship-time availability and cost. A bottom longline designed for benthopelagic species, similar to commercial gear was used for the survey. Detailed information on the survey design is given by Pinho (2003), Menezes *et al.* (2006) and ICES (2010b).

The catch per hook (CPUE) was calculated for each species, area, and stratum and an index of relative abundance in number (or weight) obtained by multiplying each of these CPUE values by the corresponding area size.

8.2.2 Estimation of the index of abundance

The CPUE is calculated for each species by area, and station stratum and an index of relative abundance in number or weight is obtained by multiplying the CPUE values by the corresponding area sizes. An average relative abundance estimate for each area and stratum is then calculated. The annual abundance for each area and for the Azores is estimated by summing the abundance values across strata and across areas, respectively. A bootstrap method is used to calculate confidence intervals and check for statistical differences of the annual abundance estimates. Not all depth strata were sampled at each station as a consequence of bottom topography, lost gear or ship operation difficulties and missing values are not considered for the abundance computations.

This procedure was performed for strata to a depth of 600 m to cover all time series. Additional abundance estimates have been computed by species for the entire survey depth strata (50–1 200 m) and for all the period (1995–2011) for illustration purposes.

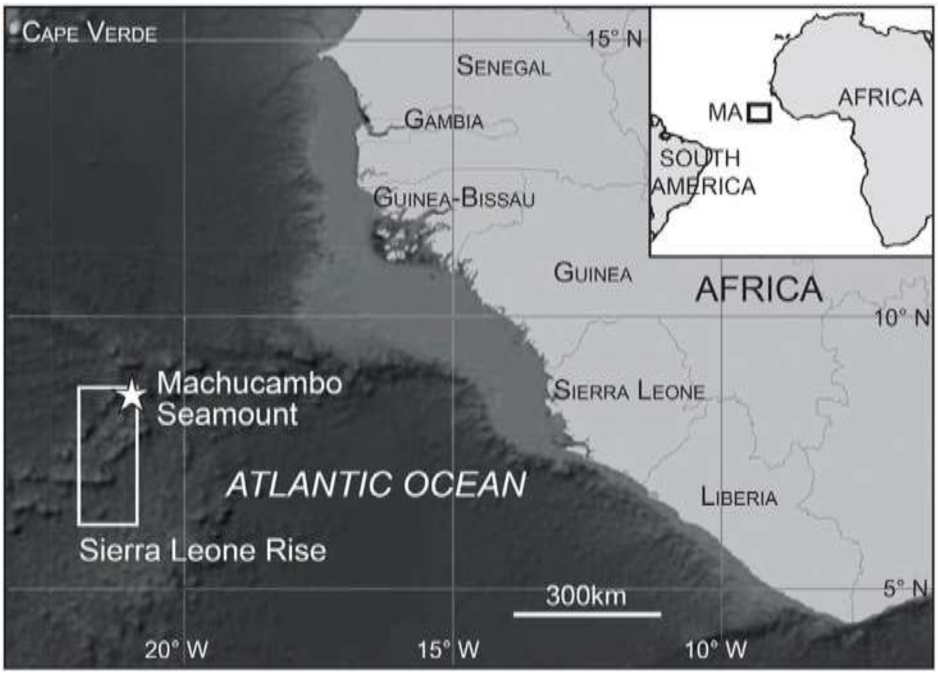
8.2.3 Survey results

Abundance of alfonsino in ICES Area Xa2 showed a slight decline, with high interannual variability ($p < 0.005$). Abundance was particularly low and stable in the period 2000–08 with the exception of 2003, with an apparent increasing trend during the last two years. This species is caught in all areas sampled of the Azores and has a depth distribution between 100 and 800 m, with a mode of 400 m. Alfonsino lengths ranged from 15 to 41 cm with a mode around the 26 cm. Larger individuals were found in deeper strata but this could be the result of the sampling design. The annual mean length has declined slightly over time.

8.3 Seamounts on the Sierra Leone Rise

From January to July 2001, the Spanish Institute of Oceanography conducted an experimental fishing survey of five seamounts (Machucambo, Falsos-Southeast, Falsos-Northeast, Rompetodo and Escolares seamounts) on the Sierra Leone Rise (5–10°N, 19–27°W), a discontinuous chain of seamounts near the Mid-Atlantic Ridge. Of the fishing effort, 75 percent was spent on the Machucambo seamount (Figure 47) to identify the fishing potential of this area for Spanish demersal longliners (Salméron *et al*., 2015). These seamounts had not been fished by demersal fishing before, although the area is fished by Spanish tuna purse-seiners. Salméron *et al.* (2015) analysed the effects of this demersal longline fishery in terms of the catch of alfonsino over a short time-scale. Five seamounts were fished with longlines over 141 fishing days from January to July 2001 at depths of 200–1 200 m. The catch was dominated by alfonsino, both in numbers and biomass. Either one or two longlines were deployed with a minimum soak time of three hours.

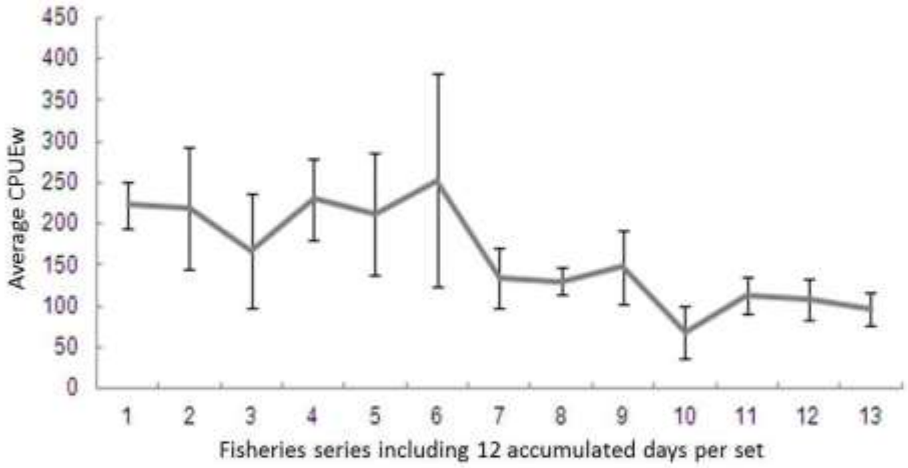
FIGURE 47
Location of Machucambo Seamount on the Sierra Leone Rise



Source: Salméron *et al*. (2015)

Salméron *et al.* (2015) used a spectral analysis procedure to show that the CPUE exhibited a clear time-trend with an observed periodicity of 12 fishing days. After about 70 days, CPUE showed a pronounced decrease (Figure 48) with no subsequent recovery during the period of the survey.

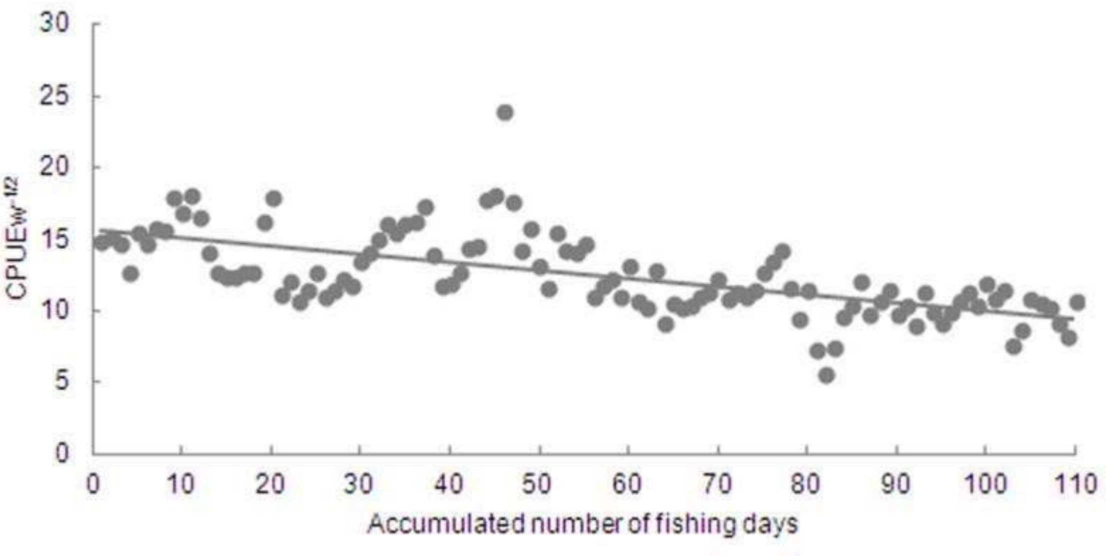
FIGURE 48
Average CPUE by weight (kg/1 000 hooks/fishing day) of alfonsino landed for sequential periods of 12 fishing days



Source: Modified from Salméron *et al*. (2015)
Note: Error bars denote SD

A significant linear regression was found for the results from the Machucambo seamount after a square-root transformation of the CPUE and cumulative fishing days (Figure 49).

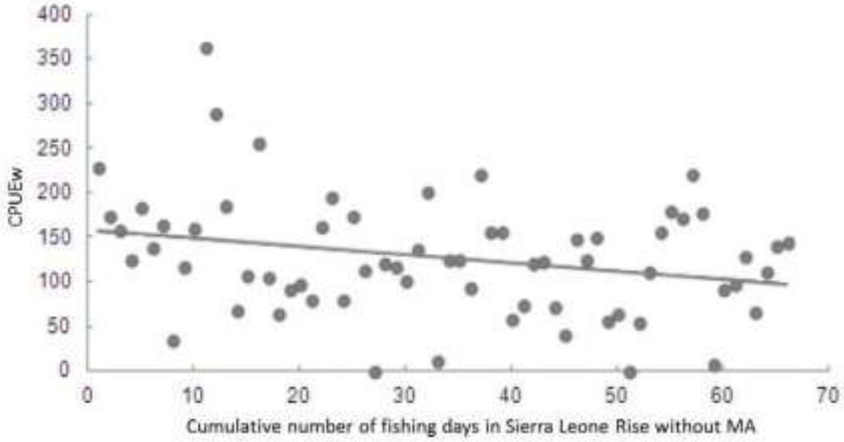
FIGURE 49
Relationship between square root-transformed CPUEw (kg/1 000 hooks/fishing day) of alfonsino and cumulative fishing days at Machucambo seamount



Source: Salméron *et al*. (2015)
Note: CPUEw $^{-½}$ = 15.692 – 0.056 *A*, where *A* is cumulative fishing days. [r^2 = 0.3992, df = 1, *F* = 71.75, *n* = 110, *p* = 1.35 × 10 – 13].

No significant differences were found between the mean lengths of fish caught during the first fishing series (*n* = 1 679; average length = 35.96 cm; SD 2.053) and the last fishing series (*n* = 728; average length = 36.18 cm; SD 2.277). A significant, negative linear regression was found between CPUE and cumulative fishing days using the pooled data from the other seamounts (Figure 50).

FIGURE 50
Relationship between CPUEw (kg/1 000 hooks/fishing day) of alfonsino and cumulative fishing days, with data pooled from Falsos-Southeast, Falsos-Northeast, Rompetodo and Escolares seamounts (excluding Machucambo)



Source: Modified from Salméron *et al.* (2015)

Salméron *et al.* (2015) conjectured that the 12–day periodic pattern in CPUE might be explained by a behavioural strategy of alfonsino that favours connectivity between subpopulations (Clark *et al*., 2010) and, hence, local declines in CPUEw may be temporary. Further, these authors believe that the longer-term trends they observed can be explained by local depletion of the alfonsino stock during the survey period. They concluded that a demersal longline fishery could substantially deplete a fish stock in less than a year.

Salméron *et al.* (2015) were uncertain whether the rapid initial decline observed in CPUE of alfonsino represented local stock depletion or a general stock depletion. The depletion they observed might have been temporary because fish could potentially migrate to the seamount at a later date. However, given the relationship between the decreased fish yield and cumulative fishing days, longer fishing periods and a small fishing area could decrease the resilience of the stock. These authors concluded that their results do not support commercial fishing of alfonsino by large-scale longlining on these seamounts. However, given the relative resilience of this species, a small-scale fishery that combines short fishing periods with long periods of inactivity could be sustainable.

8.4 Southern Indian Ocean

Paramonov (2012b) gives some abundance estimates for select areas in the Southern Indian Ocean. Tables 42–44 show the results of acoustic surveys on Bank 710 (Tits), 480 (Tonga) and other banks in the Southern Indian Ocean. No information is available about the backscattering cross-section that was used to convert echo intensity to biomass or the calibration details of the ships' acoustic systems.

TABLE 42
Results of trawl-acoustic surveys on Bank 710 (Tits seafloor feature)

Period	**Total biomass** (tonnes)	**Alfonsino** (tonnes)
May 1983	559	430
June 1983	590	454
June 1983 (2)	1 466	1 129
August 1984	1 120	1 120
August 1984 (2)	260	195
August 1984 (3)	690	690
August 1984 (4)	100	100
March 1990	1 330	1 033

Source: Paramonov (2012b)
Note: Coordinates: 37°25.6'S 50°26.7'E / 37°25'S 50°24'E

Biomass estimates were subject to considerable fluctuations, and Paramonov (2012b) believes that this may be explained by:

- the mobility of alfonsino and their ability to hide on slopes and in burrows on the bottom where they are hard to detect and catch;
- imperfections in the system of trawl-acoustic surveys.

Thus, the instantaneous biomasses are probably underestimates and should be used only as an index of biomass.

TABLE 43
Results of trawl-acoustic biomass surveys on Bank 480 (Tonga seafloor feature)

	Total biomass (tonnes)	**Alfonsino** (tonnes)
August 1983	6 031	3 926
August 1983 (2)	4 044	2 633
August 1983 (3)	6 156	4 008
August 1983 (4)	4 261	2 774
November 1988	2 700	2 684
March 1990	1 420	–

Source: Paramonov (2012b)
Note: Coordinates: 38°24.8'S 48°28.9'E / 38°26'S 48°22'E

TABLE 44
Results of trawl-acoustic surveys on other banks of the Southwest Indian Ridge

Bank	**Period**	**Total biomass** (tonnes)	**Alfonsino** (tonnes)
102	November 1988	2 650	–
102	March 1990	2 650	–
251	August–September 1987	6 300	–
251	February–March 1990	1 140	–
415	November 1988	4 950	4 850
415	March 1990	700	700
640	February–March 1990	770	–
690	February 1990	1 050	98

Source: Paramonov (2012b)

Alfonsino are caught to depths of 1 500 m but repeatedly alfonsino accumulations were observed and caught down to 2 000 m. This implies that the distances between the banks are not insurmountable barriers for alfonsino because nearby banks are mainly across waters of depths to 1 500–2 000 m. Without migration, it is hard to explain the appearance of alfonsino on Gololobov Bank (No. 360), where in most years it was absent.

Niklitschek and Patchell (2013) collected echo data using an ES38B 38 kHz split beam transducer operated at 2 kW with a pulse duration of 1.024 ms to obtain 14 snapshots of alfonsino in 2007 and 2008 from seven fishing grounds grouped into three fishing areas in the south-west and south-east of the Indian Ocean. The survey period ranged from mid-December to early February across areas and years during the spawning season (Table 45). They used geo-statistical and standard probability sampling methods to estimate the mean surface scattering cross section (S_A) from which biomass was estimated.

TABLE 45
Number of alfonsino surveys and total surveyed area by feature and year. Zones correspond to 1° x 1° areas labelled by their mean latitude and longitude

Zone code	Feature code	2007 Trip start			2008 Trip start		
		No. of surveys	Survey period	Area surveyed (km^2)	No. of surveys	Survey period	Area surveyed (km^2)
3654	EURO			43.3	1	15 Oct	2.2
2787	ENNO	4	14 Dec -8 Feb, 2008	9.9			
	ENSO	2	8 Jan 2008				
	CRNE				1	28 Dec	1.1
	TB2E				2	30 Dec-6 Jan	1.5
	TB2W				2	30 Dec-6 Jan	3.3
3357	FREO				2	27-30 Aug	4.1

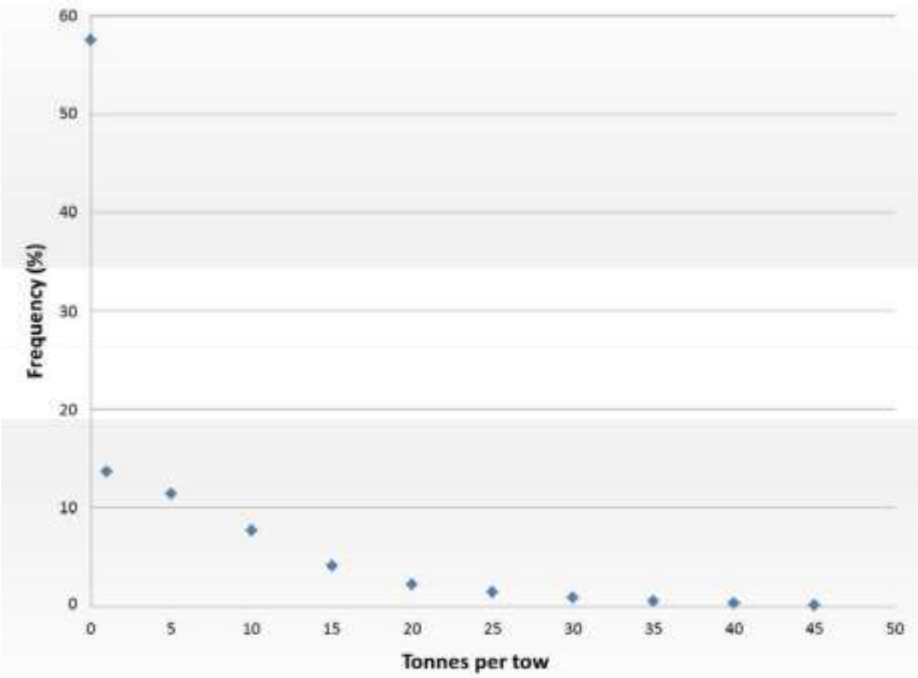
Modified from: Niklitschek and Patchell (2013)

Niklitschek and Patchell (2013) used the alfonsino target strength value (i.e. backscattering cross section) of Niklitschek *et al.* (2007). Average corrected density for alfonsino ranged between 95 and 500 tonnes/km^2. While no feature was assessed in both 2007 and 2008, pooling results within the fishing area 2787 showed an apparent increment of around four-fold in corrected biomass density. Such large increments in biomass are probably related to mobility of alfonsino stocks (Niklitschek *et al.* 2008).

Niklitschek and Patchell (2013) note that the reported total biomass estimates are closer to a relative index than to an absolute one and caution against misinterpreting the results. They believe that a significant improvement in precision and accuracy in biomass estimates would be expected if there were three survey replicates a year, a mandatory requirement to undertake surveys and a pre-planned sampling design for all vessels working a seafloor feature. Analysis of echo intensities should also consider gonad stage or gonadic index and thus the effects of stage of maturity on echo intensity. These authors used the maximum likelihood geo-statistical procedure of Roa-Ureta & Niklitschek (2007). It generally produced lower abundance estimates of abundance than that obtained with a random sampling design.

Several authors have commented on the applicability of CPUE for parameterizing stock assessment models. If the fishing technique used is aimed trawling, experience shows that many tow attempts will "miss the fish" and return a "zero" catch. In the case of one assessment for the Southern Indian Ocean aimed-trawl fishery, 58 percent of tows returned a zero catch (Figure 51). This did not indicate that there were no alfonsino; indeed, the gear would not have been deployed if that had been the case. Thus, care is needed in any "simple-minded" use of the CPUE as a model variable in aimed-trawl fisheries.

FIGURE 51
Frequency of alfonsino catch rates, one vessel, Southern Indian Ocean, 1997–2011



Source: modified from Patchell (2012)
Note: n = 7 186

8.5 Northwest Pacific

Nishimura and Yatsu (2008) used surplus production models to investigate the population dynamics of alfonsino from the SE–NHR alfonsino fisheries. Japanese trawlers started commercial fishing in this region in 1969, and 2–13 trawlers have been fishing there for North Pacific armourhead (*Pseudopentaceros wheeleri*) and alfonsino (*Beryx splendens*) since then. These authors examined two surplus-production models using unadjusted/adjusted CPUE and with catch statistics from Japan, the Republic of Korea, and the Soviet Union/the Russian Federation.

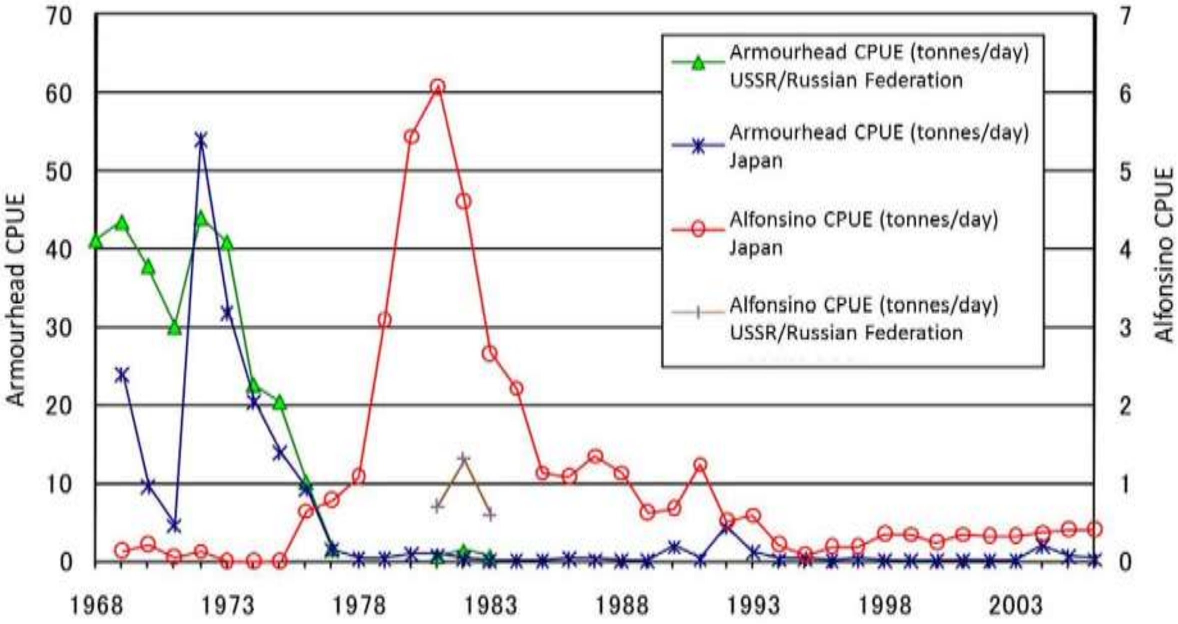
Japanese landings increased from 22 000 to 35 000 tonnes in the period 1970–76. As armourhead catches declined alfonsino was targeted and catches increased in the late 1970s to 11 831 tonnes in 1980 and then declined in the mid-1980s. In the last two decades, alfonsino catch has been fluctuating between 1 000 and 6 000 tonnes with a continuous fishing presence. The armourhead catch abruptly increased in 1992 and 2004 and the SE–NHR trawl fishery can be characterized by continuous catches of alfonsino with dominant catches shifting from alfonsino to armourhead depending on its strength of recruitment in the area.

Nishimura and Yatsu (2008) calculated CPUE using:

- unadjusted CPUE (Japanese annual alfonsino catch divided by annual total Japanese fishing hours);
- adjusted CPUE (Japanese annual alfonsino catch divided by adjusted Japanese fishing hours), where annual fishing hours for alfonsino were assumed proportional to log-transformed annual catch of alfonsino to aggregated annual catch of alfonsino and armourhead.

Fishing effort was adjusted because the raw figures did not distinguish when vessels were targeting armourhead (mainly tops of seamounts) and alfonsino (mainly slope areas). Alfonsino fisheries in the period 1979–1982 produced extremely high CPUEs (5.32–10.77) whereas after 1983 the level was much lower, 0.21–4.04 (Figure 52).

FIGURE 52
Variation in CPUE of Japanese vessels on the SE–NHR alfonsino and armourhead fishery, 1968–2003



Source: NWPRFMO (2008)

Nishimura and Yatsu (2008) estimated maximum sustainable yield (MSY) and related parameters using Schaefer's 1954 surplus-production model (the MS Excel model) and the non-equilibrium A Stock Production Model Incorporating Covariates (ASPIC) model of Prager (1994): the assumption was that CPUE was proportional to abundance. All available CPUE data from 1969 to 2006 were used in the first step of the ASPIC analyses.

For the ASPIC model the CPUE used was also adjusted using a log-transformed annual catch of alfonsino and armourhead and the CPUE was used for estimating the MSY and related parameters for stock management. The two models were used to estimate $F_{MSY}/F_{current}$ and the ratios of F at MSY to current F ($F_{current}$: average in recent 10 years, 1997–2006) under three different conditions. Several trials were performed changing initial parameters, but no plausible outputs were obtained. The analysis was then repeated with the extremely high CPUE data from the initial exploitation period from 1969 to 1984 excluded.

Nishimura and Yatsu (2008) concluded that the model fitted the CPUE data well and that reasonable parameter values were estimated. When using unadjusted CPUE the ASPIC model "suggested" that an MSY of 2 975 tonnes could be produced from a stock biomass of 3 876 tonnes (B_{MSY}) at a fishing mortality rate on biomass of 0.768 (F_{MSY}). The estimated biomass in the 1980s was relatively high and decreased in the early 1990s becoming lowest in the mid-1990s; it then increased after 2000. When the CPUE analysis using the adjusted effort was performed almost the same results those were obtained.

Nishimura and Yatsu (2008) also used a surplus-production model to improve the parameter estimation. They assumed that the parameters of this period differed from other years. The model assumptions tested were:

- variable *K* with constant *r* and *q*
- variable *K* and *r* with constant *q*
- variable *K* and *q* with constant *r*
- all parameters variable

The alfonsino catch data of 1976–2006 were used. Model parameters were those that maximized the log-likelihood function with either adjusted or unadjusted fishing effort. The third model was selected as giving the maximum likelihood.

According to the four different production models the estimated biomass trajectories from these two analyses showed similar trends. Estimated biomass was highest in the 1980s and suddenly decreased in the early 1990s. Both analyses indicate that the lowest biomass was observed in 1996. Biomass increased steadily during the latest decade.

Table 45 offers the results of the surplus production modelling analysis (from Honda, Sakaji and Nishida, 2012). Adjusting the data appears to have made little difference to the estimate of MSY – about 1.2 percent.

TABLE 45
Results of ASPIC based on splendid alfonsino data (1985–2006) in the SE–NHR area

	Unadjusted effort			**Adjusted effort**
		Confidence limits (bootstrapped)		
	Point estimate	**80% lower**	**80% upper**	**Point estimate**
Directly estimated parameters				
R	1.535	1.478	1.579	1.547
K	7 753	7 596	7 961	7 783
Q	0.0001448	0.00013	0.0001627	0.000311
Management parameters				
MSY (tonnes)	2 975	2 940	3 002	3 010
B_{MSY} (tonnes)	3 876	3 798	3 980	3 891
F_{MSY}	0.768	0.739	0.789	0.774
Observed F 10 year	1.025			1.076
$F_{MSY}/F10_{year\ mean}$	75%			72%

Source: Honda, Sakaji and Nishida (2012)

Table 46 shows the results of the Excel simulation run under the assumption of constant *r* and variable *K*, and *q* using an unadjusted CPUE (Honda, Sakaji and Nishida, 2012).

TABLE 46
Results of the Excel simulation

	1976–78 and 1983–2006	**1979–1982**
Directly estimated parameters	**Parameter estimates**	
R	1.073	1.073
K	16 710	159 173
Q	1.82E-04	8.07E-04
Management parameters		
MSY (tonnes)	4 482	42 694
B_{MSY} (tonnes)	8 355	79 586
F_{MSY}	0.54	0.54
Observed 10 year mean F	0.70	
Ratio $F_{observed}/F_{MSY}$	76%	

Source: Honda, Sakaji and Nishida (2012)

Under an assumption of constant *r* using unadjusted CPUE the estimated *q* of 1979–1982 was about five times that of the recent estimates for *q* and the estimated *K* of 1979–1982 was about 2 500 times of the recent value for *K*. In the period excluding 1979–1982 the model implied an MSY of 4 432 tonnes from a stock biomass of 9 247 tonnes at F_{MSY} = 0.48. As the observed F for the last 10 years was 0.60 on an average, it is desirable to decrease F by about 20 percent to attain the F_{MSY} level for this stock.

The model parameters and management benchmarks estimated from the adjusted CPUE were almost same as those from the nominal CPUE for the period excluding 1979–1982. The model estimated that an MSY of 4 482 tonnes could be produced from a total stock biomass (B_{MSY}) of 8 355 tonnes at

F_{MSY}. The model also indicated that it is necessary to decrease F by 24 percent to attain the F_{MSY} level. In the period 1979–1982 the estimated *K* value using adjusted CPUE was almost an order of magnitude greater than the *K* estimated for the other years. In this model the relationship between biomass and surplus production appears dome-shaped: the extremely high surplus production and biomass in the period 1979–1982 could indicate an "alfonsino regime shift". For the catch data before 1985, a CPUE adjustment seemed to be an inevitable requirement. In both cases the estimated biomass was higher in the 1980s and then quickly decreased in the early 1990s. In the last decade surplus production has been stable at a lower level with a slight recovery; however, the current biomass level is still considerably below B_{MSY}.

Nishimura and Yatsu (2008) note that according to Hilborn and Walters (1992) absolute values of F and biomass obtained from production models, while subject to great uncertainty, have relative values of F_{MSY} and B_{MSY} that are robust.

Nishimura and Yatsu (2008) conclude that:

- F_{MSY} is considered appropriate as a limit reference point;
- B_{MSY} is a candidate for a reference point but, owing to the nature of surplus-production models, should be considered as a relative value.

For the SE–NHR alfonsino stock, there was a "highly productive" regime in the period 1979–1982 followed by an "ordinary" regime lasting to the present. The $F_{MSY}/F_{current}$, the ratios of F_{MSY} to $F_{current}$ (10 year average of 1997–2006) were 72–80 percent, i.e. $F_{current}/F_{MSY}$ were 1.25–1.39. Both the ASPIC model and the best regime-dependent spreadsheet model suggested alfonsino was overfished on the basis of the fishing mortality F in some years in recent decades. Both models also suggested that current fishing effort or fishing mortality F was above F_{MSY}. Thus, it should be reduced by 20–28 percent, i.e. the alfonsino stock was suggested to be depressed below the MSY level, namely overfished and under overfishing conditions.

The "20–28 percent reduction of current fishing effort" as a conservation and management measure was recommended in the asssessment based on the results of the stock assessment. "At least 20 percent reduction of current fishing effort" has been undertaken as an ongoing first step of active adaptive learning by every member of the Multilateral Meeting on Management of High Seas Fisheries in the North Pacific Ocean, according to the above recommendation (Nishimura and Yatsu 2008).

In these models, the CPUE from the entire SE–NHR area was used in estimating the management parameters. However, if alfonsino at different seamounts have their own characteristics, then separate stock assessments for each fishery at the separate seamounts are needed. Moreover, the assumption that a single alfonsino population exists within the study area has not been verified: discussions are reported, and available information suggests alfonsino of the SE–NHR form a single population and a meta-population with the stocks of adjacent waters.

Russian research data suggest that the CPUE increased rapidly in the period 1981–83 and dropped in the next few years. Estimates of stock size on the Colahan, Milwaukee, Kimmei and Koko seamounts were undertaken in 2005–07 by the Republic of Korea vessel FV *Oryong 503*. A swept-area method was used in the analysis by scientists of the Republic of Korea, and the assumption was made that vulnerability to capture was 0.5. Biomass estimates were 1 086 tonnes in 2005, 717 tonnes in 2006 and 570 tonnes in 2007. Any error in the estimate of vulnerability will have a similar and direct affect upon estimates of biomass.

As Nishimura and Yatsu (2008) note, the data they have appears to describe two different fishery regime periods, 1979–1984 and 1985 and after. When disaggregated this results in substantially different estimates of the total potential stock biomass, i.e. stock carrying capacity (a fourfold difference) and a difference of about fivefold in the catchability coefficient, with the estimate higher in the high biomass period. The main consequence of such results is to underline the need to ensure the validity of using a surplus-production model with the data that are available. Many, if not most, of the assumptions of the surplus-production model hold either weakly or are violated in the circumstances understood to control the dynamics of the fleet and fishing activity, especially in the early "fishing down" period of the fishery. The latter years of the fishery were its less productive era and it would be risk averse not to disaggregate the data used in the analysis, removing the high CPUE data points. This conclusion is compatible with the assumptions of surplus-production models. However, further discussion is necessary to better understand the consequences involved in the methods and biology related to alfonsino stock assessment.

Effort data were transformed – "where annual fishing hours for alfonsino was assumed proportional to log-transformed annual catch of alfonsino to aggregated annual catch of alfonsino and armourhead" (Nishimura and Yatsu, 2008). This transformation was required because effort data for two targeted species (alfonsino and armourhead) were aggregated and there was no other way of assigning an estimate to the amount of effort directed to alfonsino. There can be no way of knowing the extent, if any, to which the assumptions implicit in this move were violated. However, it is of interest that Nishimura and Yatsu (2008) note that transforming the effort data made little difference to the estimates of r and K and, hence, MSY, B_{MSY} and F_{MSY} (Table 47). Such independence of the results to major changes in the processing of the data should raise concerns as to the applicability of the model, or at least important violations in the data requirements.

TABLE 47
Results of ASPIC based on splendid alfonsino data (1985–2006) in the SE–NHR area

Parameter	Unadjusted effort	Adjusted effort
R	1.54	1.55
K	7 753	7 783
q	0.000144	0.000311
F_{MSY}	0.768	0.774

Source: Nishimura and Yatsu (2008)

Nishimura and Yatsu (2008) acknowledge the uncertainties in their data. Perhaps one main benefit of their analysis is the determination of model parameters for comparison with other instances where fitting a surplus production model has been attempted.

The analysis of surplus production as a function of estimates of biomass based on output of the ASPIC model (Prager, 1994) did not appear informative. Visual examination of the relationships implied an almost flat relation between predicted surplus production and estimated biomass – perhaps a consequence of failure in the assumptions implicit in fitting the model.

The methodology of surplus production is still considered useful enough to be included among alfonsino stock assessment models to estimate F_{MSY} as an appropriate limit reference point. However, further evaluation is needed of using the B_{MSY} estimate derived from the surplus-production model as a reference point. Meanwhile, the biomass estimation by the surplus-production model should be considered as a relative value owing to the substantial problem of model plausibility.

8.6 New Zealand

Langley and Walker (2002a) note that standardized catch rates derived from generalized linear modelling of the target catch and effort data for the East Chathams QMA BYX 3 fishery revealed no systematic trend in CPUE between 1995–96 and 1999–2000, although catch rates in 1999–2000 were about 50 percent those in 1995–96. However, the power of the CPUE model was limited owing to the small number of records (200–350 per year) and the high variability in observed catch rate. Consequently, the annual indices derived from the CPUE model are poorly determined.

There were considerable changes in the annual number of the data records over the study period in a number of the significant variables included in the CPUE model, principally vessel, subarea, month, and start time. Because of the umbalanced nature of the dataset the parameterization of the variables in the model may obscure annual changes in standardized catch rate. The CPUE model also reveals conflicting annual trends in catch rate among individual vessels and, to a lesser extent, among individual subareas fished. Some of the changes in the distribution of fishing effort may be attributable to vessels avoiding large bycatches of bluenose warehou in recent years.

The natural logarithm of the alfonsino catch from the trawl was used for three model options to determine the CPUE estimate in the model. For these options trawl duration was introduced as a potential predictor variable in the model, enabling the model to determine the most appropriate relationship between trawl catch and trawl duration. As an alternative measure of CPUE the catch rate model used the logarithm of catch/hour as the CPUE estimate. However, this measure imposed an assumption of a constant linear relationship between catch and trawl duration. An examination of unstandardized catch rates from the fishery revealed catch rates were greatest for trawls of less than 15 minutes and declined with increasing trawl duration up to 30 minutes. Catch rates were relatively constant at a low level for trawls of between 30 minutes and 2 hours.

Langley and Walker (2002a) concluded that the standardized CPUE indices derived for the East Chathams QMA BYX 3 fishery do not represent a reliable index of abundance. However, there may be sufficient contrast in the catch rate data from the target fishery to detect a decline in the abundance of alfonsino, although such an analysis would be capable of detecting only a large decline. Moreover, the utility of any resulting index would be restricted to the specific area of the fishery. The areal extent of the current target fishery is extremely limited relative to the known distribution of alfonsino within QMA–BYX 3 and, consequently, any trends in CPUE data from the target fishery are unlikely to be indicative of trends in abundance for the wider QMA–BYX 3 stock.

Many of the results described by Langley and Walker (2002a) would be considered self-evident to those operating in the fisheries, e.g. the largest vessel had the highest catch rate; catch rates were highest in the summer (the fishery is concentrated in the summer); there is a strong diurnal trend in the catch rates from the fishery with highest catches taken around midnight and lowest catches around midday (it is well known that alfonsino are difficult to catch during the day as they are highly mobile). More importantly, the amounts of variation explained by the model were low – from 7.4 to 25 percent (in both cases, catches were log transformed, which would have markedly reduced variance).

Langley and Walker (2002b) found that there were insufficient data to undertake a formal stock assessment of the QMA BYX 3 fishery and that it was unlikely that an assessment would be practicable within 3–5 years. They recommended that an estimate of the growth parameters for the QMA BYX 3 fishery be established by collection of age and length data. This, they believed, would reveal the age at recruitment to the fishery, the number of age classes supporting the commercial catch, the maximum age of fish in the catch and the variability in recruitment strength. These data would also enable comparison with the other New Zealand fishery in QMA BYX 2 and might provide insight into the stock relationships. The CPUE should be continued to be monitored and methods for its analysis refined.

All catch curves (frequency versus age) for alfonsino from the Palliser Bank showed a steep decline in abundance with increasing age. Moreover, the age composition of landings was vastly different between Palliser Bank and Tuaheni High when fish were abundant. These two factors indicate that some age-specific migration is occurring. It is unlikely that these age structure differences are due to fishing mortality. The Tuaheni sample was collected after one year of concerted fishing and the first Palliser sample after two years. Fishing over one year is unlikely to account for the observed differences, especially as the Palliser samples showed no appreciable difference over a year. Given the probable occurrence of age-specific migration, natural mortality cannot be determined at present.

No running-ripe alfonsino were found despite regular sampling on the Palliser Bank over 14 months. Thus, fish probably spawn in other (currently unknown) areas. Spawning may occur in midwinter because there was a peak in the percentage of fish with yolked eggs around June and a peak in gonadosomatic index between May and September for both males and females (Horn and Massey, 1989).

Alfonsino biomass on the Chatham Rise was estimated in two surveys in March and July 1983. The mean biomass value (27 000 tonnes) is an estimate of B_0 as catches of alfonsino on the Chatham Rise prior to 1983 were probably < 1 000 tonnes. Assuming $M = 0.2$ (based on known growth parameters) then maximum constant yield (MCY) = 0.2 114 B_0, or MCY = 1 350 tonnes.

Estimates of constant annual yield (CAY) were calculated for alfonsino in QMA BYX 2 using a “status quo” methodology (i.e. maintain a constant fishing mortality). An analysis of CPUE data from the domestic trawl fishery indicated a significant decline in abundance on all grounds. The mean catch per day dropped by 42–92 percent and the mean decline over all grounds from the start of the fishery was about 67 percent. Assuming that CPUE is an accurate index of fish abundance, then the yield (= CAY) necessary to equate current F with F in 1983–84 would be 33 percent of the 1983–84 catch. Landings of alfonsino from QMA BYX 2 in 1983–84 were 1 530 tonnes; hence, CAY = 505 tonnes.

Stocker and Blackwell (1991) note that CPUE data have been used to monitor the QMA BYX 2 alfonsino trawl fishery. The unit of fishing effort for the trawl fishery is a 24-hour day spent targeting alfonsino for one trawler. The CPUE values and corresponding coefficients of variation (CV) are used in the results given in Table 48.

TABLE 48
Alfonsino QMA–BYX 2 trawl catch, effort and CPUE data by fishing ground

Fishing year	Catch (tonnes)	Effort (fishing days)	CPUE	CV
1982–83	657.6	71	9.26	11.9
1083–84	1 152.5	169	6.92	7.3
1984–85	1 015.6	172	5.90	8.1
1985–86	1 478.9	243	6.09	6.2
1986–87	1 229.0	317	3.88	7.7
1987–88	1 151.0	260	4.43	10.4
1988–89	1 218.5	219	5.56	8.6
1989–90	1 451.4	305	4.76	6.5

Source: Stocker and Blackwell (1991)
Note: CV = coefficient of variation

Stocker and Blackwell (1991) also note that it is not known whether there is more than one stock in New Zealand and that there have been no successful biomass surveys of alfonsino in New Zealand.

Stocker and Blackwell (1991) use the age- and sex-structured model of Hilborn *et al.* (1991) to estimate the virgin biomass and current biomass for alfonsino in QMA–BYX 2. The modelling procedure is similar to the stock reduction method described by Francis (1990). The dynamics of the population are described by a standard discrete age-time structured model. Given a known catch history, some indices of abundance and life-history parameters of the fish stock, a deterministic trajectory of stock biomass is estimated. The objective is to search over biological parameters that not only give the best fit between the model trajectory and the observed indices of abundance, but also give a posterior distribution of alternative hypothesis about the virgin biomass and current stock size.

Stocker and Blackwell (without explanation) used two formulations of the catchability coefficient, q and ln(q), and two values for M, 0.20 and 0.23, and calculated posterior distributions of B_0.

The alfonsino life-history parameters used in age- and sex-structured stock reduction analysis and the parameters of the weight-length relationship: $W = aL^b$ are given in Table 49.

TABLE 49
Alfonsino life-history parameters used in an age- and sex-structured model

Parameter	Males	Females
Estimate (i.e. assumption) as to M	0.20	0.20
	0.23	0.23
Age at recruitment – t_r	5	5
Age at maturity – t_m	4	4
Maximum length – L_∞	57.5	51.1c
K (yr^{-1})	0.08	0.11
Age at length zero – t_0	–4.10	–3.16
Coefficient a	0.0226	
Coefficient b	3.018	
Recruitment steepness	0.95	

Source: Stocker and Blackwell (1991)

Table 50 gives estimates of B_0 and biomass in October 1990 for q and ln(q) and assumptions of M = 0.2 and M = 0.23.

TABLE 50
Estimates of B_0 and biomass, October 1990

	ln(q)	q
M = 0.20		
B_0 (tonnes)	18 800	19 000
B_{1990} (tonnes)	11 600	11 800
B_0/B_{1990}	0.62	0.62
M = 0.23		
B_0 (tonnes)	17 500	17 500
B_{1990} (tonnes)	10 800	10 800
B_0/B_{1990}	0.62	0.62

Source: Stocker and Blackwell (1991)

Stocker and Blackwell (1991) give the "posterior" distributions of biomass to show the uncertainty as to the actual values of B_0 and B_{1990}. They estimated MCY as:

$$MCY = 2/3*MSY$$

They used an age-structured model and a Beverton and Holt stock recruitment relationship with an assumed "steepness" of 0.95. Two values of M (0.20 and 0.23) and two formulations of the catchability coefficient (q) were used (ln[q] and q). The results from the two formulations of the catchability coefficient were either identical or similar; only the results for q are shown here. Table 51 shows the estimates of MCY (with corresponding 50 percent confidence intervals).

TABLE 51
Stock parameters obtained with two assumed M values

M = 0.20	Tonnes	
B_0	19 000	17 000 – 21 000
MSY	1 640	1 460 – 1 800
MCY	1 110	980 – 1 200
M = 0.23		
B_0	17 500	15 500 – 19 500
MSY	1 790	1 580 – 1 990
MCY	1 200	1 050–1 330

Source: Stocker and Blackwell (1991)

Stocker and Blackwell (1991) calculated a "current annual yield" using the Baranov catch equation with estimates of $B_{1991–92}$ and assuming F_{ref} is equal to $F_{0.1}$. The beginning-of-season biomass for 1991–92 was estimated by running the model forward from the estimate of B_0 using the reported landing history. The 1990–91 catch was assumed to be the TAC of 1 274 tonnes. The fishing mortality rates of $F_{0.1} = 0.25$ (for M = 0.20) and 0.32 (for M = 0.23) were applied to the beginning-of-season biomass estimates for 1991–92 to estimate the CAY for 1991–92. Table 52 estimates of B_0, $B_{1991–92}$, $CAY_{1991–92}$ long-term equilibrium biomass using an $F_{0.1}$ strategy, B_{equil} and yield at $F_{0.1}$ with corresponding 50 percent confidence intervals for the two natural mortality assumptions.

TABLE 52
Biomass and yield estimates for two assumptions as to natural mortality for alfonsino in QMA YX 2

	M = 0.20		**M = 0.23**	
	(tonnes)			
B_0	19 000	17 000 – 21 000	17 500	15 500 – 19 500
$B_{1991–92}$	11 400	9 400 – 13 500	10 600	8 600 – 12 600
$CAY_{1991–92}$	2 050	1 690 – 2 430	2 280	1 850 – 2 700
B_{equil}	6 600	5 900 – 7 300	6 000	5 310 – 6 680
Yield at $F_{0.1}$	1 480	1 320 – 1 640	1 610	1 430 – 1 800

Source: Stocker and Blackwell (1991)

Stocker and Blackwell (1991) also calculated $F_{0.1}$ yield for the combined sexes together with an assumed Beverton and Holt stock-recruitment model but without recruitment variability. The long-term stable yield was 9 percent of biomass and occurred at a biomass of 0.35. The estimate of $B_{1991–92}$ was greater than the equilibrium biomass and the estimate of $CAY_{1991–92}$ was substantially greater than the $F_{0.1}$ yield.

Stocker and Blackwell (1991) note that the fishery for alfonsino in QMA–BYX 2 is relatively new. For both estimates of M, $CAY_{1991–92}$ is substantially greater than the $F_{0.1}$ yield, and the fishery is still in the fishing-down phase. The current TAC of 1 274 tonnes is less than the two estimates of F_{MSY} yield and is considered sustainable. Reported landings of 1 478 tonnes in 1989–1990 were closer to the $F_{0.1}$ yield and were considered sustainable.

8.7 Chile

The current state of knowledge on alfonsino in Chile is fair relative to other deepwater fishes. Basic knowledge about growth, natural mortality (Gili *et al*., 2002) and macroscopic maturity data are available (Guerrero and Arana, 2009; Flores *et al*., 2012). A routine sampling programme has been undertaken in this fishery since 1999 by the Instituto de Fomento Pesquero (IFOP-Chile), which collects information using logbooks and fish-length data. Four acoustic surveys have been done to evaluate the biomass of alfonsino in the Juan Fernández Islands. This information has provided the basis for a stock assessment programme since 2004 that provides estimates of biomass and the status of resource exploitation.

8.7.1 Standardized CPUE

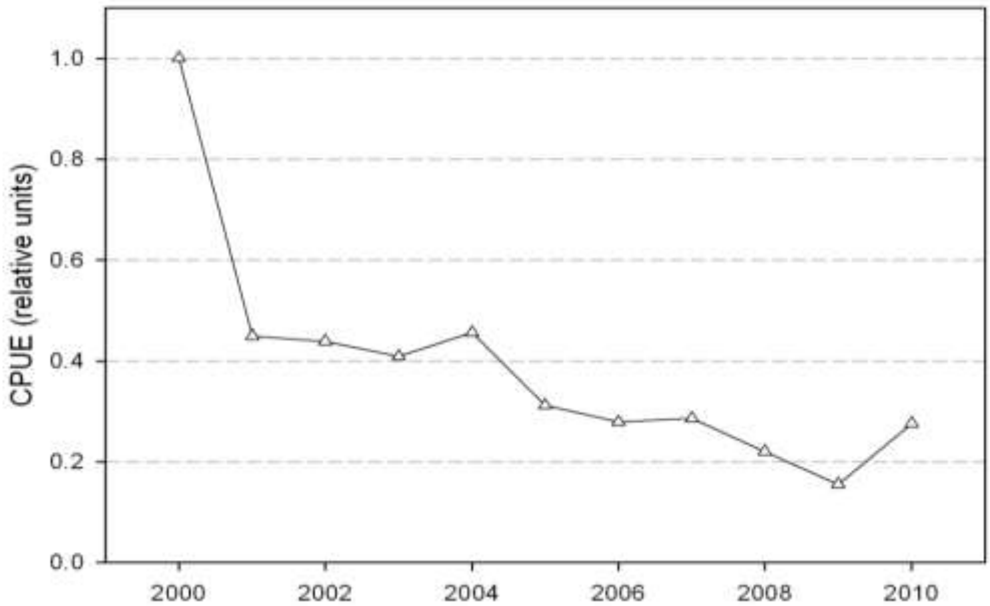
Contreras and Canales (2008) reviewed the standardization procedure for CPUE in the alfonsino fishery of the Juan Fernández Islands. They noted five major points in their analysis:

- Almost all hauls containing alfonsino targeted this specie so what is the target species is not an issue in this fishery.
- Hauls reporting zero catches are negligible, thus only positive hauls should be modelled.
- Generalized linear models using gamma error distribution and log link seems to be the most adequate method to model CPUE as a stochastic variable.
- The final depth of the haul is an important covariate.
- A subset of all vessels including alfonsino on their records seems to give a better CPUE as an abundance index.

Several vessels were active at the start of the fishery, but only two or three have been active for its entire history.

The Contreras and Canales (2008) model uses year, month, vessel, seamount and depth as covariates. Only information regarding the seamounts JF1 and JF2–3 and two fishing vessels is considered to provide representative information that can be used to generate an abundance index from the commercial catch data. Standardized CPUE in the alfonsino fishery shows a rapid decrease in time, reaching a minimum in 2009 and then increasing in 2010. This could be related to low fishing effort and disturbance of the fishing grounds during latter years. ANOVA indicated that all covariates were significant ($p < 0.05$), and the total deviance explained by the model was 6 percent. Results indicate that the nominal and standardized CPUE are almost identical. Figure 53 shows the trend in CPUE for this fishery for the period 2000–2010.

FIGURE 53
Trend in CPUE in the alfonsino fishery in Chile, 2000–2010



Source: Wiff *et al.* (2012)

The information used was: (i) landings between 1998 and 2010; (ii) length structures from commercial catches reported between 1999 and 2010 (see Gálvez *et al*., 2011); (iii) length structures from acoustic surveys for 2005, 2006, 2007 and 2010 (Niklitschek *et al*., 2007, 2008; Niklitschek and Toledo, 2011); (iii) a standardized CPUE time series from 2000 to 2010; and (v) biomass estimates from acoustic surveys for 2005, 2006, 2007 and 2010 (Niklitschek *et al*., 2007, 2008; Niklitschek and Toledo, 2011).

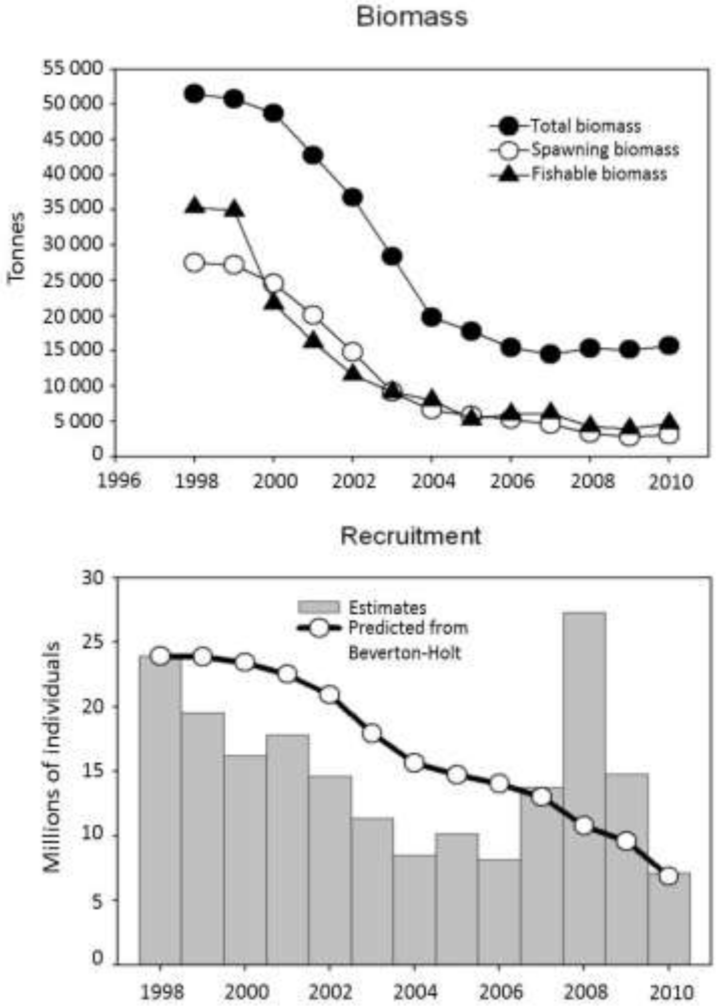
8.7.2 Age-structured model

The model assumes the existence of one single stock inhabiting the Juan Fernández Islands with age classes present of 1–19 years and with sexes combined. Catch-at-age data are not available for this fishery and, thus, an age-at-length key is modelled using growth parameters reported by Gili *et al.* (2002). Thus, the model assumes age-class dynamics but uses a simulated age-at-length key. The abundance equation used is that of the Baranov models and uses a plus group for residual age classes. Model optimization was done using MATLAB to minimize the negative log-likelihood assuming multinomial error for length structures and log-normal error for the abundance indices. A Schaefer production model (Schaefer, 1954) was also used to examine the consistency of state variables from the age-structured model. The production model used the standardized CPUE and acoustic time series as indices of abundance. Wiff (2010) describes mathematical details and the goodness-of-fit of the models to the data.

8.7.3 Recruitment and biomass estimates

Unfished biomass was estimated at 50 000 tonnes in 1998 and decreased to 15 000 tonnes in 2010. In addition, unfished spawning biomass was estimated in 27 500 tonnes at 1998 and at 3 000 tonnes in 2010. This indicated a depletion of the spawning biomass to 12 percent of the original value (95%CI = 7-17 percent) in 2010 (Figure 54).

FIGURE 54
Trends in age-structured model variables – biomass and recruitment



Source: adapted from Wiff *et al.* (2012)

Estimates of recruitment were lower than those predicted from the Beverton–Holt recruitment model for most years except 2008 and 2009. An increase in recruitment in those years was caused by the increase in the CPUE index in 2010. This resulted in a slight increase in the biomass estimate during the last year.

8.7.4 Acoustic surveys

Four acoustic surveys were conducted in the austral spring (October) of 2005, 2006, 2007 and 2010 to evaluate the biomass of alfonsino in the Juan Fernández Islands. A commercial trawler that was same as those used in the fishery was used each year to survey the seamounts of the archipelago. This information has provided the basis for a stock assessment programme since 2004 that provides estimates of biomass and the status of resource exploitation. Relative abundance and biomass is estimated by the geostatistical method described by Roa, Niklitschek and Lamilla (2008).

Niklitschek and Toledo (2011) reported on three research cruises during the spring of 2010 to estimate the abundance and biomass of aggregations of alfonsino on five seamounts adjacent to the Juan

Fernández Islands. A semi-stratified adaptive survey plan was implemented, consisting of an initial exploration with transects on average one mile apart followed by repeated transects with a separation of 0.2–0.5 nm in the zones of fish concentrations. Depths ranged from 200 to 600 m.

A geostatistical method was used to estimate abundance and biomass using maximum likelihood and linear models of the form developed by Roa-Ureta and Niklitschek (2007). Abundance was estimated over an area of 554 km^2 with fish found only in an area of 18.8 km^2. The relationship of Niklitschek *et al.* (2007) was used to determine the backscattering cross-section area of alfonsino. The number of individuals in the survey area was estimated at 23.1 million (CV = 24 percent) for an estimated total biomass of 7 743 tonnes (CV = 29 percent). The major area of alfonsino distribution was around the seamount JF2, which has an area of 9 km^2.

An extension of Aitchison's (1955) approximation and Pennington's (1983) geostatistics methods were used in which the total number of observations were fitted to a spatially explicit binomial model based on presence or absence of alfonsino. The positive observations are treated separately to estimate the average in those zones where there were fish.

The target strength of alfonsino was calculated using the relation of Niklitschek *et al.* (2007):

$$TS = 20 \log (L) - 67.74 \text{ (dB)}$$

The average area scattering coefficient was estimated at 4 901 m^2/nm^2. This gave an estimate of 23.1 million individuals (SE = 5.5 million) equivalent to 7 743 tonnes with a CV of 0.29 for a total area of 26 807 m^2. Details by zone are given in Tables 53 and 54.

TABLE 53
Area surveyed, estimated proportion of the survey area occupied by the stock, p (S_A > 0), effective area occupied by the stock ($\ddot{\alpha}$), mean coefficient of acoustic scatter per unit area ($\hat{S}(\ddot{\alpha})$) and its standard error, total scattering coefficient ($\hat{\Phi}$) of the fraction of alfonsino present in the area during the study period in 2010 and standard error. Totals correspond to sums or weighted averages as appropriate

Seafloor feature	Area surveyed km^2	p (S_A >0)	SE p(SA >0)	($\ddot{\alpha}$)	SE ($\ddot{\alpha}$)	$\hat{S}(\ddot{\alpha})$	SE ($\hat{S}(\ddot{\alpha})$)	$\hat{\Phi}$ m^2	SE $\hat{\Phi}$ m^2
JF1	373.3	0.005	0.0017	1.9	0.63	14 900	6 184	8 403	4 421
JF1.1	11.2	0.119	0.0656	1.3	0.74	7 729	1 314	2 998	1 736
JF2	142.3	0.063	0.0385	9	5.47	2 505	596	6 557	4 291
JF6	27.3	0.229	0.047	6.5	1.28	4 658	686	8 849	2 175
Total	554.1	0.034	0.0071	18.8	5.7	4 901	1 051	26 807	6 761

Source: adapted from Niklitschek and Toledo (2011)

TABLE 54
Estimated numerical density, abundance (N) and biomass (B) corresponding to the fraction of alfonsino present in the Juan Fernandez Archipelago during the study period in 2010

Seafloor feature	Density (n/m^2)	SE of density	Abundance N x 10^6	SE (N)	Biomass (tonne)	SE biomass	CV biomass
JF1	3.03	1.256	5.9	3.08	2 589	1 379	0.53
JF1.1	1.23	0.21	1.6	0.95	1 015	590	0.58
JF2	0.64	0.151	5.7	3.74	2 200	1 454	0.66
JF6	1.51	0.223	9.9	2.42	1 939	760	0.39
Total	1.23	0.25	23.1	5.5	7 743	2 223	0.29

Source: adapted from Niklitschek and Toledo (2011)

Niklitschek and Patchell (2013) compared acoustic and numeric alfonsino densities from the Indian Ocean and the Southeast Pacific Ocean (Juan Fernandez Archipelago) (Table 55) and found relatively lower estimates for the Indian Ocean (Table 56), which they believed were probably related to the smaller areas surveyed. They also suggested that higher stock presence ratios in the Indian Ocean reflect the tighter survey patterns, related to the actual fish distribution or they could have occurred because fish shoals were targeted rather than stock areas.

TABLE 55
Mean density, abundance and biomass estimates for alfonsino in the Indian Ocean and Juan Fernandez Archipelago in the SE Pacific Ocean. Maximum likelihood geo-statistical approach of Roa-Ureta & Niklitschek (2007)

	Zone	Year	Fish/m^2		Abundance x10^6		Biomass (tonnes)		
			Density	SE	N	SD	Biomass	SD	CV%
Southern Indian Ocean	EURO	2007	1.77	0.843	0.75	0.608	1 666	1 352	0.81
	ENSO	2007	0.06	0.009	0.04	0.022	78	49	0.63
	ENNO	2008	0.38	0.215	0.16	0.101	349	225	0.64
	CRNE	2008	0.56	0.091	0.23	0.078	386	132	0.34
	TB2E	2008	0.4	0.123	0.24	0.249	1 269	425	0.33
	TB2W	2008	0.81	0.726	0.77	0.396	1 701	886	0.52
	FREO	2008	0.31	0.305	0.47	0.462	1 032	1 024	0.99
South East Pacific	1	2007	0.6	0.047	17.5	2.87	7 767	2 735	0.35
	1.1	2007	1.35	0.869	0.2	0.18	138	125	0.9
	2	2007	1.61	0.333	15.2	3.82	13 793	3 656	0.27
	6	2007	0.71	0.344	4.8	2.37	3 213	1 753	0.55

Extracted from: Niklitschek and Patchell (2013)

TABLE 56
Spatial distribution, acoustic density and relative abundance indexes estimated for alfonsino in the Juan Fernandez Archipelago in 2007. Maximum likelihood geo-statistical approach of Roa-Ureta & Niklitschek (2007)

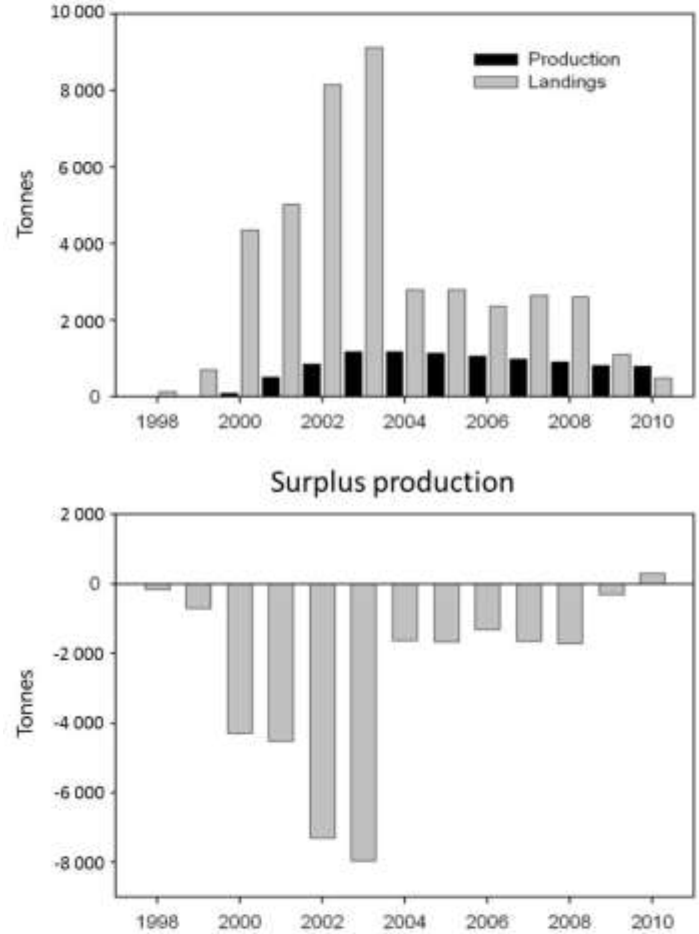
	Zone	Year	Survey area km^2	Stock Presence Ratio		Stock area (km^2)		Acoustic density	
				p	SE	σ	SE	S_A	SE
Southern Indian Ocean	EURO	2007	13.2	0.03	0.021	0.4	0.277	1 666	16 999
	ENSO	2007	3.9	0.14	0.084	0.51	0.328	78	185
	ENNO	2008	1.1	0.37	0.107	0.41	0.118	349	4 326
	CRNE	2008	2.4	0.17	0.05	0.41	0.12	386	1 153
	TB2E	2008	4.1	0.45	0.061	1.185	0.25	1 269	1 556
	TB2W	2008	1.9	0.23	0.073	0.44	0.139	1 701	14 644
	FREO	2008	3.3	0.46	0.066	1.52	4.23	1 032	6 143
Mean				0.26				925	
South East Pacific	1	2007	383.3	0.076	0.011	29.2	0.12	7 767	174
	1.1	2007	7.5	0.019	0.0158	0.1	0.12	138	4 797
	2	2007	153.6	0.062	0.0089	9.5	1.37	13 793	2 141
	6	2007	32.4	0.21	0.0206	6.8	0.67	3 213	1 815
Mean				0.09				6 227	

Extracted from: Niklitschek and Patchell (2013)

8.7.5 Biomass dynamic model analysis

Total biomass estimated from the Schaefer model is similar to that estimated from the age-structured model. This model indicates a carrying capacity (K) of 44 000 tonnes in 1998, whereas in 2010, this biomass was 11 000 tonnes. Intrinsic population growth rate (r) is estimated at 0.12 years, indicating that the total biomass has a potential grow rate of 12 percent per year. In addition, parameters from the models have high uncertainty with large confidence intervals and a high dispersion for the relationship between r and K. Figure 55 shows the models estimation of the production by the stock compared with catches taken for 1998–2010. This figure implies that catches exceeded the production of the stock for most years. Production estimated from the Schaefer model was between 800 and 1 200 tonnes. The landings were higher than production during the whole fishing history except in 2010.

FIGURE 55
Landings, production and surplus production



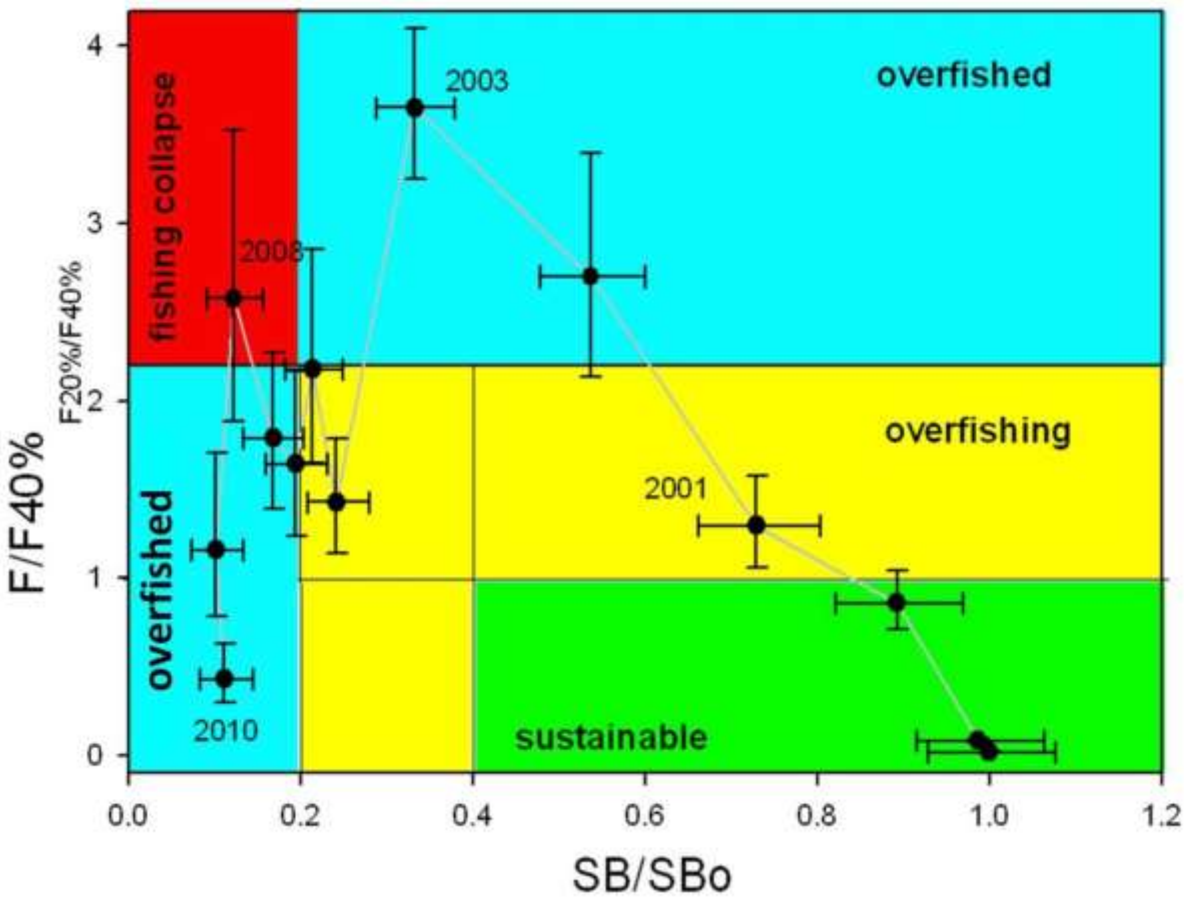
Source: adapted from Wiff *et al.* (2012)

8.7.6 Status of fishing

Wiff *et al.* (2012) present a phase diagram for fishing mortality and depletion of the spawning biomass (Figure 56). Reference points for fishing mortality were chosen so as to force the spawning biomass per recruit of a single cohort to the 20 percent ($F_{20\%}$) and 40 percent ($F_{40\%}$) of the unfished spawning biomass. In the case of depletion of spawning biomass reference points were set to 20 and 40 percent of depletion with respect to the unfished condition. Lower and upper boundaries of each reference point were chosen as limits and objective reference points respectively. A stock status that was beyond these was considered to represent overfishing

Wiff *et al.* (2012) note that the stock assessment model for alfonsino is highly uncertain owing to the lack of knowledge of its population dynamics and the use of a non-informative time series that was used to parameterize the model. The model can assume exit from the fishery of older fish, non-linearity between standardized CPUE and abundance, and variations of the relative importance of length structures. Depletion of the spawning biomass between 1998 and 2008 was estimated at 9–56 percent depending of the hypotheses used. This indicates that state variables in alfonsino are not robust to the available information and depend strongly on the assumptions chosen.

FIGURE 56
Phases diagram with fishing mortalities and depletion of spawning biomass



Source: adapted from Wiff *et al.* (2012)

The current knowledge of alfonsino in Chile is not as deficient as in other deepwater fishes – basic biological knowledge about growth, natural mortality (Gili *et al.*, 2002) and maturation (Guerrero and Arana, 2009) is available. With this information a stock assessment programme has been implemented in this fishery since 2004, but in all models implemented a poor fitting of the data is reported. A poor goodness-of-fit of the models is mostly caused by the high interannual variability of length structures and abundance indices. This has produced uncertainty on the exploitation status of alfonsino because the available information is insufficient to verify the assumptions of the model. As a consequence, the main state variables of biomass and recruitment are not robust but rather are highly dependent on the underpinning population dynamic that is assumed.

An important issue in interpreting the available data is the ontogenetic behaviour of alfonsino (Wiff, 2010), which shows that average sizes vary with depths and that young, smaller individuals live in shallow waters and move progressively into deeper waters as they become older and larger. Fishing operations have also changed with time (Wiff, 2010). The fishery started in 2000 in deep waters (550 m) catching large alfonsino (40 cm) and then moved into shallower waters (390 m) progressively catching smaller fish (32 cm in 2008). Thus, different size/depth strata have been fished across the years. As a result, one of the assumptions of stock assessment model is not met and this may explain the lack of fit of the model to observed data.

Wiff (2010) simulated a population that mimicked the life history and behaviour of alfonsino where different length/ages were found at different depths and with a fishery harvested in different age/length strata across time. Based on simulations, he found that this particular fish and fishing behaviour explained the high variability of length structures and CPUE indices across time. He also suggested that three hypothesis regarding alfonsino population dynamics should be investigated:

- Individuals older than 12 years, as they are rarely caught even though their life span is estimated at 19 years (Gili *et al*., 2002). Fishers also reported high aggregations of larger fish in deep waters, where trawling is difficult or impossible (Gálvez *et al*., 2011).
- A non-linear relationship between the CPUE index and the abundance – hyperdepletion/hyperstability. In the first years of the fishery, CPUE decreases faster than abundance – hyperdepletion. However, in later years a process of hyperstability is reported where abundance decreases faster than CPUE.
- The length structures are non-informative in terms of the population dynamics of alfonsino.

Wiff *et al.* (2012) concluded, first, that loss of availability to the fishery of older fish produces an increase in the abundance estimate and better population status, because adult individuals have a lower probability of capture and thus the model produces higher recruitments to account for the observed catches. This also caused an increase in spawning biomass because mature individuals become unavailable to the fishery, resulting in higher levels of abundance in older ages. However, this phenomenon of non-availability of older age classes has rarely been observed. Second, non-linearity between fishable biomass and CPUE produced lower estimates of abundance because non-linearity resulted in a faster decrease in biomass relative to the CPUE time series. According to the non-linear parameters used hyperstability is more important than hyperdepletion. Third, when sample size of the length structure increases recruitments show high variability across years. This is caused by the high interannual variability of length distribution of alfonsino, which is principally the result of fishing at different depths. Such a fishing process invalidates the basic assumptions of the stock assessment model. Fourth, biomass estimates from the age-structured model, assuming non-availability of larger fish agree with the theory because the underlying assumption of a production model indicates that once individuals enter the fishable fraction of the population the availability to the fishing gear remains constant.

In summary, Wiff (2012) notes that any assessment of alfonsino stocks in Chile must be subject to the following main caveats:

- limited knowledge about stock structure, migrations and connectivity;
- controversy regarding maturity (macroscopic scale);
- only preliminary results in fecundity are available because the fishery has been closed since 2011;
- lack of data available for the next few years.

9. ECOSYSTEM CONSIDERATIONS

9.1. Associated species

9.1.1 South Atlantic

Seok (2012) notes that in the alfonsino fishery of the Republic of Korea, alfonsino comprised 23 and 92 percent of the catch in the SEAFO area and FAO Area 34, respectively, in 2011. In the SEAFO area the dominant species in the catch was mackerel (35.5 percent), then after alfonsino, oilfish (*Ruvettus pretiosus*) (14.6 percent), and pelagic armourhead (12.3 percent). In FAO Area 34 the dominant species was alfonsino, then roudi escolar/snake mackerel (*Promethichthys prometheus*) (4.7 percent), *Helicolenus dactylopterus*, dory (*Zenopsis conchifer*) and cardinalfish (*Epigonus telescopes*) were caught in both areas but their catches were small. In FAO Area 34 the catch of *Helicolenus dactylopterus* was negligible.

9.1.2 Southwest Indian Ridge

Paramonov (2012c) notes that the fish fauna of the SWIR thalasso-bathyal region is poorer than that on the continental shelf at the same latitude, nevertheless in the period 1978–2001 exploratory fishing by vessels from the Soviet Unions found 217 species of fish belonging to 80 families. Of these, there were 17 commercial species from 12 families: warty dory (*Allocytus verrucosus*), orange roughy (*Hoplostethus atlanticus*), two species of alfonsino (*Beryx splendens* and *B. decadactylus)*, two species of wreckfish (*Polyprion americanus* and *P. oxygeneios*), two species of cardinalfish (*Epigonus robustus* and *E. telescopes*), Cape bonnetmouth (*Emmelichthus nitidus*), rubyfish (*Plagiogeneion rubiginosus*), pelagic armourhead (*Pseudopentaceros richardsoni*), roudi escolar (*Promethichthys prometheus*; jack mackerel (*Trachurus longimanus*), bluenose warehou (*Hyperoglyphe antarctica*), violet warehou (*Schedophilus ovalis*), striped trumpeter (*Latris lineata*), and grey jackassfish (*Nemadactylus macropterus*). Table 55 summarizes information concerning fishes of commercial value inhabiting the SWIR.

TABLE 55
Potentially commercial fishes inhabiting banks of the Southwest Indian Ridge

	Depth of catch (m)	Length (cm)		Mass (g)	
		Min–max	Middle	Min–max	Middle
Brama brama	750	24 – 62	41.3	250 – 3 260	1 710
Seriola lalandi	100 – 200	101 – 122	110.5	7 050 – 7 450	7 150
Mora moro	700 – 1 100	27 – 70	48.5	180 – 2 110	1 145
Scombresox saurus	Epipelagic	24 – 41	31.7	37 – 172	104.5
Neocyttus rhomboidalis	500 – 1 700	13 – 69	19.5	36 – 1 141	330
Helicolenus mouchezi	220 – 400	14 – 46	26.0	80 – 1 700	890
Centrolophus niger	700 – 720	64 – 70	67.0	2 880 – 4 000	3 400
Ruvettus pretiosus	600 – 900		97.0		14 350
Lepidopus caudatus	80 – 800	16 – 161	98.5	560 – 3 400	2 370
Cubiceps coeniruleus	250 – 900	18 – 27	22.5	102 – 227	164.5
Electrona carlsbergi	Mesopelagic	1.5 – 8.8	5.6	0.1 – 9.5	6.0
Electrona subaspera	Mesopelagic	6.0 – 10.0	9.0	3.1 – 11.5	9.1

Source: Paramonov (2012c)

Cape bonnetmouth is a shoaling pseudoneritic fish caught in depths of 50–420 m and usually constituted around 30–60 percent of past Soviet catches although it could sometimes constitute 100 percent of the catches. Rubyfish is a shoalling pseudoneritic fish caught at depths of 80–500 m. It forms commercially attractive spawning aggregations often mixed with Cape bonnetmouth and usually forms 20–40 percent of the bycatch although its can also be the main target species. Fish size in catches has been 10–54 cm and 28–2 460 g although most fish are 18–36 cm and 130–1 000 g. Rubyfish probably grow to 10–15 years of age and individuals of 6–9 years predominate in the catches.

Jack mackerel inhabits the banks of the SWIR and Madagascar Ridge and possibly elsewhere. They are found from the surface to a depth of 270 m, and so only just venture into the usual habitat of alfonsino. They form aggregations above the banks at night and during the day occur close to the bottom above seamounts and on the slopes. They have not been found in the open waters of the Indian Ocean. Catches of jack mackerel in the early years of the Soviet fishery reached 10 tonnes/tow – 45 percent of the catch – but subsequently declined. Fish sizes were 10–54 cm and 15–2 500 g. Length modes occurred at 12–22 cm (1–2 years) and 34–44 cm (4–8 years).

Pelagic armourhead were found on the deepwater seamounts of the SWIR and Madagascar Ridge between 410 and 850 m. Initially, they comprised 40–80 percent of the catch but their subsequent presence in the catch diminished sharply.

Bluenose warehou is the largest deepwater butterfish that is encountered and is found between 80 and 840 m; it forms commercial aggregations at 600–750 m. This species comprised 20–35 percent of catches and was targeted during many tows. Fish sizes were 58–145 cm and 2.8–6.7 kg. Larger fish were found at greater depths. Bluenose warehou mature at 6–8 years and at a length of 55–60 cm. Fish sizes in the catches were 36–60 cm and 0.9–4.9 kg; most of the catch was between 42 and 48 cm and 1.5 and 2.5 kg. Violet warehou is another butterfish found on banks between 50 and 700 m, but mainly at 310–370 m. Catches in September–October were 5.1–17.4 tonnes per hour. Fish size was 32–93 cm and 0.7–25.9 kg.

Wreckfish is a large predator found at depths of 100–800 m on banks of the SWIR and forms commercial aggregations up to depths of 600 m. Wreckfish were usually caught using hook and line or bottom longlines. Good catches of the two wreckfish species by middle-tonnage ships reached 5–10 tonnes/day. Fish size was 45–165 cm and 2.4–7.6 kg. Most of the catch was 60–110 cm, corresponding to 5-15 years. Maximum age was 23 years for males and 27 years for females. Males were generally smaller that the females. Male wreckfish mature at 50–55 cm and females at 55–60 cm. Wreckfish are mainly found in the bottom 30 m layer; however, some fish rise to 100–150 m above the sea floor at night.

Hapuku wreckfish *(Polyprion oxygeneios*) occupy the same habitat as wreckfish. Fish size in the catch was 45–155 cm and 2.5–5.3 kg. Most of the catch was 70–125 cm, corresponding to an age of 15 years. Maximum age was 16 years for males and 24 years for females.

Black cardinalfish (*Epigonus telescopus*) is the most abundant epigonid caught on the SWIR banks and inhabits depth of 100–1 600 m. Densest fish aggregations occurred from 350 to 450 m. Fish size was 21–72 cm and 40–7 100 g. Robust cardinalfish (*Epigonus robustus)* inhabit depths of 1 500–1 600 m. Fish size in the catches was 9–26 cm and 15–330 g; size increased with depth.

The warty dory is one of the more abundant demersal fish on the SWIR banks and occurs between 460 and 920 m. The fish are usually 10–44 cm and 30–1 300 g. Size in catches is usually 26–34 cm and 0.3–1.0 kg, increasing with depth. Warty dory reach 15 years of age. Dories, at certain times, have constituted 30–40 percent of the catch from deepwater banks.

The striped trumpeter inhabits banks in the Western Indian Ocean at depths of 100–600 m, with greatest concentrations at 145–250 m. The fish are mainly caught by mechanized vertical lines and at sizes of 50–105 cm and 2–16 kg. The length mode in the catch is 75–90 cm; size increases with depth.

The grey jackassfish inhabits depths of 100–300 m above shallower banks. Fish size is 42–63 cm and 1.1–3.0 kg; modal length is 45–55 cm. Roudi escolar is found above nearly all seamounts of the SWIR at 220–720 m, and constitutes 15–80 percent of Soviet catches. The size of this fish was 41–72 cm and 0.4-2.5 kg. Roudi escolar move to upper layers at night and to the bottom during the day and can be caught at considerable distancesfrom seamounts. Orange roughy is also taken by this fishery in this area but is the target of another fishery.

9.1.3 Northwest Pacific

The dominant bycatch of trawlers from Japan, the Republic of Korea and the Russian Federation operating in the Northwest Pacific included Japanese boarfish (*Pentaceros japonicus*), *Beryx decadactylus*, Japanese butterfish (*Hyperoglyphe japonica*), mirror dory (*Zenopsis nebulosa*), skilfish (*Erilepis zonifer*), boarfishes (*Antigonia* spp.), cardinalfishes (*Epigonus* spp.), snake mackerel (*Promethichthys prometheus*), morid cods (Moridae), squalid sharks and scorpionfishes (Sebastidae and *Helicolenus* spp.) (Sasaki, 1986).

9.1.4 Australia

In Australia, bycatch species include *Hyperoglyphe antarctica*, boarfish (*Pentaceros richardsoni*) and orange roughy (*Hoplostethus atlanticus*).

9.1.5 New Zealand

Langley and Walker (2002a, 2002b) note that the development of the alfonsino fishery caused an increase in the bycatch of bluenose warehou (*Hyperoglyphe antarctica*) such that the bluenose quota was exceeded in all fishing years since 1994–95. Bluenose warehou has represented an important bycatch in the target QMA (see Figure 19) BYX 3 trawl fishery. This has caused concerns regarding the large increase in the annual catches of alfonsino and, subsequently, of bluenose. In the northern Tasman Sea, alfonsino is taken as a targeted species and a bycatch species for fisheries targeting orange roughy.

9.1.6 Southwest Pacific

Anon. (2009) notes that for the Southwest Pacific fisheries alfonsino are often found in association with bluenose (*Hyperoglyphe antarctica*), gemfish (*Rexea solandri*), hoki (*Macruronus novaezelandiae*) and javelinfish (*Lepidorhynchus denticulatus*). In Chile, alfonsino is mainly associated with *Helicolenus lengerich*, *Emmerlichthys* sp., *Epigonus robustus* and the crustacean *Projasus bahamondie*. Orange roughy is rarely taken by the alfonsino fishery because the hauls are done at different depths.

9.2 Effects of gear

The main method used to catch this species is a trawl that is generally fished close to, or on, the bottom. Trawling for this species on seamounts – which has taken place – will bring about habitat change, but the precise impact of this on the alfonsino populations and other species on the seamounts is unknown (Anon., 2009).

Trawling for alfonsino on seamounts is known to affect benthic habitat (Clark and O'Driscoll, 2003; Koslow *et al*., 2001), but the impact of this on alfonsino populations or other fish species associated with seamounts is unknown. Bottom trawling also tends to homogenize the sediment, which damages the habitat for certain fauna. Benthic processes, such as the transfer of nutrients, remineralization, oxygenation and productivity, which occur in undisturbed, healthy sediments are also impaired. As fishing gear disturbs soft sediment it produces sediment plumes and remobilizes previously buried organic and inorganic matter. This increase in the rates of nutrients in the water column has important consequences for the rates of biogeochemical cycling (Kaiser, 2002). Waller *et al*. (2007) give an account of anthropogenic impacts on the Corner Rise seamounts in the Northwest Atlantic Ocean that they attribute mainly to the affects of the past Soviet trawl fishery in that area.

9.3 Feeding and the role of the species in the ecosystem

Feeding occurs mainly in the morning and evening twilight hours and there is an increase with the intensity of the tide flow and alfonsino feed for longer periods when there is less food available. When tidal flow is strong the feeding period increases and alfonsino spend more time on bottom. Feeding increases from 1–1.5 h to 3.5–4 h. Galaktionov (1984) found that alfonsino feed in the mornings and evenings when they were above the bottom as this coincided with the time where there was fresh food in their stomachs. He concluded that changes in feeding conditions affected the time the fish were off the bottom and that the feeding time increased from 1–1.5 hours to 3.5–4 hours when food items had decreased availability. Lehodey, Grandperrin and Marchal (1997) report a similar behaviour for New Caledonian studies on alfonsino.

Alfonsino feed on macrofauna, mainly small squids and fish, and also crustaceans (e.g. copepods, amphipods, shrimps, prawns and euphausiids). They normally occur within 20 m of the bottom, but are believed to rise from the bottom to make feeding forays, generally at night. Alfonsino are prey at various stages of their life to other bony fishes and sharks (Anon., 2009). Vinnichenko (1996a, 1997a) reports that large alfonsino were reported to feed mostly on mesopelagic fish (Myctophidae, Sternoptychidae, Chauliodontidae, etc.) and to a lesser degree on squids, shrimp and euphausiids. Euphausiids were reported to be the main food item for smaller alfonsino.

Dürr and González (2002) obtained a large number of stomach samples from *Beryx* spp. taken from 500–700 m. They found the alfonsino's diet to consist mainly of macroplankton and nekton. Fish, mainly myctophidae were the most important prey item, more so for *B. decadactylus*. Crustaceans were the most diverse group. Decapods represented 26 percent by weight of diet items for alfonsino and 19.0 percent by number of prey items. Cephalopods were present in considerable numbers in the prey of alfonsino, 69.7 percent of stomachs and 20 percent by number of prey, although in terms of weight their importance was much less, 5.3 percent. Euphausiacea and Mysidacea were also common dietary items.

Dürr and González (2002) were of the view that variation in dietary items might have been a consequence of their sampling regime – only during the day. As most of the prey items they found were known to make considerable diel vertical migrations they posited that perhaps it was not alfonsino that moved through a vertical diel cycle, but only their prey.

Porteiro and Sutton (2007) note that alfonsino feed on midwater micronekton and that they actively track the deep scattering layer in contrast to seamount fish species, whose feeding behaviour has been described as “feed and rest”, i.e. these species wait for prey species to be advected onto the seamount or be trapped on the seamount in “the early morning” when prey are trapped on their downward migration and become visible in the morning light, as described by Vinnichenko (1997a) and by Dubochkin and Kotlyar (1989) and Parin, Mironov and Nesis (1997) on the Nazca and Sala y Gómez Ridges in the East Pacific. Main prey were reported to be migrant and non-migrant midwater fishes such as Gonostomatidae, Sternoptychidae, Stomiidae, Myctophidae, crustaceans such as decapods and euphausids, and salps. With such a wide range of prey species, it is unlikely that alfonsino would suffer from lack of food because of declines in the abundance of a single prey species.

9.4 Gear modifications in relation to bottom effects in New Zealand

MF (2008) give a detailed account of how gear effects are mitigated in the case of the New Zealand high seas deepwater trawl fishery. New Zealand vessels use aimed-trawling that targets relatively dense aggregations of fish, which are exclusively located and targeted acoustically. In the past two decades, New Zealand deepwater trawlers have increasingly used modifications and procedures to reduce costs associated with damage to fishing gear, to increase efficiency of trawling operations, to maximize catch rates and to reduce the time and fuel costs of fishing operations. Many of the modifications relate to electronic systems to facilitate accurate aiming of the gear at dense aggregations of fish, weigth reduction of the gear to facilitate manoeuvrability, towing modifications, and modifying the trawl doors, rigging and gear to minimize the probability of doors and warps touching the sea bed.

The nets used are designed to provide net mouth openings (ground-rope lengths) between wing-tips of 15–20 m under optimal towing conditions, with headline heights of 5–6 m above the footrope. Nets are also equipped with net-sounders and headline sensors to monitor the net opening to determine position of the net relative to the sea bed and to facilitate accurate targeting of nets at acoustic fish targets.

In bentho-pelagic trawl fisheries for alfonsino the gear may come very close to the bottom, but this gear is typically lighter and links on the ground-rope are designed to break if the gear touches the bottom so as to minimize damage to the net even though this also results in loss of the catch for that tow. Most of the tow time for deepwater trawls is spent shooting and hauling with actual bottom contact and fishing time being very short, and ideally only in the vicinity of the dense aggregation being targeted. The bottom times of targeted tows are typically short, perhaps 2–10 minutes, compared with 2–5 hours for traditional flat-bottom trawling.

Any contact of the trawl gear with rough ground often fished in these fisheries has the risk of gear damage and associated expense for repair of trawl systems: these are typically worth USD75 000-100 000. This encourages continual investment in systems that catch fish efficiently with minimal bottom contact. A major driver of efficiency in these fisheries is the need for accuracy and precision of placement of the gear and there has been continuous investment in acoustic, navigational and gear systems to reduce trawling time and to minimize the number of empty tows.

Since the development of trawling in waters deeper than 700 m there has been substantial improvement in navigational systems to position the vessel such as the Global Positioning System (GPS), which has an accuracy of to 1.5 m. New Zealand vessels often carry more than one system to ensure continuous service. These are integrated into navigational plotters and echo sounder systems to provide fishing masters with full three-dimensional (3D) displays of the area being fished and the position of the vessel in relation to sea-bed features and fish aggregations.

The recent move to sophisticated 3D plotting software such as the Piscatus® or MaxSea® under-way mapping systems allows vessels to rapidly generate high-resolution three-dimensional maps of an area without the need for experimental tows. The level of detail available from such plots allows very precise and consistent placement of the gear. These systems also accurately record the vessel trawl tracks and footprint, which potentially provides information useful for evaluation of habitat impact.

The advent of deepwater fishing has led to the installation of echo sounders that have greater power (10 kW) and lower frequency (28 kHz) capable of delivering detailed and accurate images at great depths. More recently, acoustic systems have moved to personal-computer based technology, which allows for rapid and enhanced signal processing, as well as ceramic transducers. Which are continually being improved, for better acoustic transmission and reception. Many vessels now also use some form of scanning sonar to scan areas other than below the vessel, for example, to locate fish aggregations in three dimensions provide lateral images of the sea bed, or track fishing gear in relation to fish aggregations and sea-bed features.

Deepwater trawlers have acoustic link monitors on the trawl nets to obtain information on the vertical position of the trawl net in relation to the sea bed. Thus, the time, extent and pressure of contact of the gear with the sea bed can be accurately monitored and controlled. These systems can also provide information on water temperature and the volumes of fish entering the trawl. Net-positioning systems allow accurate placement of the net on the intended target trawl zone, minimizing the impact of currents, which could push the net off the tow line. Acoustic link systems are used to prevent any seabird that might result from using cable-linked systems.

The ability to control the gear rapidly and accurately in response to information provided by the electronic systems described above is completely dependent on the power and control of the vessels winches. New Zealand deepwater trawlers have all moved to using hydraulically or electrically controlled self-tensioning systems that have sufficient power to respond rapidly to the instructions related to altering the net position or behaviour.

Since the commencement of deepwater trawling there have been major changes to the trawl gear to minimize bottom contact by doors and sweeps and to minimize the risk of trawls sticking fast on the sea bed, and subsequently being damaged. There has been a shift from old-style vee doors to modern, high-aspect ratio hydrodynamic doors (Plate 4). These doors are designed to be towed within the water to reduce the risk of them coming into contact with the sea bed. There have also been modifications to the trawl net design to facilitate highly accurate targeting of fish aggregations. Most significantly, the move towards shorter sweeps and bridles and smaller net openings both improves the manoeuvrability of nets and also reduces the width of ground-rope impact. Successful targeting of fish aggregations reduces the duration and extent of ground contact by the trawl. The shift away from steel bobbins to rubber bobbins, and then to rubber-disc rockhopper gear, has also been designed to reduce the risk of gear becoming fast on the sea bed, instead hopping over obstacles that are encountered.

PLATE 4

Pelagic-style trawl doors as used in aimed bentho-pelagic trawling. These doors are not designed for demersal trawling. (FV *Will Watch*, Port Louis, Mauritius.

Photo credit: R. Shotton

Current New Zealand deepwater fishing skippers have built up substantial personal experience, both working in various crew positions on deepwater vessels and subsequently learning how to fish sea-bed areas and features most efficiently. This experience is critically important to fishing efficiency and minimizing sea-bed impacts, and its importance is typically underestimated.

10. MANAGEMENT

10.1 North Atlantic

In 2006, NAFO closed four seamount areas including Corner Rise to bottom fisheries as a precautionary measure (NAFO, 2006) and in 2010 this measure was extended for four years so that these seamounts were closed to bottom fishing until 31 December 2014 (NAFO, 2010b).

In 2009, the North East Atlantic Fisheries Commission (NEAFC) established a Southern Mid-Atlantic Ridge closed area, which is located north of the 200-mile EEZ of the Azores, to protect vulnerable habitats. It prohibits bottom fishing on three of four seamounts that had commercial aggregations of alfonsino. This measure will be in force until 31 December 2015. The regulations of the NEAFC control fishing effort in deepwater fisheries. Fishing effort is not to exceed 65 percent of the highest level of fishing effort in previous years for the relevant species. Effort is calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels that participate. The measure is in force until 31 December 2015 (NEAFC, 2015).

The advice from ICES in 2008 (ICES, 2010a) was the same as that given in 2006: “As a consequence of their spatial distribution associated with seamounts, their life-history and their aggregation behaviour, alfonsino are easily overexploited by trawl fishing; they can only sustain low rates of exploitation. Fisheries on such species should not be allowed to expand above current levels unless it can be demonstrated that such expansion is sustainable. To prevent depleting entire subpopulations that have not yet been mapped and assessed the exploitation of new seamounts should not be allowed.” A TAC system is in force under the Common Fisheries Policy of the European Union (Member Organization). Fishing with trawl gears is forbidden in the Azores region (EC. Reg. 1568/2005). An exclusion box of 100 miles length that limits fishing to deepwater vessels registered in the Azores was created in 2003 (EC. Reg. 1954/2003). A TAC of 328 tonnes for vessels of the European Union (Member Organization) was in force for 2009–10 (EC. Reg. 1359/2008). Technical measures have been introduced for the Azores since 1998. In 2009, new measures were introduced, particularly to control the effort of longliners through restrictions on fishing area, minimum alfonsino length, gear and effort. The Condor Seamount was closed to the fishery for two years (2010–11). There are NEAFC regulations on effort in the fishery for deepwater species and closed areas to protect vulnerable habitats.

Vinnichenko (2012) notes that the current status of alfonsino stocks in the open North Atlantic should consider the following.

- Compared with other deepwater fishes, alfonsino has a relatively short life, high growth/reproductive rates, and high individual fecundity. These characteristics imply relative resilience of alfonsino to heavy fishing (Clark *et al*., 2007; Kulka *et al*., 2007, Vinnichenko, 2010). Recovery of alfonsino stocks in the absence of fishing to a level allowing profitable fishing should take 4–5 years (Vinnichenko, 1998, 2010).
- Rapid depletion of stocks, vulnerability to capture and pulse trawl fishing for alfonsino, a consequence of their aggregating behaviour and small population sizes on seamounts (Vinnichenko, 1997, 1998; Clark *et al*., 2007).
- The heavy fishery in the 1990s had a negative impact on alfonsino stocks on the Corner Rise and Azores seamounts. This is evident from the gradual decline in fishing success of trawlers from 1993 to 2000 and by the reduction in size, density and stability of alfonsino aggregations.
- There has been no fishery targeting alfonsino in the Azores area in the last decade. The fishery on Corner Rise has been occasional by Spanish vessels since 2004 with limited annual catches.

10.2 Southern Indian Ocean

10.2.1 Introduction

Shotton (2014a) examined the yield per recruit (Y/R) of alfonsino as a function of fishing mortality (F) and age of recruitment into the fishery using the well-accepted Y/R function of Beverton & Holt (1957). With the exception of a brief note by Ivanin & Rybek (2012) no population parameter values have been specifically determined for alfonsino stocks in the Southern Indian Ocean. While determining such values for Southern Indian Ocean stocks is, of course, desirable, indeed essential, it is not believed that appreciable errors will result from using values that have been determined for alfonsino in other oceans.

Shotton (2014a) found that estimates of M have generally increased with time (Table 56) though he did not provide reasons for this.

TABLE 56
Estimates of M over the period 1958–2009

Date of Estimate	Citation	Value of M (both sexes combined)
1958	Taylor	0.101
1975	Alverson & Carney	0.281
1976	Rikhter & Evanof	0.134
1984	Alagaraja	0.155
1988	Roff	0.213
2009	Horn & Sutton	(mid-value) 0.23
Average		0.185

Source: Shotton (2014a)

In estimating yield per recruit Shotton (2014a) used values of M of 0.24, 0.19 and 0.14. A von Bertalanffy growth relation was used to model growth. Many workers have determined the parameters of the von Bertalanffy growth coefficient (K with dimensions of yr^{-1}), the asymptotic weight (W_∞) and the age at which an alfonsino is estimated to have zero length (a model fitting parameter), t_0 and found them to be different for the two sexes. Where only one value is given Shotton it is assumed that the fish were not sexed.

There is a considerable range in the values of L_∞ that have been obtained. The only estimate for alfonsino sampled from the Southern Indian Ocean (Ivanin & Rebyk 2012) is also one of the largest – 73.4 cm - and Shotton (2014a) was of the view that it should be treated as an outlier. The mean estimate for male fish is 48.5 and for females, 60.0, though this includes the large estimate of Massy & Horn (1990) that has a confidence interval of 22.5 cm. It would seem prudent to also treat this value as an outlier too, in which case the mean for females becomes 56.8 cm. The mean of the two sexes combined is 52.9 cm. This appears consistent with the estimates for the two sexes separated – 52.5 cm. A L_∞ of 52.9 cm is used in his calculations.

10.2.2 Selection of Model Parameters

10.2.2.1 Asymptotic weight

An estimate of W_∞ was derived from length-weight relations and these are listed in Table 36, Section 4.4 for the weight-length relation $W = aL^b$ with weight in grams, length in centimeters. Figure 34 shows the length-weight relation for alfonsino samples from Southwest Indian Ridge banks taken during 1980-1988 (Ivanin & Rebyk 2012). de Leon & Malkov (1979) calculated length-weight equations for alfonsino from the Corner Rise (c. 35° N, 50° W) and New Year Rise (c. 15° N, 54° W) in the west-central Atlantic. The relation of Ivanin & Rebyk (2012) was derived from much smaller fish (17-36 cm) than those of Massey & Horn (1990) and de Leon & Malkov (1979).

To avoid excessive cross-confounding of parameter estimates Shotton (2014a) used the parameter estimates of Ivanin & Rebyk (2012), Lehodey & Grandperrin (1996) and Massey & Horn (1990) for Palliser Bay. This choice was somewhat arbitrary but stood for analysis of alfonsino from the Southern Indian Ocean and two locations in the South-west Pacific – Noumea and New Zealand.

The estimates of W_∞ Shotton (2014a) used were as follows:

Ivanin & Rebyk (2012):

$$W_\infty = 0.0384\ SL^{2.98}$$

Where SL = standard length, the maximum is assumed here to be 55.0 cm.

Thus, $W_\infty = 5\ 897$ g

Ivanin & Rebyk (2012) note "On SWIR length of fish in catches hesitated from 12 to 55 cm (age from 2 to 18 years), making 27.2 cm on the average, mass was 70-6 260 g (average – 437 g). Basis of catches of alfonsino was made by fish by modal group 24-32 cm."

Lehodey & Grandperrin (1996):

Note, these authors give separate lengths for males and females. The males were far smaller than the females and Shotton (2014a) uses their maximum female length, which will confound comparisons for estimates that use both sexes combined. These authors do not determine a length-weight relationship. Therefore Shotton used the values of Ivanin & Rebyk (2012) and Massey & Horn (1990) and took the average. Thus, using Ivanin & Rebyk's (1996) estimates:

$$W_\infty = 0.0384\ SL_\infty^{2.98}$$

Where

$$SL_\infty = 51.3/0.91$$

Thus,

$$W_\infty = 3617\ \text{g.}$$

Using Massey & Horn's (1990) parameter estimates:

$$W_\infty = 0.001930\ L^{3.061} = 3\ 313\ \text{g}\ (3\ 310\ \text{g})$$

The average is thus 3 465 g.

Massey & Horn (1990) provide four estimates of the first coefficient – by sex and for two seasons and Shotton (2014a) used the average of the four.

Massey & Horn (1990):

Shotton took the average of the two observations where values are given for males and females, i.e.

$$L_\infty = (51.1 + 57.5 + 54.9 + 76.3)/4 = 59.9\ \text{cm}$$

Shotton (2014a) recommended treating the last value as an outlier, but as it had been observed it was included it the estimate of the average. Thus

$$W_\infty = 0.001930\ 59.9^{3.061} = 5\ 324\ \text{g}$$

In summary,

'Source'	**W_∞ (g)**
Ivanin & Rebyk (2012)	5 897
Lehodey & Grandperrin (1996)	3 465
Massey & Horn (1990)	5 324

These results indicate that the estimate based on Lehodey & Grandperrin (1996) may be an outlier or underestimate and Shotton arbitrarily used the average of Ivanin & Rebyk (2012) and Massy & Horn (1990) as a 'best estimate' (5897 + 5324)/2 = 5610 g.

10.2.2.2 Von Bertalanffy Gowth Coefficient

Table 31 shows estimates for the von Bertalanffy growth coeffiecient and t_0, the theoretical time when the extrapolated length of newborn fish would be zero. Table 57 below shows values given by three of these works.

Massey& Horn (1990) only give coefficient values disaggregated by sex: the values were taken for the the two sexes and averaged, through this almost certainly introducing incalculable biases as the K and t_0 values have a relation with each other. Further averaging these values for the two errors will compound such a statistical liberty.

TABLE 57

Growth-related parameter values for alfonsino

Source	K	t_0
Ivanin & Rebyk (2012)	0.0823	-2.60
Lehodey & Grandperrin (1996b)	0.119	0.005
Massey & Horn (1990)		
Palliser	0.099	-3.83
Tauheni	0.0675	-6.275
Average	0.0832	-5.052
Grand average	0.0948	-2.667

Shotton (2014a) notes that a better procedure would be to do a single fitting of the parameters to all of the available data using actual data from the Southern Indian Ocean, but ageing analyses of alfonsino from the Southern Indian Ocean remains to be done.

10.2.3 Estimation of yield per recruit

10.2.3.1 Yield per recruit model

Shotton used the original model of Beverton & Holt (1957) for yield per recurit:

$$\frac{Y_w}{R} = FW_\infty \sum_{n=0}^{n=3} \frac{\Omega_n e^{-nK(t_{\rho'}-t_0)}}{Z+nK} + \left[1 - e^{-(Z+nK)\lambda}\right]$$

Where:

$\frac{Y_w}{R}$ = Yield per recruit

F = fishing mortality

W_∞ = asymptotic weight of alfonsino

Ω_n = summation operator for n = 1,-3, 3 and-1

K = von Bertalanffy growth constant, i.e. the rate at which length reaches its asymptote

$t_{\rho'}$ = age of recruitment to the fishery

t_o = age at which fish length was theoretically zero and

λ = fishable life span in years between recruitment and death.

He examined how the expected yield from a single alfonsino varies as the fishing mortality and age of recruitment to the fishery changes. If these variables can be altered then so the estimated yield per recruit can be changed – increased or decreased.

10.2.3.2 Fishing mortality in the fishery

The two fisheries for alfonsino in the Southern Indian Ocean target separate populations: aimed trawling targets large mature fish while extensive trawling targets younger and often immature fish. Thus, at present no estimates of what is the actual F in the SIO fishery exist and Shotton used a range of values from F = 0.0 to F = 1.0 in increments of 0.2 for his calculations.

10.2.3.3 Age at time of recruitment to the fishery

Shotton (2014a) undertook an analysis for two ages at recruitment to the fishery, when mean fish length was 22 cm and when mean fish length was 35 cm. He assumed here that recruitment to the fishery is 'knife edge', i.e. no fish are caught smaller than 22 cm (or 35 cm). This, of course, is a simplification of what actually happens in the fishery. These lengths are converted to age by rearranging the standard relation,

$$L_t = L_\infty (1 - e^{K(t-t0)})$$

Thus[10],

$$t = \frac{-\ln\left(1 - \frac{L_t}{L_\infty}\right)}{K} + t_0$$

Thus calculated age at L_t = 22 cm is 2.8 yr and at L_t = 35 cm is 8.4 yr. These values were taken as the two possible ages of recruitment to the fishery.

10.2.3.4 Yield per recruit estimates

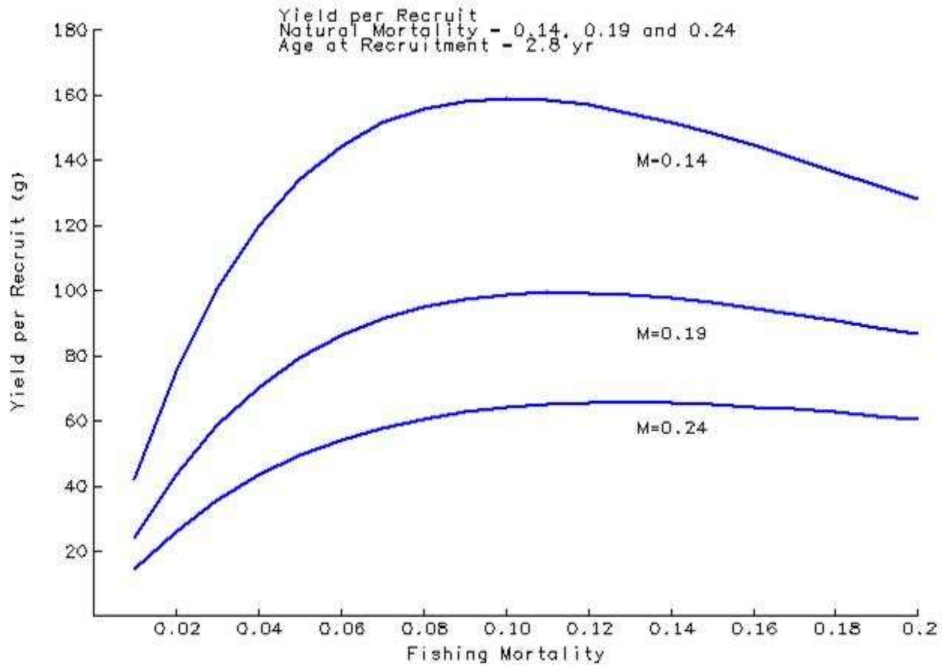
Shotton (2014b) used the following parameter values.

Variable	Value
W_∞	5 610 g
K	0.098
t_0	-2.67
t_ρ	2.8, 8.4
M	0.19, 0.24, 0.14

Y/R estimates have been plotted against the three choices for natural mortality, M. The results are shown in Figure 57 assuming an age of recruitment of 2.8 years, i.e. fish of length 22 cm. As expected yield per recruit decreases, by almost three fold from an M of 0.24 (high estimate) to an M of 0.14 (low estimate). However, fishing mortality that results in maximum yield per recruit is reasonably stable. Thus, any management decision on desirable levels of fishing effort is not likely to be greatly affected by changes in the assumptions about M.

[10] Arithmetic shown in Appendix I.

FIGURE 57
Yield per Recruit: Change in M

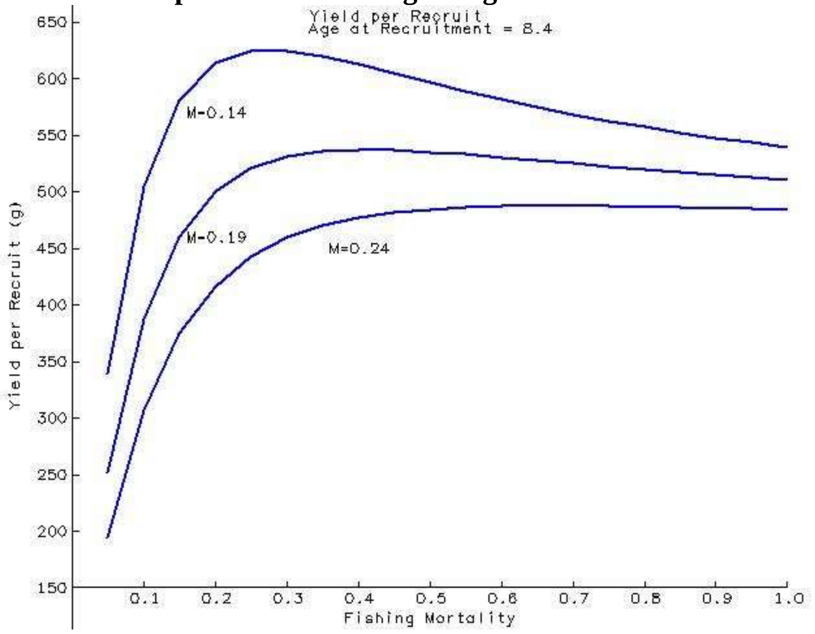


Source: Shotton (2014a)

When the age of recruitment to the fishery is increased to 8.4 years (i.e. length of 35 cm) the most striking result is the increase in yield per recruit (Figure 58).

The differences arising from different assumptions about the natural mortality follow the pattern seen in Figure 57. However, all three curves show a major increase in the potential yield per recruit that is possible.

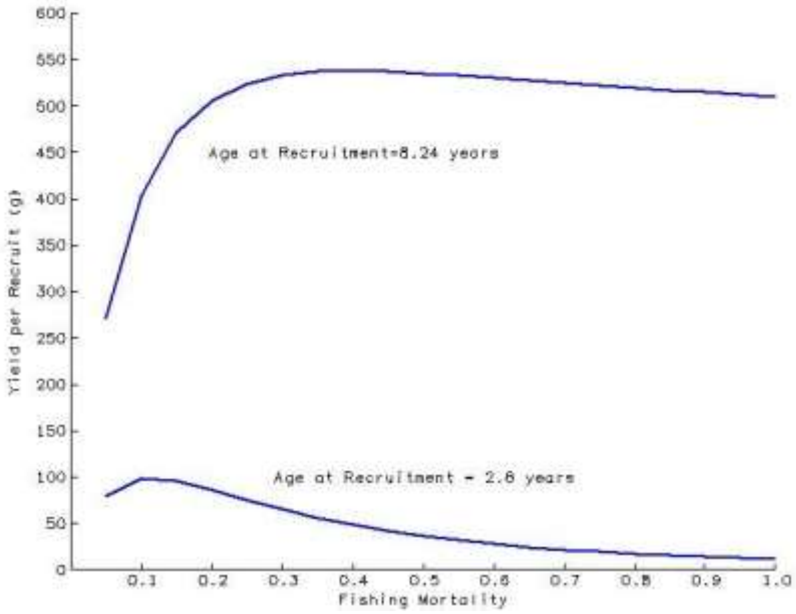
FIGURE 58
Yield per Recruit: Change in age of recruitment



Source: Shotton (2014a)

Figure 59 shows the results of comparing the two options for age at recruitment, corresponding to first size of capture of 22 cm and 35 cm. These results show the considerable benefits from delaying recruitment to the fishery to an older age.

FIGURE 59
Comparison of Yield per Recruit from age 2.8 years (22 cm) to 8.4 years (35 cm).



Source: Shotton (2014a)

Shotton (2014a) concluded that a potential increase in catches of an order of magnitude (x 10) by fishing with a target age at recruitment of 8.4 or length of 35 cm was possible.

10.3 Japan / Northwest Pacific

Honda, Sakaji and Nishida (2012) note that both the ASPIC model and the best regime-dependent spreadsheet (MS Excel) models indicate that alfonsino is overfished on the basis of the fishing mortality in some years in recent decades based on Nishimura and Yatsu (2008). Both models suggest that current fishing effort or fishing mortality was above F_{MSY}, and $F_{current}$ should be reduced by 20–28 percent. Honda (2012) considers F_{MSY} an appropriate limit reference point and B_{MSY} as a reference point should be considered as a relative value.

The present analysis using surplus-production models suggests:

- There was a highly productive regime in 1979–1982 and an "ordinary" regime thereafter.
- Alfonsino is overfished – current fishing effort is above F_{MSY} and should be reduced considerably.
- Despite the unresolved population structure and lack of information about movement between other areas, the recommendation is to reduce current fishing effort by about 20 percent, as a first step in an adaptive learning process.

Japan is implementing a limited-entry system for trawl and gillnet fisheries in areas beyond national jurisdiction.

In the North Pacific Ocean, high-seas biomass of alfonsino has been increasing following the rapid decline in the early 1990s although it is still below the level that would theoretically provide the MSY. Member States of the new North Pacific RFMO have recently applied coordinated regulation measures to the fishery for alfonsino on the high seas. The participating countries – Japan, the Republic of Korea and the Russian Federation – have agreed to decrease fishing mortality by 24 percent for alfonsino, as was determined in the most recent stock assessment of Emperor Seamounts populations (Nishimura and Yatsu, 2008). To achieve this interim management measure Japan has implemented its original measures since 2009, namely, a 20 percent reduction in average fishing mortality, F, in the period 1997–2006. This is equivalent to a 20 percent reduction in fishing time for bottom trawlers and closure during November and December on all fished seamounts (Honda, 2012). Also to this end the Russian Federation temporarily closed its fishery for alfonsino in November–December to reduce fishery mortality on all fished seamounts except for exploratory and research activity in the area under consideration (Baitaliuk and Katugin, 2012). The Russian Federation is currently developing rules to regulate bottom fisheries in the area.

10.4 The Republic of Korea

The Republic of Korea limits the number of bottom-fishing vessels through its government licensing system.

10.5 Northwest Hawaiian Islands deep-slope and seamount bottom fishery

Mitsuyasu (2006) notes that the Western Pacific Fishery Management Council of the United States of America implemented a bottomfish fisheries management plan that includes deepwater species found in Hawaii and other Pacific islands of the United States of America. Alfonsino was one of the bottom-fish management unit-species along with ratfish/butterfish (*Hyperoglyphe japonica)* and armourhead (*Pseudopentaceros richardsoni*) in the seamount groundfish group.

In addition to policies of the Magnuson–Stevens Act the above council established objectives for managing bottom fish resources in the Western Pacific region through promulgation of the fisheries management plan. The Bottomfish and Seamount Groundfish Fishery Management Plan was implemented in 1986. A moratorium was placed on the harvest of alfonsino and armourhead on the Hancock Seamounts, the only exploitable seamount habitat in the management area (63 FR 35162, 29 June 1998) in an effort to rebuild the groundfish stocks. The moratorium was to remain in effect until August 2010.

10.6 Australia

10.6.1 Management procedures and protocols

The Australian fishery for alfonsino is managed as part of the Southern and Eastern Scalefish and Shark Fishery (SESSF). Overall management of this fishery is mainly through annual TACs allocated as statutory fishing rights. Since 2005 a “tiered harvest strategy framework” has been applied that has evolved over time (AFMA, 2009; DAFF, 2003). The harvest strategy has three tiers (in the past there used to be four) that cater for the different levels of uncertainty about the state of the stocks and each stock is assigned to a tier based on how much knowledge exists regarding its state (Smith and Smith, 2005).

Tier 1 is the highest level and applies to stocks that have “high quality” information available. A quantitative model-based stock assessment is undertaken in these cases. These provide estimates of current biomass levels and fishing mortality relative to target and reference points. The target biomass is that which can produce maximum economic yield; where this is not known, then it is taken as 1.2 times the biomass producing MSY. The proxy for B_{MSY} is 40 percent of the unfished biomass; for B_{MEY} it is 48 percent of B_0. The limit reference point is $0.2B_0$, i.e. 0.5 B_{MSY}. Fishing mortality for a fish stock is set to zero when the biomass is less than the limit reference point. If the biomass is less than $0.35B_0$ the level of fishing mortality is decreased to enable the biomass to rebuild. The fishery management uses the term “recommended biological catch” (RBC), which may or may not be the TAC.

Tier 2 fisheries are managed using a catch-curve analysis (Wayte and Klaer, 2010) to estimate the average recent fishing mortality based on the age structure of the catch, biology of the species, total catch weight and selectivity of the fishing gear. The limit reference point is the level of fishing mortality that would lead, in the long term, to a biomass equal to 0.5 B_{MSY} or a proxy. The target reference point is fishing mortality that would lead to a biomass equal to B_{MEY} or its proxies. The reference B catch is set as a proportion of average recent catch, where the proportion depends on the relationship between the estimate of current fishing mortality and the reference points.

Tier 3 fisheries consist of those about which least is known, e.g. only catch rate trends. In principle, Tier 3 uses CPUE reference points as proxies for B_{LIM} and B_{TARG} and assumes that the CPUE reflects the trend in biomass of a species. The target CPUE is the average for a period of years (the reference period) when the species was considered to be fully fished, CPUE and catch were relatively stable and the fishery was considered to be both profitable and sustainable. For species that do not have a long history of being fished the average CPUE for a reference period early in the fishery is considered to represent a relatively unfished state and the target CPUE is set at half this level (approximating the default proxy for B_{MEY} of 0.48 B_0). In both cases the limit reference point is set at 40 percent of the target (approximating 0.2 B_0). The RBC is set as a proportion of the average catch in the reference period (or half this value for relatively unfished species) where the proportion depends on the relationship between the current standardized CPUE and the reference points.

The target and limit reference points reflect the tier to which the fishery has been assigned. The level of "precaution" in the TACs is intended to increase from Tier 1 to Tier 3 reflecting the greater uncertainty in assessments at higher tier levels. Each tier has specific harvest control rules to determine an RBC. The Tier 2 and 3 assessments do not include any inherent level of increasing precaution to offset increasing uncertainty. Therefore, "precaution" is introduced through a default discount factor that reduces the RBCs by 5 percent for Tier 2 species and 15 percent for Tier 3 species. The resource assessment group can recommend that the discount factors are not required if there is evidence that adequate precaution is already afforded through other management measures (e.g. closures) or that the fishery has exhibited stability at current catch levels. Application of appropriate discount factors for Tier 3 and 4 stocks is needed to ensure that these stocks are not at increased risk as a result.

The discount factors that are applied to Tier 3 and 4 fisheries are fundamental to the tier system as they are the main mechanism for increasing precaution with increasing uncertainty in the assessments; however, the discount factors remain a source of debate within the regional advisory groups.

Post-assessment modifiers
In addition to the above harvest-control rules additional rules have been developed in response to industry concerns. These are applied by the Australian Fisheries Management Authority (AFMA) in recommending TACs to the AFMA Commission:

- Recent catch-rate multiplier: This incorporates the recent industry catch-rate data in recognition of the time lags inherent in the assessment process. The TACs are adjusted up or down according to whether the standardized CPUE for the most recent year is higher or lower than in the previous year.
- Maximum change: Increases in TACs are limited to no more than 50 percent to avoid rapid large changes.
- Minimum change: To avoid variation in TACs that may reflect minor interannual variation no change is made if the recommended change in the TAC is less than 10 percent or 50 tonnes (whichever is less). However, if a trend in the RBC figure within the 10 percent or 50 tonnes limit (either up or down) continues over successive years the recommended increase or decrease in the TAC will be adopted.

Species below the biomass limit reference point
In the case of overfished stocks where the current biomass is estimated to be less than 20 percent of unfished biomass the RBC is set to zero and there should be no targeted fishing, in line with the harvest strategy plan. For these species AFMA sets "bycatch TACs" at low levels to allow for unavoidable catch taken during targeted fishing for other species. The process for setting bycatch TACs is not detailed for the high seas fishery.

Carryover and change to fishing year
Operators can carry over a limited credit of uncaught quota or a debit of catch in excess of their quota to the following fishing year. For most stocks in the SESSF this amount is generally set at a maximum of 10 percent. There is no carryover of uncaught quota for bycatch TACs. AFMA also sets a "determined amount", which is the maximum amount, in addition to the percentage of "overcatch" that an operator

may take under certain conditions without committing an offence. However, twice the quantity of any catch above the quota, but below the determined amount that applies for a stock is deducted from the operator's statutory fishing rights for the following season.

The Australian Bureau of Agricultural Economics notes that there are stocks for which no tier levels are appropriate: There are stocks for which the Regional Advisory Group has limited or no confidence in the available assessment approaches and an alternative approach should be considered to guide RBCs for these species.

Vessel-level management is by Statutory Fishing Rights for alfonsino and TACs (orange roughy and boarfish). Consultative forums are the South East Management Advisory Committee and the Slope/Deep Resource Assessment Group, which advise on management (Slope/Deep RAG, 2011).

Effort in the East Coast Deepwater Trawl Sector (ECDTS) has been very low since 2007. A single trip took place in the 2009–10 fishing season landing 14 tonnes and there were no trips in the 2010–11 fishing season. Since 2000, 1 298 tonnes of alfonsino has been landed in the ECDTS and 249 tonnes in the Commonwealth Trawl Fishery, which is not covered by quota.

10.6.2 Harvest strategy

The ECDTS is managed under the SESSF harvest strategy framework (AFMA, 2009). A TAC of 500 tonnes has been in place since 2005 and was applied for the 2010–11 fishing season. The sporadic fishing has made data collection and assessment difficult. The standardized CPUE series does not provide informative trends, primarily owing to the small number of vessels and records in the fishery. The 2009 Tier 3 assessment was based on age-frequency data from otoliths collected in 2003 and 2007 as there were no length frequency data. Use of these data assumes that the samples for ageing were a "robust" representation of the age frequency. The current catch was estimated based on the SESSF and high-seas catch since 2000. The catch-curve analysis (Klaer, 2008) suggested that the current fishing mortality was above the target fishing mortality (F_{48} – the fishing mortality that would result in a biomass of 48 percent of unfished levels, $0.48B_0$) but below the limit (F_{20}), and the harvest control rules resulted in an RBC of 82 tonnes. As the data have been collected from a restricted area (100 km^2) southwest of Lord Howe Island AFMA recommended a TAC of 500 tonnes for the broader area to encourage fishing and further data collection (SEMAC, 2010). A trigger of 100 tonnes was put in place for the area southwest of Lord Howe Island; this area would be closed if this trigger were reached.

The 2010 updated Tier 3 assessment used age-frequency data from otoliths collected in 2007 and 2009 (Klaer, 2011) and the current catch was calculated from the ECDTS and adjacent high-seas catch since 2000. The catch curves for both years were relatively consistent and the average slope of the curve was used. The catch-curve analysis estimated a lower total mortality than the previous assessment and assuming a constant natural mortality a much lower current fishing mortality.

The current fishing mortality is less than F_{48} and so the Tier 3 harvest control rules resulted in an RBC of 1 160 tonnes (Klaer, 2011). The 50 percent change limiting rule would have constrained the increase in TAC for the 2011–12 fishing season to 750 tonnes (Slope/Deep RAG, 2011). The fact that two years of ageing data are now available and the age structure is relatively consistent between the years gave Slope/DeepRAG (2011) confidence in the robustness of the catch-curve analysis and assessment. No fishing took place in the 2010–11 fishing season. The most recent assessment indicates that the fishing mortality is below the target fishing mortality and so the stock is considered not subject to overfishing.

Generally, Tier 3 assessments cannot be used to provide an indication of biomass status. However, the Tier 3 assessment in this case includes the entire history of the fishery from 2000. As the Tier 3 assessment determined that fishing mortality was not large enough to be considered overfishing and this has been the case for the entire history of the fishery the stock is considered not overfished. There is uncertainty owing to the limited data available as well as the catch-curve analysis being based on the age-frequency data from fish collected for otoliths, which may not be representative of the actual age frequency.

10.7 New Zealand

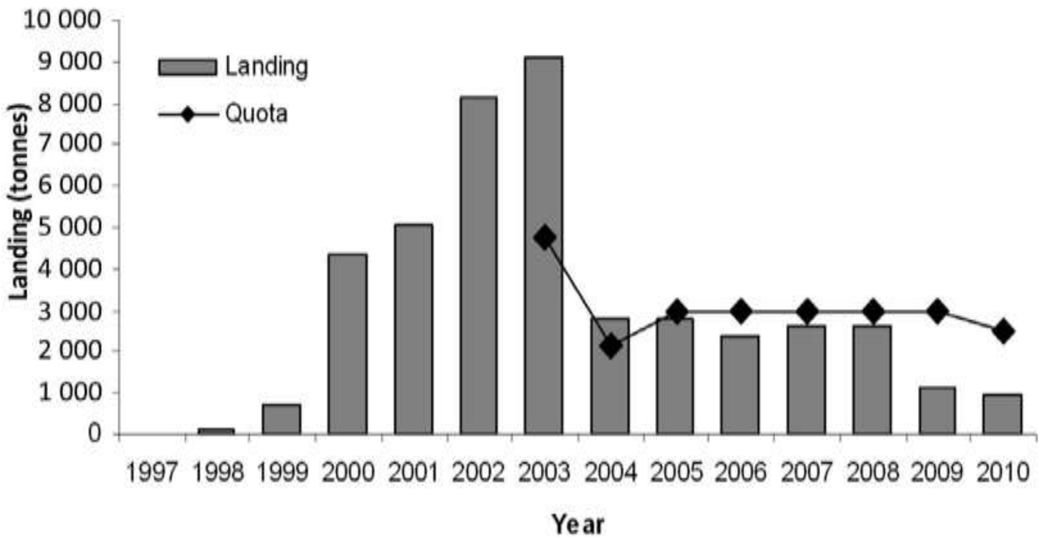
In the 1986–87 fishing year the TAC for the Central Fishing Management Area was caught and those for all other regions were undercaught. If it is assumed that the CPUE annual means are an accurate index of biomass then there is cause for some concern. The CPUE values for the two longest-exploited grounds (Palliser and Motukura) have declined to about one-third of their original levels. The declines on the Tuaheni High and Paoanui Ridge have been even greater. The decline in CPUE is consistent with comments from commercial fishers that alfonsino are less abundant, harder to catch and may be smaller in size than in previous years, and the knowledge that overseas stocks of alfonsino were seriously depleted after only short periods of commercial fishing. This suggests that the current TAC may not be sustainable.

The possibility that alfonsino in New Zealand waters are part of a widely distributed South Pacific stock complicates management. It is not known whether the fish exploited in New Zealand comprise a relatively insignificant component of the whole stock or whether virtually all pre-reproductive alfonsino visit New Zealand waters. If the latter is the case heavy exploitation could have serious implications for future recruitment.

10.8 Chile

The rapid increase in landings that occurred after 1999 to about 8 000 tonnes in 2002 resulted in the capping of fishing permits in 2003 and the setting of temporary quotas until mid-2004. In August 2003, the Subsecretaria de Pesca set a TAC of 5 002 tonnes, of which 4 277 tonnes were target species landings. In August 2004 this was reduced to 2 130 tonnes and the fishery was declared a "fully exploited regime", a classification established under the Chilean General Fishing Law on Fishing and Aquaculture that, in general, empowers the management authority to set an annual quota. The first annual quota of 3 000 tonnes was established in 2005 and in following years has fluctuated around 2 500 tonnes (Figure 60).

FIGURE 60
Fluctuations in landings and quota of the Chilean alfonsino fishery



Source: modified from Wiff *et al.* (2012)

During 2012, the alfonsino fishery in Chile was closed owing to low catch rates, small median size of fish in the catch and serious overfishing. Since 2006, landings have been less than quotas set in 2009 and 2010; indeed, less than the half of the allowable catch was landed. The Subsecretaria de Pesca is now trying to implement a stock rebuilding programme.

Despite the available information, the current status of alfonsino is considered overfished and the spawning biomass reached 0.12 B in 2010. Several causes have been proposed for the collapse of the alfonsino fishery, but the main cause is related to the high landings before an annual quota was established. According to Chilean fisheries law a fishing resource with low catches and scarce targeting is an "open access regime", i.e. any fishing vessel can be licensed for the fishery and have no catch limits – this promotes a "race for fish". When authorities suspect that a resource is threatened with overfishing it is then declared a "fully exploited regime", which empowers the authorities to stop issuing fishing permits and introduce an annual quota. Because of the high vulnerability of deepwater fisheries to poor fisheries management (Large *et al*., 2001) the introduction of the application of the "fully exploited regime" was too late for alfonsino – the fishery was already overfished.

Stock assessments carried out from 2004 to 2008 included high levels of intra- and inter-model uncertainty, which influenced management decision for maintaining similar level of quotas to that established in 2005. High levels of uncertainty relating to the stock assessment were caused by non-informative abundance indices coming from acoustic surveys and CPUE trends and variable length distributions between years. In addition, there is still a lack of knowledge about the main aspects of the population dynamics of the stocks around the seamounts in the Juan Fernández Islands. The most recent acoustic surveys (in 2010) contributed to reducing uncertainty about the biomass estimates. However, the reduction in uncertainty of state variables, although considerable, was too late to influence management authorities to reduce quotas.

Management authorities decided to close the alfonsino fishery in Chile in 2012 and they are already preparing a rebuilding stock strategy. This is the third deep-sea demersal fishery to be closed in Chile after orange roughy in 2008 and cardinalfish in 2009. The main uncertainties are: lack of knowledge of the stock structures, maturation dynamics, stock relations within the seamounts of Juan Fernández, spawning areas, migrations and stock structure. Some information relating to maturity is now available (Roa, Niklitschek and Lamilla, 2008; Guerrero and Arana, 2009), but considerable uncertainty remains. Flores *et al.* (2012) show that the maturity ogives may be biased because the maturity scale in Lehodey, Grandperrin and Marchal (1997) had been misused. Moreover, the spawning period and geographic area of reproduction are unknown; thus, that samples used for assigning maturity may have different spatial–temporal origins. This may be the reason why mature alfonsino have been difficult to find. These sources of uncertainty need to be considered by future research, and overall uncertainty needs to be incorporated into management decisions following the FAO guidelines for the precautionary approach.

Koslow *et al.* (2001) note that the productivity of alfonsino is much higher than that of "deeper-water" species, such as orange roughy and the oreosomatiids, which inhabit waters deeper than 500 m and have extremely slow growth and low natural mortality rates and, hence, are more vulnerable to fishing. González *et al.* (2003) note that alfonsino have a specialist life-history style, are only moderately fecund and moderately productive, and appear relatively sedentary. Hence, they conclude that alfonsino are relatively susceptible to growth overfishing and population depletion.

10.9 Alfonsino, a deepwater fish to be managed as a deepwater species?

Despite a relatively large amount of information on alfonsino and its fisheries (both peer-reviewed and grey literature), few authors or regional management bodies have proposed or imposed specific management procedures or operational objectives for alfonsino fisheries, such as target fishing mortalities or target biomass reference points.

Fisheries targeting alfonsino are usually categorized as deepwater fisheries and have the biological characteristics typical of deepwater species (e.g. TNC, 2011; Clark *et al.*, 2015; Koslow *et al.*, 2015) as summarized by FAO (2009) with the following text:

> **"Characteristics of species exploited by deep-sea fisheries**
> 13. Many marine living resources exploited by DSFs in the high seas have biological characteristics that create specific challenges for their sustainable utilization and exploitation. These include: (i) maturation at relatively old ages; (ii) slow growth; (iii) long life expectancies; (iv) low natural mortality rates; (v) intermittent recruitment of successful year classes; and (vi) spawning that may not occur every year. As a result, many deep-sea marine living resources have low productivity and are only able to sustain very low exploitation rates. Also, when these resources are depleted,

recovery is expected to be long and is not assured. …"

While the FAO text is qualified ("*many* marine living resources", *many* deep-sea marine living resources), the preceding sections of this review indicate that these characteristics do not appear to apply to alfonsino. Maturation is relatively rapid (Chapter 5); growth rates are "reasonable", as is maximum age (Chapter 4); several fisheries target alfonsino from ages two and older, natural mortality is not excessively low (Chapter 7); and alfonsino are reported to be serial spawners (Section 5.5), a spawning strategy that should result in annual recruitment that is robust to environmental vagaries. Gordon (2005) offers a pertinent comment in a section titled "Validity of generalizations". He starts by noting that text such as "Deepwater fish are long lived and slow growing, have a high age and large size at first maturity and have low fecundity" is frequently used in the context of deepwater fisheries. He then asks how valid this generalization is. In a table taken from ICES (2001b) that ranks the vulnerability of deepwater species based on life-history parameters using redfish (*Sebastes marinus*) and Greenland halibut (*Reinhardtius hippoglossoides*) as reference species where a score of 1 indicates most vulnerable, and 5 least vulnerable, alfonsino scores 5.0 (and *B. decadactylus* 4.7). Orange roughy, by contrast, scores 1.6. As a consequence, Gordon notes: "we should be cautious about making broad generalizations about the life history patterns of deepwater fishes."

Which life-history and behavioural characteristics of alfonsino should be of concern to fisheries managers? Despite the several views offered as to the degree of discreteness of alfonsino stocks in the high seas environment, it is difficult to be confident about any assertions as to the degree, or lack, of population exchange between adjacent populations of alfonsino, at least from the material covered in this review. Although adults may live as discrete populations, their strategy of serial spawning would require retention processes of the kind envisaged by Bakun (1996) to prevent oceanic dispersal and mixing of their larvae. Outside of the typical, and possibly rather rare, seamount physiography, such a retention strategy is unlikely to be common. The conclusions of Hoarau and Borsa (1999, 2000) in Chapter 6, i.e. genetic homogeneity of alfonsino at an interoceanic scale, are intriguing in this regard.

Alfonsino form dense aggregations during the day (see Figure 13), frequently over rocky/rough bottoms. In these circumstances, alfonsino are difficult to fish by benthopelagic trawling as there is a risk of vessels losing or damaging their gear; however, line fishing could be viable. Alfonsino can be highly mobile and easily avoid approaching fishing gear. Even skippers highly experienced in aimed benthopelagic trawling find this species to be "problematic" when attempting to capture them. In the southern Indian Ocean fishery, trawlers targeting alfonsino by aimed trawling generally do not even attempt to fish alfonsino during daylight hours given their ability to avoid approaching fishing gear.

Because fishing for alfonsino often targets their aggregations, there is a danger of hyperdepletion of alfonsino populations, as for any fish that form aggregations/schools. Thus, the use of CPUE as an index of abundance may not be appropriate – catch rates of species that continually aggregate can be maintained until the stock is depleted. Recent advances in multifrequency acoustic assessment appear promising, and it may be an important component of future assessment efforts. Further, the acoustic systems needed to undertake such assessment are already installed on many deep-sea fishing vessels. FAO (2012) offers insights into ways in which this may be done.

A particular aspect of the size of most alfonsino fisheries, as noted above, is that their catches are relatively small in scale and fish high seas populations associated with sea floor features and/or oceanic islands, which themselves are usually associated with mid-oceanic ridges. Except for the, now few, places where there is no RFMO, effective management of alfonsino fisheries will depend on the ability of the relevant RFMO to manage fishing effort targeting the stock and enforce conservation regulations, or at least be sure of compliance. However, the geographical isolation of such fisheries provides a challenge to achieving effective monitoring, and one potential impediment to effective governance is that fishing of some alfonsino stocks may occur without any outside knowledge or reporting.

The isolation of high seas alfonsino fisheries, which may require fishing vessels to steam for many days to reach, or switch, grounds, may encourage pulse fishing. That is to say, once on the grounds, the fisher may be inclined, for immediate financial reasons, to fish a stock to commercial exhaustion and not return to the ground until several/many years later, assuming that the stock does in fact recover. Experience in some areas, e.g. Corner Rise in the mid-Atlantic (Section 3.1), indicates that such recoveries should not be taken for granted, not least because once a stock is depleted, recruitment success may become problematic and a long interruption in the fishery may follow.

Those RFMOs attemting to achieve management reference points may find that annual sustainable harvests from individual alfonsino stocks are commercially non-viable, and RFMOs may face arguments to allow periodic harvesting of such populations. However, it seems that there are no biological reasons why conventional methods of fisheries management for alfonsino cannot be used to achieve sustainable fisheries and so contribute social and economic benefits to society. Further, there do not appear to be undue environmental risks from alfonsino fisheries. While single-species management appears to be appropriate for alfonsino, an important research question remains about alfonsino stock structure.

11. CONVERSION FACTORS FOR DETERMINING WHOLE WEIGHTS FROM PROCESSED WEIGHTS OF ALFONSINO[11]

11.1 Current practices

Normal industrial practice on fishing vessels is to record only the processed weight of retained fishes. Usual product forms are "dressed"[12] or fillets. Some species and sizes may be frozen whole although these tend to be smaller species or specimens. Scientists require weights of catches in terms of the whole weights for resource management purposes and thus need to be able to back-calculate such weights from the processed weights that are recorded. Dressed fish are headed and gutted and the pectoral fin is removed by cutting back along the fish and removing some of the belly flap and head meat. This processing is done when the fish are sold directly into the market in this form and the customer does not want the pectoral fin present. Dressing of fish is especially the case for alfonsino sold in Japan. Larger sizes of alfonsino are dressed as secondary processors usually have no wish to deal with pectoral fins, wings or bones when they are filleting large quantities of fish and this work is undesirable in machine filleting.

Heading machines come in two basic types: (i) single blade, i.e. only capable of a straight cut but operators can vary the angle; and (ii) two-blade, these make a V-cut up into the head. Both Baader and Pisces make versions of both straight- and V-cut heading machines. The "normal" universal heading machine from Baader is the 424 (Figure 61) or a Josmar, which is essentially a Spanish-made copy of the Baader 424.

The head may be cut off 'straight' (see right image, which is of a redfish – *Sebastes marinus*) or at an angle depending on how the fish are fed into the machine: the appropriate conversion factor to be used will be affected by this choice. The left image shows cod (*Gadus morhua*) being processed with a straight cut. The centre image shows the Baader 424 machine (now superseded by a 429 model). The actual location of the cut will depend on operator experience and diligence in placing the fish on the machine.

[11] Unless otherwise specified, this material is taken from MacGibbon *et al*. (2008).

[12] 'Dressed' means, — (a) in relation to all species of finfish not otherwise listed the body of a fish from which the head and gut have been removed with:

(i) the anterior cut being a continuous straight line passing immediately behind the posterior insertions of both pectoral fins; and

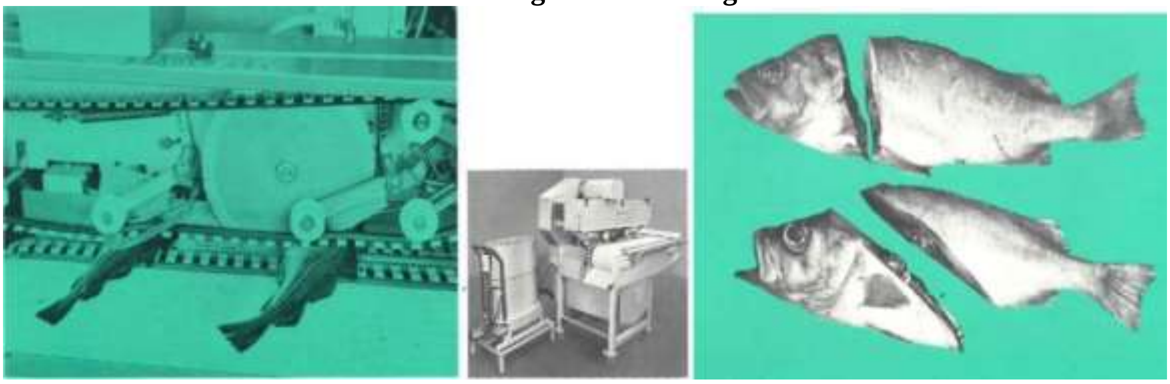
(ii) the forward angle of the anterior cut not less than 90 degrees in relation to the longitudinal axis of the fish; and

(iii) no part of the tail cut shall be forward of the posterior base of either the hindmost dorsal fin or the hindmost anal fin, whichever is nearer the caudal fin; and

(iv) the belly-flap either intact or divided along the ventral midline:"

Available at: www.fish.govt.nz/NR/rdonlyres/8BDBB85D-C6C6-44DF-9238-7A744BABD168/0/conversionFactorsNotice.pdf.

PLATE 5
Baader® 424 Straight Cut Heading Machine



Source: Baader Gmbh + Co. KG

Vessel operators, including their crews who are paid on landed weight, want to leave as much weight on the processed trunk as possible without unduly affecting the price a processor will pay. Processors want to minimize waste and processing costs. Recovery of processed product from the whole fish is usually constantly monitored. Processors have little or no regard for vessel recovery rates as they simply demand a trunk that has as many unusable bits as possible removed.

Hence, the important issue for vessel operators is that their vessels maximize the amount of product they obtain from the fish that they catch. They thus have an interest in these conversion factors as they provide an indication of the yields that are being obtained from the catch. High conversion factors indicate that poor yields are being obtained from the catch. This may imply that the processing equipment is poorly adjusted, such that they are removing too much of the body in the heading or filleting cutting operation and that the equipment is in need of adjustment. More probably, operator inattention, fatigue or disinterest may be the cause of the lower conversion rates that are possible. Hence, no matter what processing equipment is being used, operator expertise and efficiency are important.

Documented observations by data recording officers are relevant here[13]. For example, AFMA (2008) notes: "Alfonsino (*Beryx splendens*) and Indian Ocean Trevalla (*Schedophilus labyrinthica*) were processed using factory machinery on board the *SIODFA 3*8 headed by a 424 Baader and operator. The Baader 424 is set at a fixed speed, so the speed of the product being cut is governed by the amount of product applied to the machine. The head is removed with an angle cut intersecting just behind the head and the pectoral fin, the viscera and blood line is manually removed. The product is now in the HGU state."

While small changes in the value of conversion factors may have considerable significance for the profitability of the vessel operators, they are unlikely to result in major changes in management strategy. However, it is preferable to identify appropriate conversion factors accurately in order to ensure that what these values should be are not an issue in resource management.

A further source of error is that freezer trays or cartons were, and are, commonly packed to an estimated weigh, i.e. processed weight is determined not by scales but from "volume". This is believed to underestimate actual processed weights by 6–7 percent. For example, AFMA (2006a) notes that "Trays were packed to an estimated weight …." in referring to the operations of the FV *SIODFA 3* – normal operating practice. Landed weights should be used in these cases. Table 58 lists a general hierarchy of processed states.[14]

[13] Specific vessels names have been replaced with the term "SIODFA" to preserve confidentiality.
[14] More information available at: www.fish.govt.nz/NR/rdonlyres/BB9BAF3F-B57E-4586-903C-8030FA84266F/0/CFNoticeBackgroundAndIntroduction.pdf.

TABLE 58
General hierarchy of processed states

State	Reporting code	Conversion factor
Gutted	GUT	1.10
Headed and gutted	HGU	1.50
Dressed	DRE	1.80
Fillets, skin on	FIL	2.50
Fillets, skin off	SKF	3.10
Fish meal	MEA	5.60

Source: MacGibbon *et al*. (2008)

11.2 Alfonsino conversion values

For alfonsino in the fishery of the Southern Indian Ocean Deepsea Fishers Association (SIODFA) a Baader 323 processor is used for a straight cut. Alfonsino is diagonally cut using a Baader 424 on three, if not all, of the SIODFA vessels. Table 59 present the sources of information on processing conversion factors for alfonsino.

Anon (2003) notes that 55 bins of alfonsino with an average count of 15 fish a bin were used for the calculations. The fish were selected from a random sample and were not selected for size. Hattersley (2003) reports the results of three conversion factors analyses for alfonsino obtained during Cruise 24 by the FV *SIODFA 3*. These are given in Table 60.

The conversion factor is not consistent with grade size. The value reported by AFMA (2003a) for Cruise 25 of FV *SIODFA 3* was 2.04 based on a sample of 785 fish with a whole weight of 1 496.3 kg. Despite this, a conversion factor of 1.95 was used in reporting whole weights. However, the standard reporting practice is to use the conversion factors nominated by the New Zealand Ministry of Fisheries irrespective of what conversion trials achieve at sea.

A series of conversion factors for alfonsino were reported in McBride (2004) for the studies undertaken during Cruise 29 of FV *SIODFA 3*. Processing was done using a Baader 424 Header – as for the other vessels in the fleet. McBride notes that the head was removed “immediately posterior to the pectoral fins at an angle that would include some of the belly flap. The roe and viscera were removed by hand”, although there is uncertainty that this was the case. The conversion factors achieved by four operators are documented in Table 59.

TABLE 59
Sources of information on processing conversion factors for alfonsino

	Gutted	Headed & gutted	Dressed	Fillets skin on	Fillets skin off	Comments
FV *SIODFA 1*		1.4				
AFMA 2003a		2.04				1 496.3 kg whole weight; 785 fish sampled. YY 25.
AFMA 2003b YY 28		1.95				No conversion factor tests undertaken. All grades
AFMA 2006a		1.95				
AFMA 2006b		1.95				From factory production records; all grades
AFMA 2007a		2.01				YY 44
AFMA 2007b		2.01				222 kg gave 2.04; 226 kg gave 1.99. Section 4.6.
AFMA 2008		1.89				
AFMA 2007a		1.95				For ungraded, S, M, L & XL.
Lever 2004		1.95				For FLS/TSH and 5 different size classes
Cantwell 2004		1.95				For 5 size classes
McBride 2004		2.00				Based on 633 fish
Sutherland 1999		1.95				Based on "New Zealand MinFish conversion factors"
Taylor 2006		1.7				YY 39. All grades
FV *SIODFA 4* AFMA 2002		1.98				AL 33. L Grade, based on 28.72 kg, 12 fish. Process weight 14.47 kg
AFMA 2003		2.04				785 fish, sample weight 1 496.3 kg.
AMFA 2002		1.98				Based on sample of 28.72 kg of L grade fish
FV *SIODFA 2*		1.92				
New Zealand Convention	1.10	1.40	1.95	2.30	2.85	
USSR (1984)						V. Paramonov, personal communication.
Manual processing		1.587				
Machine processing		1.488				

Source: MacGibbon *et al*. (2008)

MacBride (2004) notes that "as the trip progressed, the operators became more adept and consequently, more consistent." Samples were also measured without the knowledge of the processors, and McBride reports that the results were not different to those obtained when the measurements were done with the cooperation of the operators. No explanation is given for the conversion factor of 2.00, which is 2.5 percent higher that that commonly reported for this species. Tables 60 and 61 list weights and average weights by grade for alfonsino and conversion factors from whole weights to fillets for alfonsino as provided by MacGibbon *et al.* (2008).

TABLE 60
Weights and average weights by grade for alfonsino (kg)

Grade	Weight of fish	Average weight per fish	Processed weight	Conversion factor
XL	29.48	2.08	15.12	1.95
L	143.60	2.24	71.96	1.99
M	98.68	1.54	51.40	1.91
XL	34.10	2.84	16.76	2.03
L	26.02	1.73	13.70	1.89

Source: MacGibbon *et al*. (2008)

TABLE 61
Conversion factors for fillets – alfonsino

Operator	No. samples	Weight of fish (kg)	Quantity of fish	Fillet weight (kg)	Range	
					Max.	Min.
1	13	451	196	115.25	2.05	1.86
2	9	302	139	66.75	2.08	1.95
3	7	310	148	125.98	2.13	2.00
4	3	106	50	62.98	2.05	1.92

Source: MacGibbon *et al*. (2008)

AFMA (2007a) reports the results of two conversion analyses for alfonsino during Cruise 44 of FV *SIODFA 3*. These are given in Table 62.

TABLE 62
AFMA conversions values, Cruise 44

Date	Grade	Weight of fish (kg)	Average weight per fish (kg)	Processed weight (kg)	Conversion factor
04/01/07	All	222.06	1.85	108.73	2.04
14/01/07	All	226.06	1.88	113.20	1.99

Source: AFMA (2007a)
Note: This result is lower than the conventionally used value of 1.9

AFMA (2008) reports the results of three conversion analyses for alfonsino during Cruise 48 of FV *SIODFA 3* as follows (Table 63).

Results obtained by the FV *SIODFA 2* in February 2009 from a controlled analysis of 120 individual alfonsino measured during the peak spawning season showed that 227.10 kg of fish (mean weight 1.89 kg; standard deviation 0.30) resulted in 118.35 kg of product, for a mean conversion factor of 1.92 (standard deviation of sample, 0.12; standard deviation of mean, 0.0109). This is 1.5 percent less than the standard defined by the New Zealand Ministry of Fisheries.

TABLE 63
Conversion analyses for alfonsino during Cruise 48 (kg)

Haul	Grade	No. fish	Whole weight	Processed weight	CF
28	S	100	92.82	51.56	1.80
45	S	100	86.48	48.20	1.79
62	M-XL	50	92.13	47.77	1.92
69	M-XL	50	89.76	45.08	1.99
78	L-XL	56	123.36	62.85	1.96

Note: The overall average was 1.89
Source: AFMA (2008)

Conversion factors used in New Zealand's domestic fisheries are[15]:

Headed and gutted	1.40
Dressed	1.95
Fillets	2.30
Skin-off fillets	2.85

MacGibbon (2013) notes that in New Zealand some conversion factors for alfonsino have changed since it became managed by that country's quota management system. Most alfonsino catch is landed green so there is no conversion factor issue. However, there has been a change in conversion factor for "trunked" fish. Although other processed states contribute only a small proportion of the catch there have been changes in the conversion factors for some of these states too. This means that different amounts of greenweight catch are associated with the same amount of processed catch for some product forms throughout the dataset for the New Zealand fishery. MacGibbon *et al.* notes the standardized weights using the most recent conversion factor for those processed states for which there have been changes in conversion factors. He assumes that the changes in conversion factors reflect improving estimates of the actual conversion when processing alfonsino rather than real changes in processing methodology across the fleet.

[15] Taken from: www.fish.govt.nz/NR/rdonlyres/E264B2E8-4B02-4FA5-8540-91B737D45499/0/CFNoticeSchedules.pdf.

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APPENDIX 1
Workshop agenda

Workshop on Assessment and Management of *Alfonsino* Fisheries
Nigeria Room (CC215), FAO, Rome, Italy
10–12 January 2012

Tuesday 10 January			
1	09.00	Opening of meeting,	
2	09.10	(a) Information to participants (b) How the workshop will proceed	Business items – per diems, navigating FAO, etc. To be discussed/agreed to by participants
3	09.30	Description of main fisheries i. Japan ii. Australia iii. Chile iv. Japan v. Korea vi. New Zealand vii. Portugal viii. Russia ix. Ukraine x. Others Description of biology of the species relevant to its fisheries and management;	Participants to present Summary presentation by Shotton, then participants contributions and comments
	10.30-10.50	Coffee	
4	10.50	Regional management issues: i. North Atlantic Ocean ii. South Atlantic Ocean iii. Indian Ocean iv. North Pacific Ocean v. South Pacific Ocean Global management issues ***Summary of management issues and current status of management***	Participants; Discussion Discussion
	1230	Lunch	
5	14.00	Review of status and adequacy of reporting of data of *Beryx* fisheries in regards to management requirements; • Global reporting (FAO, Fishstat+) • Regional requirements and challenges (RFMO level)	Shotton/Tandstad

		Required data and fisheries biology information (national and regional): i. Catch and size composition ii. Catch-effort relations iii. Measures of recruitment; recruitment relations iv. Estimates of biomass/stock abundance ***Discussion and summary of reporting and data requirements and issues***	All participants
	15.30	Coffee	
6	15.50	Start on Fisheries Biology: i. Age at recruitment into the fisheries ii. Age at maturity iii. Fecundity relationships – on size and compensatory responses (evidence?); other?	All participants
	17.00	Close for the day	
Wednesday 11 January			
7	09.00	Growth parameters and models	All participants
8	10.00	Mortality estimates	All participants
	10.30	Coffee	
9	10.50	***Summary and synthesis on biological aspects (Discussion)***	
	12.30	Lunch	
10	13.30	**Stock assessment methods:** Acoustic methods –practicality; technical issues (backscattering cross section – biomass relations etc.) Yield Models i. Surplus Production Models: evaluation of applicability	Industry involvement-FAO report
	1530	Coffee	
11	15.50	Yield Models continued…. i. Y/R models and estimates; parameter requirements; estimation of fishing mortality ii. Management reference points PSA- Productivity Sustainability Analysis. Potential use and applicability in deep-sea fisheries	All participants Bianchi
	17.00	Close for the day	
Thursday 12 January			
12	09.00	g TACs: i. Assessment of errors in TACs estimates ii. Risk management considerations	All participants
	10.30	Coffee	
13	10.50	Analysis/research of population structure: i. DNA methods; results; requirements ii. Meristic analyses? iii. Ageing?	All participants
	1230	Lunch	
14	13.30	Ecosystem implications of *Beryx* fisheries considering different nature of fisheries and gears used:	All participants

		i. Benthos ii. Associated species iii. Dependent species iv. Sea birds v. VME related information and data vi. Other Discussion	
15	15.00	Developing a programme to satisfy management requirements of *Beryx* fisheries: ongoing research potential for application of Bayes methods – what have we Management Strategy Evaluation – time to think of this?	
	15.30	Coffee	
16	15.50	Main conclusions and recommendations. Meeting reporting:	
	16.30	Close meeting	

APPENDIX 2
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