Supplementary material - model details

1 Multi-stanza model groups

Anchovy, sardine, Cape hakes and Cape horse mackerel are important fished species in the southern Benguela and were modelled as juvenile versus adult stanzas in order to capture fishing and trophic differences (Table S1).

Table S1. Parameters adopted to facilitate modelling of multi-stanzas in the case of key fish species. P/B = production per unit of biomass (unit: y^{-1}); BA is annual biomass accumulation (expressed as a fraction of total biomass B) to facilitate stock increases of anchovy and sardine in early years; K is the von Bertalanffy growth efficient; Wmat is weight at maturity; Winf is weight at infinity; Transition age is age in years at which juvenile/recruit/small fish stanza moves into the adult/larger fish stanza, juv. is juveniles, ad. is adults.

Species	Transition age (years)	P/B	BA /B	K	W_{mat}/ W_{inf}	Data sources
Shallow-Water Cape hake *Merluccius capensis*	3	2 (juv.) 0.8 (ad.)	-	0.046	0.011	Shannon (2001) (P/Bs); Growth parameters based on Punt and Leslie (1991) and Leslie (1998a, 1998b)
Deep-water Cape hake *Merluccius paradoxus*	3		-	0.046	0.011	Shannon (2001) (P/Bs); Growth parameters based on Punt and Leslie (1991) and Leslie (1998a, 1998b)
Anchovy *Engraulis encrasicolus*	1	1.2	-	2.590	0.680	Growth parameters based on de Moor and Butterworth (2015) M assumed to be 1.2 for all ages in the anchovy assessment model (de Moor, 2016)
Sardine *Sardinops sagax*	1	1.4 (juv.) 1.2 (ad.)	0.3	1.060	0.250	Growth parameters based on de Moor and Butterworth (2015) M = 1.0 for 0-year olds and 0.8 for 1 year and older sardine (de Moor and Butterworth, 2016) Higher turnover assumed when stock was rebuilding in the late 1970s/early 1980s
Horse mackerel *Trachurus t. capensis*	2	1.2 (juv.) 1.0 (ad.)	-	0.400	0.280	Fishbase; M. Kerstan (formerly Marine and Coastal Management, pers. comm.); Naish et al. (1991); and others

2 Species names and allocation to model functional groups

Species listings in aggregated demersal fish and chondrichthyan groups are provided below (Table S2).

Table S2. Allocation of species to large pelagic fish (Sciaenids, Sparids and other linefish), demersal fish and chondrichthyans model groups.

Functional group	Examples of species included
Sciaenids	geelbek *Atractoscion aequidens* silverkob *Argyrosomus inodorus*
Large Sparids (reef-associated)	Dageraad *Chrysoblephus cristiceps* Red steenbras *Petrus rupestris* Seventy- four *Polysteganus undulosus*
Medium Sparids SC (reef-associated dominant sparids of the South Coast)	Carpenter *Argyrozona argyrozona* Red roman *Chrysoblephus laticeps* Santer *Cheimerius nufar* Red stumpnose *Chrysoblephus gibbiceps*
Medium Sparids WC (Dominant species of the West Coast)	Steentjie *Spondyliosoma emarginatum* Hottentot *Pachymetopon blochii* White stumpnose *Rhabdosargus globiceps*
Pelagic-feeding demersal fish	Angelfish *Brama brama* Southern rover *Emmelichthys nitidus nitidus* Pencil cardinal *Epigonus denticulatus* Buttersnoek (ribbonfish) *Lepidopus caudatus* Jutjaw *Parascorpis typus* Windtoy *Spicara axillaris* Cutlass fish *Trichuiurus lepturus* Cape John Dory *Zeus capensis*
Benthic-feeding demersal fish	West Coast sole *Austroglossus microlepis* Agulhas sole *Austroglossus pectoralis* Hairy conger *Bassango aalbescens* Sharp-nosed rattail *Caelorinchus braueri* Large-scaled rattail *Caelorinchus simorhynchus* Rattails *Caelorinchus* sp. Cape gurnard *Chelidonichthys capensis* Lesser gurnard *Chelidonichthys queketti* Gurnards *Chelidonichthys* sp. Bank steenbras *Chirodactylus grandis* Large-scaled rattail *Coelorinchus fasciatus* Spinenose horsefish *Congiopodus spinifer* Smooth horsefish *Congiopodus torvus* Redspotted tonguefish *Cynoglossus zanzibarensis* Red rover *Emmelichthys nitidus* Kingklip *Genypterus capensis* Beaked sandfish *Gonorhynchus gonorhynchus* Jacopever *Helicolenus dactylopterus* Monkfish *Lophius vomerinus* Smooth-scaled rattail/ Purple grenadier *Malacocephalus laevis*

	Dragonette *Paracallionymus costatus* Panga *Pterogymnus laniarius* African gurnard *Trigloporus l. africanus*
Pelagic-feeding chondrichthyans	Copper shark *Carcharhinus brachyurus* Short-finned mako shark *Isurus oxyrhincus* Blue shark *Prionace glauca* Skates and Rays *Raja* spp. Leopard skate *Raja leopardus* Twineye skate *Raja miraletus* Biscuit skate *Raja straeleni* Smooth hammerhead *Sphyrna zygaena* Dog shark *Squalus acanthias* Dog shark *Squalus mitsukurii* Atlantic electric ray *Torpedo nobiliana*
Benthic-feeding chondrichthyans	St Joseph's shark *Calliorhincus capensis* Ragged-tooth shark *Carcharius taurus* Blue stingray *Dasyatis chrysonota* Stingrays *Dasyatis* spp. Thorntail stingray *Dasyatis thetidis* Soupfin shark *Galeorhinus galeus* Puffadder shyshark *Haploblepharus edwardsii* Smooth houndshark *Mustelus mustelus* White-spotted hound shark *Mustelus palumbes* Houndsharks *Mustelus* spp. Sawshark *Pliotrema warreni* Spotted catshark *Porodera africanum* Striped catshark *Porodera pantherium* Barbled catsharks *Poroderma* spp. Spearnosed skate *Raja alba* Slimeskate *Raja pullopunctata* Blancmange skate *Raja wallacei* Yellowspotted catshark *Scyliorhinus capensis* Dogfish *Squalops megalops* Spiny dogsharks *Squalus* spp. Two fin electric rays *Torpedo* spp. Electric ray *Torpedo fuscomaculata* Spotted gully shark *Triakis megalopterus*
Apex chondrichthyans	Great white shark *Carcharodon carcharias* Six-gilled shark *Hexanchus griseus* Seven-gilled shark *Notorhinchus cepedianus*

3 Model Parameterisation with respect to previous fitted model

3.1 Zooplankton

Previously (Shannon et al., 2004) the 1978 system required the following zooplankton densities to support its predators: 1.801 t.km^{-2} microzooplankton, 7.600 t.km^{-2} mesozooplankton and 12.70 t.km^{-2} macrozooplankton. The revised model requirements are 2.178 t.km^{-2}, 8.875 t.km^{-2} and 13.737 t.km^{-2} of microzooplankton, mesozooplankton and macrozooplankton respectively (Table 2), equating to an increase of a factor of 1.12.

3.2 Small pelagic fish

In the case of anchovy, the cut-off used by stock assessors for adults versus recruits was 10.5cm in May/June of 1985 and 1986 (Table 3 in de Moor et al. (2016)), equating to 36% of the 1984 anchovy catch being of 1-year and older fish (calculated from Table 1 in de Moor et al., (2011). Given the fishery is largely a recruit fishery and the proportion of recruits versus adult anchovy caught in later years was progressively larger (de Moor et al. 2011), the 0.952 t.km^{-2} of anchovy caught in 1978 was allocated to recruits and adults in the ratio of 75:25, accordingly (Table S.3).

Anchovy stock size was estimated to be 2.8 mill tons in 1984 (de Moor, 2016), with an average around 10.2 t.km^{-2} for 1984-1990. The two-stanza EwE model set with survey-estimated anchovy spawner biomass (7.063 t.km^{2}, DAFF unpublished data) and stock assessment-derived growth parameters (Table S1), estimates recruit biomass of 4.535 t.km2 in 1978, to give an anchovy stock size of 2.6 million tons, in close agreement with the stock assessment value available for 1984.

Sardine spawner stock size was estimated to be 0.22 t.km^{-2} directly from the 1984 survey, and 0.62 t.km^{2} for 1984-1986 in stock assessments (November total biomass) – these are the years after the sardine crash but before the major recovery in sardine. Assuming 0.5 t.km^{-2} for adult sardine in 1978 gives juvenile sardine B of 0.19 t.km^{-2} and still yielded EE over 5 (5 times the production of sardine needed to sustain the system (predation) and fishery). Noting that catches alone amounted to 0.441 t.km in 1978, a starting adult biomass density of 0.6 t.km^{-2} was tested in the model. Given the growth parameters adopted (Table S1), biomass density of juveniles was estimated by the model to be 0.228 t.km^{-2}, with a total sardine standing stock of 0.828 t.km^{-2} (182 000t). This seems a reasonable estimate considering sardine are again currently at a very low biomass level of 210 667t (Shabangu et al., 2019). Nevertheless, this lower, updated biomass (c.f. Shannon et al. 2004) could not sustain previously-estimated predation pressure. Therefore the fractions of sardine in the model diet of the hake in particular small *Merluccius paradoxus*, and seals, was necessarily reduced to reflect the low sardine stock levels in 1978. In addition, the relative juvenile-adult sardine contributions in the model diet of several predators such as seabirds and marine mammals were adjusted to account for relative sardine stanza biomass estimated by the model.

Predation mortality exerted on the “other small pelagic fish” model group is in most part inflicted by the “other seabirds” model group that ate gobies etc. Biomass of “other small pelagics” was estimated to be the minimum required and supported by the model ecosystem. Biomass was initially set to 0.364 t.km^{-2} in 1978 (Shannon et al., 2004) but needed to be revised upwards by a factor of 1.35 to 0.493 t.km^{-2} in order to sustain “other seabirds” in the revised model.

3.3 Large pelagic fish

Biomass density of snoek *Thyrsites atun* in the previous 1978 model (Shannon et al., 2004) was 0.142 t.km^{-2} but this was insufficient to support the revised snoek catches in 1978. Therefore model biomass needed to sustain catches was estimated to be 0.198 t.km^{-2} i.e. 1.4 times larger snoek stock, which subsequently exerted heavy predation pressure in anchovy recruits. Therefore, 5% of snoek diet previously attributed to anchovy was attributed to redeye in the revised model (Table S4).

3.4 Chokka squid

The squid *Loligo* spp. jig fishery only started in 1996, therefore, as in the case of midwater trawl for horse mackerel, negligible catches were input for 1978 to facilitate modelling to incorporate the squid jig effort series from the 1990s onwards. Predation pressure exerted by small *Merluccius capensis* was slightly lessoned to balance with input squid biomass by reducing the overall cephalopod fraction in the model of small *M. capensis* down from 5% to 3% and enhancing zooplankton consumption by the dietary deficit.

3.5 Hake

Fisheries on hake are parameterized as follows: the south coast inshore trawl catches small and large *M. capensis* (Rademeyer et al., 2008) whereas in the previous model (1978), only large hake were assumed to be caught. Between 2% and 20% of *M. capensis* of aged 1 and (mostly) 2-years were caught by inshore trawling between 1989 and 2000. The average of 7% was taken as the proportion of small *M. capensis* in the inshore trawl fishery for the revised model. Both large *M. capensis* and large *M. paradoxus* are caught in the west coast longline fishery, whereas the longline and handline fisheries on the south coast target large *M. capensis*. Longline and handline for hake only started in 1983 and 1985 respectively (DAFF data), therefore negligible catches for these fleets were set in the model for 1978 to facilitate modelling of catches by these gears in later years in the time series fitting process.

Dietary contributions of anchovy and sardine to diet of hake stanzas was slightly adjusted to reflect biomass of small pelagics in the revised model.

3.6 Chondrichthyans

Cortés (1999) provides a standardized shark diet for pelagic-feeding sharks of around 2% of diet consisting of chondrichthyans. Previously, a 10% contribution of sharks in the diet of this groups was used. Here, this fraction was reduced to 2% (inter-group consumption) and the remaining 8% of the diet fraction was assumed to comprise of other cephalopods, as recommended in Cortés (1999).

Although Cortés (1999) suggests there the diet of benthic-feeding sharks may be made of as much as 30% cephalopods, in the southern Benguela model, the cephalopod model group was already heavily preyed upon by a multitude of predators, in particular pelagic-feeding chondrichthyans. Macrobenthos and fish proportions assumed were otherwise consistent with Cortés (1999).

Previously (Shannon et al., 2004), apex chondrichthyan diet were assumed to be comprised of around 90% other chondrichthyans, and 7% and marine mammals, whereas Cortés (1999) suggests around half the contribution of chondrichthyans, with some cephalopod and more mammalian contribution to the diet. This is likely given what we know of Great White Sharks feeding off the Cape (Loosen, 2017). Subsequently, apex chondrichthyan diet was revised accordingly (Table S4).

3.7 Marine Mammals

The proportion of small versus large Cape hake in the diet of seals (previously 10% small *M. capensis* and 2.2 % large *M. capensis*; Shannon et al., 2004) was adjusted slightly (small *M. capensis* comprising 7.2% of seal diet and large *M. capensis* comprising 5%) to reflect large hake stolen off long lines as reported by (Wickens et al., 1992).

Previously, density of cetaceans was estimated to be 0.074 $t.km^{-2}$. Balancing of predation pressure under the revised model estimated that cetacean biomass was 12% larger (0.083 $t.km^{-2}$). Given the uncertainty associated with estimating cetacean biomass, this was considered acceptable.

3.8 Seabirds

Predation mortality exerted by “other seabirds” on *M. capensis* was well above 1 y^{-1} given 30% of seabird diet being comprised of hake. Since “other seabirds” include migrants feeding beyond the modelled ecosystem for at least part of the year, this fraction was reduced from 30% to 10%, and a quarter of “other seabird” diet was rather attributed to “imports” to the modelled ecosystem when specifying consumption.

3.9 Rock Lobster

Rock lobster were previously not included in the general Ecopath models of the Southern Benguela (Shannon et al., 2003, 2004; Smith et al., 2011). However, to provide future flexibility in fisheries and climate scenario modelling, rock lobsters were added as two functional groups. A wide range of densities of west coast rock lobster (WCRL) *Jasus lalandi* have been observed along South Africa’s west coast. Mayfield (1998) estimated WCRL density at 0.67 lobsters per m^2 between Cape Hangklip and Danger Point, whereas Pollock (1979) had earlier estimated a density of 1.9 lobsters per m^2 off Robben Island. In the 1980s, localized WCRL abundance was estimated to be 3900 $t.km^{-2}$ in the vicinity of Malgas Island (Barkai and Branch, 1988), whereas in 1983, 170.6 $t.km^{-2}$ of WCRL was estimated at Oudekraal in 1983 (Zoutendyk, 1988). These are only very small areas in the large Southern Benguela ecosystem, therefore a density of 0.5 $t.km^{-2}$ was used as a starting point for WCRL. Negative biomass accumulation was permitted to facilitate a decline in WCRL after 1978, as observed (Pollock, 1989).

In the case of South Coast Rock Lobsters (*Palinurus gilchristi*), vital rates ($P/B=1.2y^{-1}$ and $Q/B=4y^{-1}$) were taken from Heymans and Sumaila (2007). These parameter values were similar to those used by Coll et al. (2006) for lobster in the South Catalan Sea. However, West Coast Rock Lobster are extremely slow growing (e.g. Pollock and Beyers, 1981), turning over at very slow rates (Berry and Smale, 1980) and this reported value of 0.42 y^{-1} is used for WCRL P/B. Q/B for WCRL can be calculated to be 1.9 y^{-1} based on Zoutendyk (1988).

In general, rock lobster are preyed upon by dog sharks (here assumed to be *Squalus megalops* as this feeds demersally and thus rock lobsters would likely be available to this species as prey), seals and octopus (Pollock, 1986, 1989).

3.10 Unassimilated food

The proportion of unassimilated food was assumed to be 35% for zooplanktivorous fish, 30% if diet comprises both zooplankton and fish, and 20% in the case of heavily predatory species groups.

3.11 Catches

Catch data was kindly made available by DAFF and apportioned to the model functional groups and gear types (Table S3).

Table S3. Catches (t.km^{-2}.y^{-1}) by gear type estimated as input to the Southern Benguela model in 1978. For fishing fleet details see Table 1. For species composition of groups see Table 1 and Table S2.

Group name	Purse Seine	Dem Trawl	Par WC offsh trawl	Par SC offsh trawl	Cap WC offsh trawl	Cap SC offsh trawl	Hake Inshore Trawl	Hake Longline	Hake Handline	Sole insh trawl	Linefishery	Squid jig	Hmack Midwater trawl	WCRL	SCRL	Tuna Pole	Large Pelagic Longline
Phytoplankton 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phytoplankton 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microzooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesozooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrozooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gelatinous Zooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anchovy recruits	0.714	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anchovy spawners	0.238	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile sardine	0.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adult sardine	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Redeye	0.305	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other small pelagics	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile Hmack	0.016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adult Hmack	0	0.155	0	0	0	0	0	0	0	0	0	0	1.0E-05	0	0	0	0
Chub mackerel	0.011	0.028	0	0	0	0	0	0	0	0	0.0002	0	0	0	0	0	0
Lanternfish	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lightfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Snoek	0	0.037	0	0	0	0	0	0	0	0	0	0	1.0E-05	0	0	0	0
Tuna&Swordfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large Sparids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Medium Sparids	0	0.00025	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sciaenids	0	0.0005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other linefish	0	0.00025	0	0	0	0	0	0	0	0	0.0007	0	0	0	0	0	0
Mullet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chokka Squid	0	0.023	0	0	0	0	0	0	0	0	0	1.0E-05	0	0	0	0	0
Other cephalopods	0	0.0001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small *M.capensis*	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0
Large *M. capensis*	0	0	0	0	0.09	0.012	0.02	1.0E-05	1.0E-05	0	0	0	0	0	0	0	0
Small *M. paradoxus*	0	0	0.1	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0
Large *M. paradoxus*	0	0	0.39	0.02	0	0	0	1.0E-05	0	0	0	0	0	0	0	0	0
PF Demersals	0	0.022	0	0	0	0	0	0	0	0	0	0	0.0001	0	0	0	0
BF Demersals	0	0.08	0	0	0	0	0	0.013	0	0	0	0	0.0002	0	0	0	0
Agulhas Sole	0	0	0	0	0	0	0	0	0	0.004	0	0	0	0	0	0	0
PF Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BF Chondrichthyans	0	0.009	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0
Apex Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cetaceans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
African Penguin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape Gannet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape Cormorant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthic Producers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WC rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03	0	0	0
SC rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007	0	0
Sum	1.731	0.3551	0.49	0.022	0.09	0.012	0.021	0.01402	1.0E-05	0.004	0.0009	1.0E-05	0.00032	0.03	0.007	0	0

continued

Group name	Dem Shark Longline	Beach Seine&Gillne	Large Sparids WC line	Medium Sparids WC line	Sciaenids WC line	Chonds WC line	Snoek WC line	Tuna & billfish WC	Yellowtail WC line	Large Sparids SC line	Medium Sparids SC line	Sciaenids SC line	Chonds SC line	Other	Total
Phytoplankton 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phytoplankton 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microzooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesozooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrozooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gelatinous Zooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anchovy recruits	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.714
Anchovy spawners	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.238
Juvenile sardine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.041
Adult sardine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4
Redeye	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.305
Other small pelagics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001
Juvenile Hmack	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.016
Adult Hmack	0	0	0	0	0	0	0	0	0	0	0	0	0	0.099	0.25401
Chub mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0392
Lanternfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.005
Lightfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Snoek	0	0	0	0	0	0	0.031	0	0	0	0	0	0	0.0006	0.06861
Tuna&Swordfish	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0.01
Large Sparids	0	0	5.4E-05	0	0	0	0	0	0	0.000246	0	0	0	0	0.0003
Medium Sparids	0	0	0	0.00427	0	0	0	0	0	0	0.00273	0	0	0	0.00725
Sciaenids	0	0	0	0	0.00176	0	0	0	0	0	0	0.00224	0	0	0.0045
Yellowtail	0	0	0	0	0	0	0	0	0.002	0	0	0	0	0	0.002

Other linefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00095
Mullet	0	0.007	0	0	0	0	0	0	0	0	0	0	0	0	0.007
Chokka Squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02301
Other cephalopods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0001
Small *M.capensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001
Large *M. capensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12202
Small *M. paradoxus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.102
Large *M. paradoxus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.41001
PF Demersals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0221
BF Demersals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0932
Agulhas Sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.004
PF Chondrichthyans	0	0	0	0	0	0.0014	0	0	0	0	0	0	0.0006	0	0.002
BF Chondrichthyans	0	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0.011
Apex Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0.005	0.005
Cetaceans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
African Penguin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape Gannet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cape Cormorant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Benthic Producers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WC rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
SC rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.007
Sum	0	0.008	5.4E-05	0.00427	0.00176	0.0014	0.031	0.01	0.002	0.000246	0.00273	0.00224	0.0006	0.1046	2.94626

4 Main diet data sources

Noteworthy is the incorporation of updated dietary estimates for mesopelagic fish, based on Tyler (2016), and assumed for lanternfish to consist of 40% mesozooplankton and 60% macrozoplankton, compared to 67% mesozooplankton and 33% microzooplankton in the diet of lightfish.

Revised line fish model groups necessitated dietary estimation mainly from Fishbase. Mullet are detrital feeders, feeding off soft bottom substrata rather than actively hunting fish prey like many of the other line fish species modelled. Dageraad are reported to eat crustaceans, molluscs, worms and small fish (taken to be small benthic-feeding demersal fish). Red steenbras eat octopus, crabs, and fish, in particular Spodylisoma that eat off the bottom. Seventy-four eat fish and squid. Medium sparids are benthic predators thus diet was assumed to comprise of macrobenthos and benthic-feeding demersal fish, as well as a small quantity of mullet which eat off the bottom so may be available as prey to medium sparids while themselves foraging. Geelbek prey on pelagic fish such as chub mackerel and horse mackerel, whereas kob prey on macrozooplankton, small pelagic fish and also mullet, spotted grunter and Cape stumpnose (other linefish), as well as shrimps. Yellowtail are a west coast species and eat small fish, squid and crustaceans. Other linefish (Table S2) are assumed to eat off the bottom, feeding on macrobenthos (worms, molluscs, mussels, echinoderms) and on benthic producers (algae).

Diets of African penguins, Cape gannets and Cape Cormorant were taken from Crawford et al. 1991. Isotope studies on Eastern Cape revealed that chokka squid is an important prey item nowadays, comprising around 35% in diet of penguins there (Connan et al., 2016) compared to 2% on the west coast and 13% on the south coast as reported in earlier years (Crawford et al., 1991). The contribution of chokka squid to the diet of the African penguin was assumed to be 11% in the current model for 1978. The proportions of hake in the diet of gannets were allocated more heavily towards large than small hake stanzas, assuming this was of offal discarded by trawlers (see Grémillet et al. (2008)). This proportion may be higher than the 18% estimated to be the portion of hake in gannet diet on the west coast, and 2% dietary contribution estimated for south coast gannets (Crawford et al. (1991), given that as much as 43% of prey items (note this is not mass) in gannet diets were of pieces of hake scavenged from trawlers (Grémillet et al., 2008). Green et al. (2014) showed >93% of gannet diet by numerical abundance (again, not by mass) from 1979-2012 was attributable to anchovy, sardine and saury, the latter in the “other small pelagics” model group. For the current model it was assumed that hake contributed around 8.5% by mass to gannet diet in the Benguela overall, and it is recognised that Cape gannet diet is incredibly plastic, with breeding gannets reverting to eating discarded hake when anchovy and sardine abundances are low (Tew Kai et al., 2013).

Table S4. Diet composition adopted as input to the balanced model for the Southern Benguela in 1978. Predators are listed as columns, numbers corresponding to prey group numbers, where prey are placed in rows (see section 4 for diet data sources). * indicates 0.0001.

	Prey \ predator	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	Phytoplankton 1	0.4	0.5	0	0	0.25	0	0.25	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Phytoplankton 2	0	0	0.33	0	0.25	0.05	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0
3	Microzooplankton	0.05	0.5	0.33	0	0.5	0.04	0.5	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Mesozooplankton	0	0	0.34	0.64	0	0.57	0	0.29	0.6	0.81	0.75	0.39	0.01	0.4	0.67	0	0	0	0	0	0	0	0	0.02
5	Macrozooplankton	0	0	0	0.12	0	0.34	0	0.07	0.4	0.16	0.25	0.524	0.8	0.6	0.33	0.17	0.15	0	0	0.2	0.2	0	0.05	0.27
6	Gelatinous zooplankton	0	0	0	0.04	0	0	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Anchovy recruits	0	0	0	0	0	0	0	0	0	0	0	0.025	0.02	0	0	0.15	0.06	0	0	0.05	0.1	0	0	0.03
8	Anchovy spawners	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.277	0.2	0	0	0.05	0.05	0	0	0
9	Juvenile sardine	0	0	0	0	0	0	0	0	0	0	0	0.001	0.01	0	0	0.03	0.01	0	0	0.1	0.15	0	0	0.001
10	Adult sardine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0
11	Redeye	0	0	0	0	0	0	0	0	0	0	0	0.06	0.01	0	0	0.11	0.01	0	0	0	0.1	0	0	0.05
12	Other small pelagics	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0.001	0	0	0.1	0.1	0	0	0
13	Juvenile Hmack	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.001	0	0	0.2	0.1	0	0	0
14	Adult Hmack	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0.001	0	0	0	0	0	0	0
15	Chub mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0.001	0	0	0.1	0	0	0	0
16	Lanternfish	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0	0	0.025	0.025	0	0	0	0	0	0	0.05
17	Lightfish	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0.025	0.025	0	0	0	0	0	0	0.05
18	Snoek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Tuna&Swordfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Large Sparids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Medium Sparids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Sciaenids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Yellowtail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0
24	Other linefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

25	Mullet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.005	0.01	0.1	0	0	0	0
26	Chokka Squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0.15	0	0	0
27	Other cephalopods	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.2	0.3	0	0	0.05	0	0	0.02
28	Small *M. capensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.05	0	0	0	0	0	0	0.022
29	Large *M. capensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Small *M. paradoxus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.05	0	0	0	0	0	0	0.078
31	Large *M. paradoxus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	PF Demersals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0.1	0	0	0	0	0	0	0
33	BF Demersals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.195	0.49	0	0	0	0	0
34	Agulhas Sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	PF Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	BF Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	Apex Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Cetaceans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	African Penguin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	Cape Gannet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	Cape Cormorant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	Other seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	Benthic Producers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.15	0
45	Meiobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.3	0.03
46	Macrobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0.8	0	0.379
47	WC rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	SC rock lobster	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	Detritus	0.55	0	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.45	0
	Import	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.006	0	0	0	0	0	0	0

Continued

	Prey \ predator	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	45	46	47	48
1	Phytoplankton 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Phytoplankton 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Microzooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Mesozooplankton	0.02	0	0	0	0	0.01	0.01	0	0	0	0	0	0.03	0	0	0	0.003	0	0	0	0
5	Macrozooplankton	0.29	0.792	0.046	0.769	0.255	0.648	0.05	0	0	0	0	0	0.04	0	0	0	0.08	0	0	0	0
6	Gelatinous Zooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0	0
7	Anchovy recruits	0.03	0.03	0.099	0.084	0.0005	0.001	0.003	0	0	0	0	0.1	0.15	0.4	0.064	0.7	0.029	0	0	0	0
8	Anchovy spawners	0	0	0.2	0	0.0015	0.001	0.002	0	0.02	0	0	0.15	0.15	0.19	0.2	0.214	0.1	0	0	0	0
9	Juvenile sardine	0.001	0.006	0.001	0.001	0	0	0	0	0	0	0	0.001	0	0.004	0.02	0.066	0	0	0	0	0
10	Adult sardine	0	0	0	0	0	0	0	0	0.01	0	0	0.007	0.07	0.2	0.3	0	0.014	0	0	0	0
11	Redeye	0.05	0.031	0.087	0.054	0.028	0.11	0.025	0	0.049	0	0	0.025	0.03	0.05	0.024	0	0.023	0	0	0	0
12	Other small pelagics	0	0	0.01	0.001	0.002	0	0	0	0.02	0	0	0.003	0.02	0.002	0.234	0	0.039	0	0	0	0
13	Juvenile Hmack	0	0	0.03	0	0	0	0	0	0	0	0	0.01	0	0.005	0.01	0.007	0.011	0	0	0	0
14	Adult Hmack	0	0	0.158	0	0	0	0	0	0.09	0.01	0.025	0.022	0.27	0	0	0	0	0	0	0	0
15	Chub mackerel	0	0	0.02	0	0	0	0	0	0.01	0	0.001	0.013	0	0.009	0.022	0	0	0	0	0	0
16	Lanternfish	0.05	0.044	0.025	0.041	0.182	0.075	0.025	0	0.125	0.005	0	0.005	0.02	0.001	0.007	0	0.086	0	0	0	0
17	Lightfish	0.05	0.044	0.025	0.04	0.182	0.075	0.025	0	0.125	0.005	0	0.005	0.02	0.001	0.007	0	0.086	0	0	0	0
18	Snoek	0	0	0.002	0	0.001	0	0	0	0.001	0	0.01	0	0	0.006	0.012	0	0	0	0	0	0
19	Tuna&Swordfish	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0
20	Large Sparids	0	0	0	0	0	0	0	0	0.001	0	0.01	0	0	0	0	0	0	0	0	0	0
21	Medium Sparids	0	0	0	0	0	0	0	0	0.001	0	0.01	0	0	0	0	0	0	0	0	0	0
22	Sciaenids	0	0	0	0	0	0	0	0	0.001	0	0.01	0	0	0	0	0	0	0	0	0	0
23	Yellowtail	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0
24	Other linefish	0	0	0	0	0	0	0	0	0.001	0	0.01	0.001	0	0	0	0	0	0	0	0	0
25	Mullet	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0.001	0	0	0	0

26	Chokka Squid	0.01	0.01	0.01	0.003	0.04	0.007	0.007	0	0.1	0.01	0.01	0.1	0.05	0.112	0	0	0.02	0	0	0	0
27	Other cephalopods	0.01	0.02	0.02	0.007	0.064	0.013	0.013	0	0.18	0.02	0.1	0.131	0.104	0	0	0	0.083	0	0	0	0
28	Small *M. capensis*	0.07	0	0.095	0	0	0.004	0.001	0	0	0	0.005	0.072	0.01	0	0.001	0	0.1	0	0	0	0
29	Large *M. capensis*	0	0	0.02	0	0	0	0.002	0	0.04	0.01	0	0.05	0.01	0	0.003	0	0	0	0	0	0
30	Small *M. paradoxus*	0.01	0.021	0.15	0	0.1	0.016	0.008	0	0	0	0.005	0.1	0.017	0	0.01	0.0132	0	0	0	0	0
31	Large *M. paradoxus*	0	0	0	0	0.02	0	0.002	0	0.05	0	0	0.018	0.009	0	0.07	0	0	0	0	0	0
32	PF Demersals	0	0.001	0.001	0	0.03	0.03	0.02	0	0.05	0.005	0.05	0.049	0	0.02	0.016	0	0.008	0	0	0	0
33	BF Demersals	0	0.001	0.001	0	0.094	0.01	0.02	0.1	0.1	0.15	0.061	0.084	0	0	0	0	0	0	0	0	0
34	Agulhas Sole	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0
35	PF Chondrichthyans	0	0	0	0	0	0	0	0	0.02	0	0.1	0	0	0	0	0	0	0	0	0	0
36	BF Chondrichthyans	0	0	0	0	0	0	0.005	0	0.005	0.06	0.4	0	0	0	0	0	0	0	0	0	0
37	Apex Chondrichthyans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	Seals	0	0	0	0	0	0	0	0	0	0	0.09	0	0	0	0	0	0.001	0	0	0	0
39	Cetaceans	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0
40	African Penguin	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0
41	Cape Gannet	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0	0
42	Cape Cormorant	0	0	0	0	0	0	0	0	0	0	*	0	0	0	0	0	0	0	0	0	0
43	Other seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0	0	0	0
44	Benthic Producers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05	0.05	0.05
45	Meiobenthos	0	0	0	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0.08	0.15	0.15
46	Macrobenthos	0.309	0	0	0	0	0	0.782	0.6	0	0.625	0.01	0.004	0	0	0	0	0	0	0.07	0.3	0.3
47	WC rock lobster	0.02	0	0	0	0	0	0	0	0	0.05	0.01	0.05	0	0	0	0	0.005	0	0	0	0
48	SC rock lobster	0.08	0	0	0	0	0	0	0	0	0.05	0.01	0	0	0	0	0	0	0	0	0	0
49	Detritus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.95	0.8	0.5	0.5
	Import	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0	0	0

5 Fitting the model to historical data series

Data time series available for model fitting are documented in Table S5 below.

Table S5. Meta-database of time series of fishing effort used to drive exploited groups, and catch and abundance data used for model fitting. WC=west coast, SC=south coast. DAFF=Department of Agriculture, Forestry and Fishery; DEA=Department of Environmental Affairs. DAFF and DEA have merged to form DEFF (Department of Environment, Forestry and Fisheries). Fish data were provided by DAFF unless otherwise specified.

Data series	Data source/ database	Years for which data are available
Anchovy spawner biomass	Acoustic research surveys, November	1984-2015
Sardine spawner biomass	Acoustic research surveys, November	1984-2015
Redeye biomass	Acoustic research surveys, November	1984-2015
Juvenile Hmack biomass	Acoustic research surveys, November	1997-2015
Anchovy recruit biomass	Acoustic research surveys, May	1985-2015
Sardine recruit biomass	Acoustic research surveys, May	1985-2015
Lanternfish biomass	Acoustic research surveys, November	2006-2015
Lightfish biomass	Acoustic research surveys, November	2006-2015
Anchovy catch	Purse seine catch records	1978-2015
Sardine catch	Purse seine catch records	1978-2015
Anchovy model predicted November total biomass	Stock assessment model data; de Moor (2016) divided by survey bias	1984-2014
Anchovy harvest proportion	Stock assessment model data; de Moor (2016)	1985-2015
Sardine west component model predicted November recruitment (billions of fish)	Stock assessment model data; de Moor (2016)	1984-2014
Sardine south component model predicted November recruitment (billions of fish)	Stock assessment model data; de Moor (2016)	1984-2014
Sardine west component model predicted November total biomass	Stock assessment model data; de Moor (2016) divided by survey bias	1984-2015
Sardine south component model predicted November total biomass	Stock assessment model data; de Moor (2016) divided by survey bias	1984-2015
Sardine total (WC+SC) model predicted November total biomass	Summed SC and WC stock assessment model data series	1984-2015
Sardine west component harvest proportion	Stock assessment model data; de Moor (2016)	1986-2015
Sardine south component harvest proportion	Stock assessment model data; de Moor (2016)	1986-2015
Sardine total (west + south) harvest proportion	Stock assessment model data; de Moor (2016)	1986-2015
Juvenile horse mackerel catch	Purse seine catch records	1978-2015

Chub mackerel catch purse seine	Purse seine catch records	1978-2015
Redeye catch	Purse seine catch records	1978-2015
Lanternfish catch	Purse seine catch records	1978-2015
Chub mackerel WC biomass	Demersal swept-area research surveys - winter	1985-1988, 1990-1997, 1999, 2002-2005, 2007-2014
Chub mackerel SC biomass	Demersal swept-area research surveys – summer	1988, 1991-1996, 1999, 2003-2011, 2014-2015
Penguin breeders	DEA census of breeding pairs	1979, 1986, 1993, 1999-2001, 2003-2014
Gannet breeders	DEA census of breeding pairs	1978, 1980-1995, 1997, 1998, 2001, 2003, 2005-2009, 2011-2014
Gannet Z Lambert's Bay	Total mortality derived from annual survival estimates provided by DEA	1990-2009
Gannet Z Malgas Island	Total mortality derived from annual survival estimates provided by DEA	1990-2009
Gannet Z Bird Island	Total mortality derived from annual survival estimates provided by DEA	1990-2009
AP Z Dassen Island	Total mortality derived from annual survival estimates provided by DEA	1994-2011
AP Z Robben Island	Total mortality derived from annual survival estimates provided by DEA	1994-2011
relative JIG effort	GLM estimated by (Glazer and Butterworth, 2015)	1996-2014
Total Squid catch	Jig fishery and demersal bycatch records	2003-2014
Squid SC biomass	Demersal swept-area research surveys – summer	1988, 1991-1996, 1999, 2003-2011, 2014-2015
Horse mackerel trawl catch (adult fish)	Midwater and demersal trawl catches combined	1978-2012
Horse mackerel midwater trawl effort	Modelled CPUE from Holloway et al. (2015). Catch by gear from DAFF. Data series scaled to invoke start of the directed midwater trawl fishery of 7480t in 2000.	2003-2012
Horse mackerel WC biomass	Demersal swept-area research surveys - winter	1985-1988, 1990-1997, 1999, 2002-2005, 2007-2014
Horse mackerel SC biomass	Demersal swept-area research surveys – summer	1988, 1991-1996, 1999, 2003-2011, 2014-2015

M. paradoxus modelled SPB female	2013 stock assessment model data	1978-2013
M. capensis modelled SPB female	2013 stock assessment model data	1978-2013
M. paradoxus catch	Combined trawl catch, both coasts	1978-2015
M. capensis catch	Combined trawl catch, both coasts	1978-2015
M. paradoxus modelled recruitment (aged 0)	2012 stock assessment model data	1978-2013
M. capensis modelled recruitment (aged 0)	2012 stock assessment model data	1978-2013
M. paradoxus offshore trawl effort on the WC	Calculated from GLM-based *cpue* (Rademeyer and Butterworth, 2016) and catch data, scaled relative to 1978	1978-2015
M. paradoxus offshore trawl effort on the SC		1978-2015
M. capensis offshore trawl effort WC		1978-2015
M. capensis offshore trawl effort on the SC		1978-2015
Agulhas sole catch	Demersal trawl catch records	1978-2014
Agulhas sole effort scaled to 1	Calculated from standardized *cpue* of the Agulhas sole TAC recommendations	1994-2012
Agulhas sole biomass	Demersal swept-area research surveys – summer	1988, 1991-1996, 1999, 2003-2011, 2014-2015
Pelagic-feeding demersal fish biomass index	Abundance index estimated by DAFF in 2016 from WC and SC swept-area demersal surveys of angelfish *Brama brama* and ribbonfish *Lepidopus caudatus*	1988, 1991-1996, 1999, 2003-2011, 2014-2015
Benthic-feeding demersal fish biomass index	Abundance index estimated by DAFF in 2016 from WC and SC swept-area demersal surveys of monk *Lophius vomerinus*, kingklip *Genypterus capensis* and jacopever *Helicolenus dactylopterus*	1988, 1991-1996, 1999, 2003-2011, 2014-2015
Pelagic-feeding demersal fish catch	Catch records submitted to FAO	2003-2014
Benthic-feeding demersal fish catch	Catch records submitted to FAO	2003-2014
Thunnus alalunga abundance	2014 ICCAT report standardized *cpue* (West et al., 2014)	1999-2011
Tuna & Swordfish catch	Catch records submitted to FAO	2003-2014
West Coast Rock Lobster catches	Lobster fishery catch records	1978-2014
Large Sparids WC abundance index	*cpue* estimates from assessment models (Henning Winker pers. Comm.) were used as indices of abundance of line fish model groups.	1987-2015
Medium Sparids WC abundance index		

Sciaenids WC abundance index	Catches are those recorded for the South Africa linefishery Effort series were calculated from records of number of boat days	
Sharks & Rays WC abundance index		
Snoek WC abundance index		
Yellowtail WC abundance index		
Large Sparids Effort WC		
Medium Sparids Effort WC		
Sciaenids Effort WC		
Sharks & Rays Effort WC		
Snoek Effort WC		
Tuna & Billfish		
Yellowtail Effort WC		
Large Sparids SC abundance index		
Medium Sparids SC abundance index		
Sciaenids SC abundance index		
Sharks & Rays SC abundance index		
Large Sparids Effort SC		
Medium Sparids Effort SC		
Sciaenids Effort SC		
Sharks & Rays Effort SC		

6 Pre-balancing investigations

General parameterisation of the model was checked by means of the prebal routine (Link, 2010). In the case of the Southern Benguela model refined from Shannon et al. (2004), biomass (plotted on a log scale) spans 4 orders of magnitude across taxa, whereas the recommended guideline is 5-7 orders of magnitude in a model ecosystem (Figure S1). This is indicative of the focus on low trophic levels in upwelling systems. The criterion is met if the two phytoplankton groups are combined. Phytoplankton has been separated in the revised model configuration to improve description of the flows at the bottom of the food web as a result of favourable/unfavourable upwelling conditions in particular (van der Lingen et al., 2006). The slope of the log-biomass plot against TL should ideally reflect 5-10% decline across taxa (Link, 2010), whereas the Southern Benguela ecosystem fitted slope is fairly flat (Figure S1), reflecting the importance of mid-trophic levels in upwelling systems. Several taxa notably fall beneath the fitted linear slope (Figure S1), as a result of important taxa (ecologically, for fisheries, or for conservation purposes) being modelled as separate groups to facilitate future exploratory model simulations of management purposes, despite these groups not necessarily being sizeable in terms of biomass. Detritus is of the same order of magnitude as the combined phytoplankton standing stock, as recommended.

Vital rates (Q/B, P/Q and P/B) of several modelled groups fall above or below the expected linear trend across taxa (Figure S1). Turnover rates (P/B) are understandably high in the case of zooplankton and cephalopod model groups, low for homeotherms such as birds and dolphins (as noted by Link (2010)), otherwise the spread is fairly flat. The plot of Q/B shows much variation, largely due to high Q/B rates of the avian groups modelled separately for conservation scenario purposes at a later stage, and very low consumption rates by some low TL groups such as rock lobster and gelatinous zooplankton. Homeotherms can be expected to have higher Q/B ratios than ectotherms (Link, 2010). Excluding the avian model groups, there is a general decline in Q/B across taxa with TL (Figure S1). P/Q (gross food conversion efficiency) usually ranges between 0.1 and 0.3 in "normal" modelled ecosystems. In the Southern Benguela, P/Q is less than 0.1 for marine mammals and seabirds, as well as for the tunas and swordfish model group, and falls just below 0.1 for anchovy, sardine and juvenile horse mackerel groups in the model. On the opposite end are cephalopods, macrozooplankton and gelatinous zooplankton for which P/Q ranges between 0.35 and 0.4. These rates are all within acceptable ranges reported in the literature and reflect the inclusion in the model of non-fish groups needing tailor-made parameterisation.

Considering B and vital rates ratios amongst the different feeding guilds (as per Link (2010)), Tables 2, S6), a few ratios with high/low values characterise this ecosystem as an upwelling system. For example, the Q/B ratios of several predators to prey groups are low (Table S6), reflecting the inefficient transfer of energy through the Benguela food web, as often discussed in the form the match-mismatch of primary and secondary production in upwelling systems (Cushing, 1990) and the generally inefficient energy transfer up the food web in such systems.

The ratio of catches (human removals of biomass) to consumption of the various modelled groups is plotted (Figure S2). Many groups have ratios below 1, which indicates that the system flows are greater than the fraction of production that is removed by humans. As expected, several predatory fish model groups are caught in large quantities compared to what is consumed by predators within the ecosystem. These support important commercial fisheries and include fisheries on snoek, tuna and swordfish, medium sparids, Sciaenids, large *Merluccius paradoxus* and Agulhas sole. Noteworthy is the high proportion of adult sardine caught relative to what is consumed by predators in the system. However, when the full sardine stock is accounted for (juvenile and adult stanzas combined), this ratio is 35% which is acceptable for a forage species.

Table S6. Ratios of biomass and vital rates between the various feeding guilds, with a comment where the ratios are notably higher/lower than generally expected based on Link's (2010) guidelines. B= biomass (t.km^{-2}); P = production (t.km^{-2}.y^{-1}); C = consumption (t.km^{-2}.y^{-1}).

Biomass		
Demersals & medium pelagic piscivores/small pelagics	0.457	Ok
small pelagics/zooplankton	0.880	high predation pressure on zooplankton
small pelagics/phytoplankton	0.368	Ok
demersals/benthic invertebrates	0.180	Ok
Sharks & highly migratory species/small pelagics	0.064	Ok
Mammals & birds/small pelagics	0.010	Ok
whales/zooplankton	0.003	Ok
Q/B		
Demersals & medium pelagic piscivores/small pelagics	0.214	Ok
small pelagics/zooplankton	0.067	quite low
small pelagics/phytoplankton	n/a	
demersals/benthic invertebrates	0.090	quite low
Sharks & highly migratory species/small pelagics	0.032	quite low
Mammals & birds/small pelagics	0.026833	quite low
whales/zooplankton	0.000137	very low – expected given rates at top vs base of food web
P/B		
Demersals & medium pelagic piscivores/small pelagics	0.362	Ok
small pelagics/zooplankton	0.021	low
small pelagics/phytoplankton	0.007	trophic inefficiency - upwelling systems are poor in energy transfer
demersals/benthic invertebrates	0.109	ok
Sharks & highly migratory species/small pelagics	0.038	Ok
Mammals & birds/small pelagics	0.002	Ok
whales/zooplankton	7.55E-06	Extremely low but this is sensible for a ratio of the top vs bottom of the food web

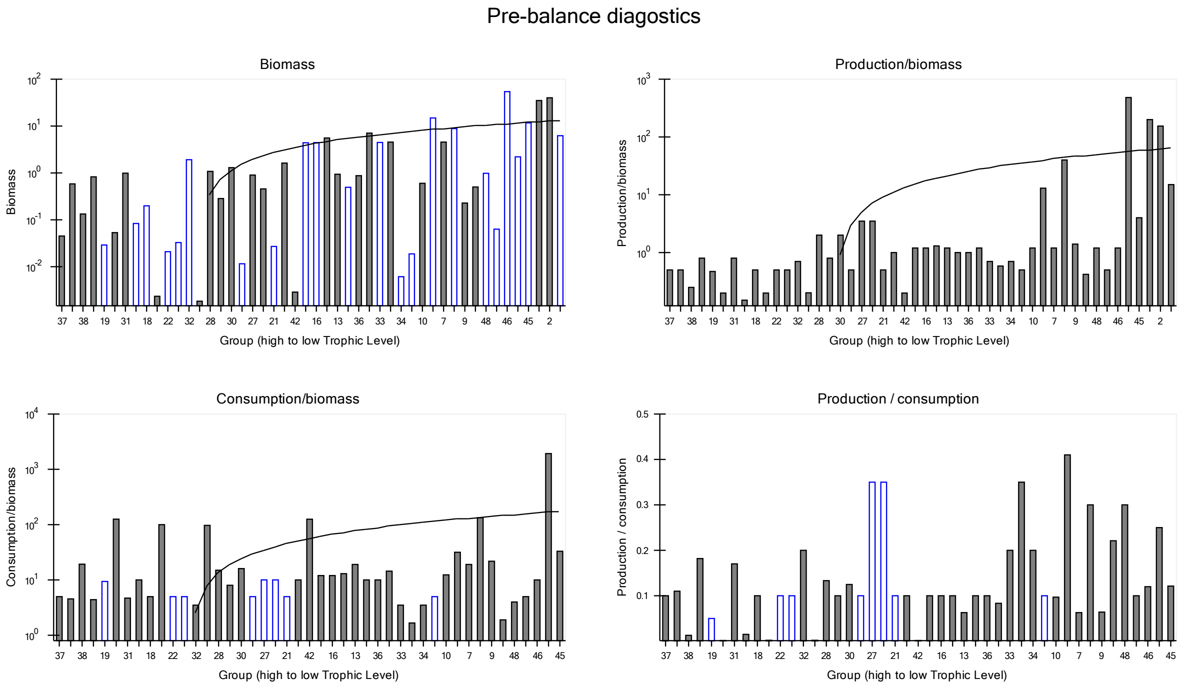

Fig S1. Pre-balance diagnostics where Ecopath parameters are plotted as a function of model group, arranged in ascending order of trophic level. Units are t.km^{-2} for biomass, y^{-1} for production/biomass and consumption/biomass, whereas production/consumption is dimensionless.

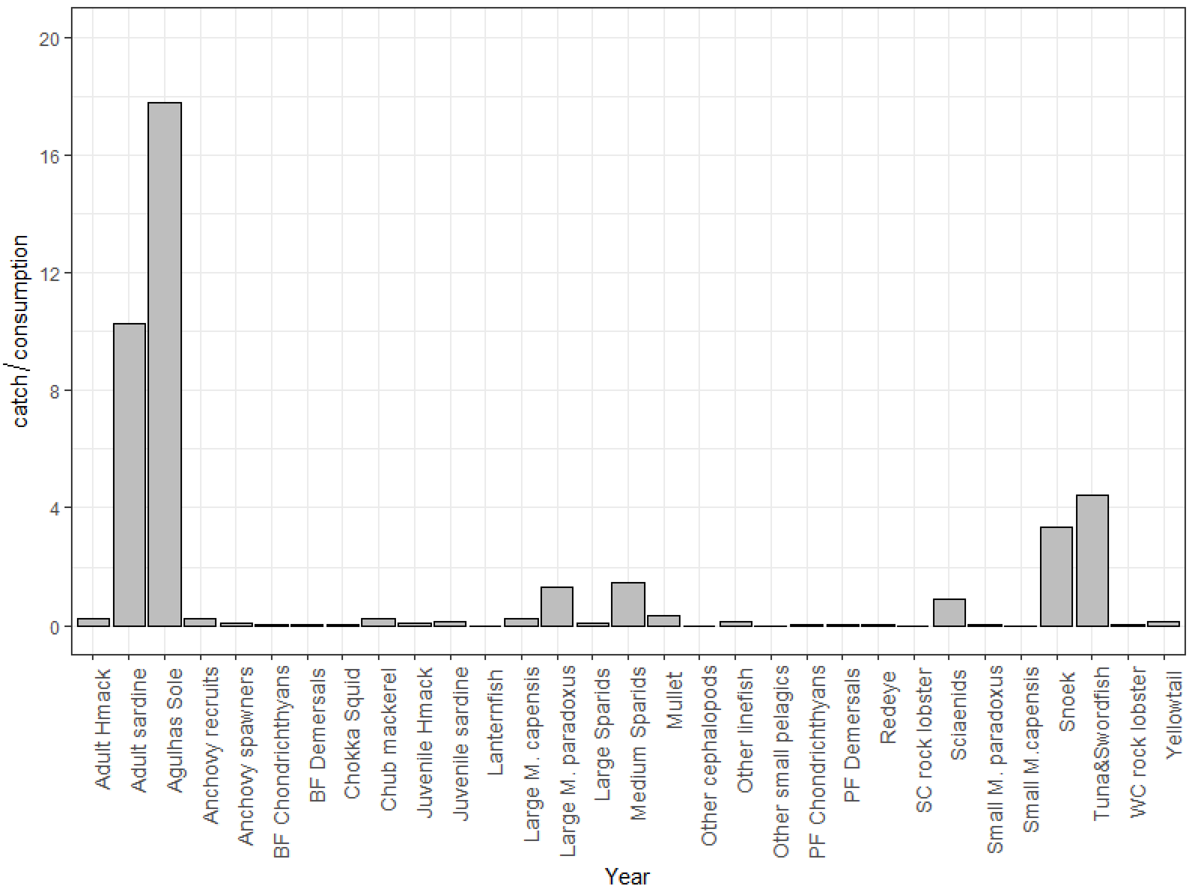

Figure S2. Plots of the ratio of catch ($t.km^{-2}.y^{-1}$) to consumption ($t.km^{-2}.y^{-1}$) of predators.

7 Model pedigree

Uncertainty around model parameters was captured by means of the Ecopath model pedigree (Table S7), where high precision is reflected in higher category numbers.

Table S7. Model pedigree indices from Ecopath. 10 represents the highest precision score, whereas -1 indicates pedigree estimation is not applicable. B=biomass ($t \cdot km^2$); P/B=production/biomass ($year^{-1}$); Q/B=consumption/biomass ($year^{-1}$).

	Group name	B	P/B	Q/B	Diet	Catch
1	Phytoplankton1	3	3	-1	-1	-1
2	Phytoplankton2	3	3	-1	-1	-1
3	Microzooplankton	1	4	4	3	-1
4	Mesozooplankton	1	4	4	5	-1
5	Macrozooplankton	1	4	4	5	-1
6	Gelatinous Zooplankton	2	4	4	3	-1
7	Anchovy recruits	6	8	8	6	4
8	Anchovy spawners	6	8	8	6	4
9	Juvenile sardine	6	8	8	6	4
10	Adult sardine	6	8	8	6	4
11	Redeye	5	3	3	6	4
12	Other small pelagics	1	3	3	1	4
13	Juvenile Hmack	5	3	3	4	4

14	Adult Hmack	5	3	3	4	4
15	Chub mackerel	2	3	3	3	4
16	Lanternfish	1	3	3	6	4
17	Lightfish	1	3	3	6	-1
18	Snoek	1	3	3	5	4
19	Tuna & Swordfish	1	3	3	3	4
20	Large Sparids	1	3	3	3	4
21	Medium Sparids	1	3	3	3	4
22	Sciaenids	1	3	3	3	4
23	Yellowtail	1	3	3	3	4
24	Other linefish	1	3	3	1	4
25	Mullet	1	3	3	3	4
26	Chokka Squid	5	3	3	4	4
27	Other cephalopods	3	3	3	3	4
28	Small *M.capensis*	4	3	3	5	4
29	Large *M. capensis*	5	3	3	5	4
30	Small *M. paradoxus*	4	3	3	5	4
31	Large *M. paradoxus*	5	3	3	5	4
32	PF Demersals	1	3	3	1	4
33	BF Demersals	1	3	3	1	4
34	Agulhas Sole	5	3	3	1	4
35	PF Chondrichthyans	1	3	3	1	4
36	BF Chondrichthyans	1	3	3	1	4
37	Apex Chondrichthyans	3	3	3	1	-1
38	Seals	4	4	4	5	2
39	Cetaceans	1	3	3	3	-1
40	African Penguin	6	8	8	6	-1
41	Cape Gannet	6	8	8	6	-1
42	Cape Cormorant	6	8	8	6	-1
43	Other seabirds	5	4	4	5	-1
44	Benthic Producers	1	3	-1	-1	-1
45	Meiobenthos	1	3	3	1	-1
46	Macrobenthos	1	3	3	1	-1
47	WC rock lobster	3	4	4	1	4
48	SC rock lobster	1	5	5	1	4

8 Weighting of time series explored in model fitting scenarios

A series of different weighting strategies were explored (Table S8) and fitting results per scenario reported in the main text (Table 3).

Table S8. Weighting values applied to data series. X indicates the time series was not used in the fitting scenario. For details of data time series, see Table S5.

	0	1	2	3	4	5	6
Anchovy Nov B	X	X	X	X	X	X	X

Sardine Nov B	X	X	X	X	X	X	X
Redeye Nov B	1	1	5	3	3	3	3
Juv hmack Nov B	1	1	5	3	3	3	3
Anch May recruit B	1	1000	6	5	5	5	5
Sard May recruit B	1	500	6	5	5	5	5
Lanternfish B	1	1	1	1	1	1	1
Lightfish B	1	1	1	1	1	1	1
Anch catch	1	1	4	10	10	10	10
Sard catch	1	1	4	10	10	10	10
Juv hmack catch	1	1	4	10	10	10	10
Chub catch purse seine	1	1	1	10	10	10	10
Redeye catch	1	1	4	10	10	10	10
Lanternfish catch	1	1	4	10	10	10	10
Chub WC B	1	1	4	1	1	X	1
Chub Sc B	1	1	2	1	X	1	1
Penguin breeders	1	10000	6	5	5	5	5
Gannet breeders	1	1	6	5	5	5	5
Gannet Z Lambert's	1	1	1	1	1	1	1
Gannet Z Malgas	1	1	1	1	1	1	1
Gannet Z Bird	1	1	1	1	1	1	1
AP Z Dassen	1	1	1	1	1	1	1
AP Z Robben	1	1	1	1	1	1	1
Total Squid catch	1	1	4	10	10	10	10
Squid SC B	1	1	5	2	2	2	2
Catch of hmack in trawls combined	1	1	4	10	10	10	10
Hmack WC B	1	1	5	3	3	X	3
Hmack SC B	1	1	5	3	X	3	3
M. paradoxus modelled SPB Female	1	1000	5	10	10	10	10
M. capensis modelled SPB female	1	1000	5	10	10	10	10
M. paradoxus catch	1	1	4	10	10	10	10
M. capensis catch	1	1	4	10	10	10	10
M. paradoxus modelled recruitment (aged 0)	1	1000	4	10	10	10	10
M. capensis modelled recruitment (aged 0)	1	1000	4	10	10	10	10
Sole catch	1	1	4	10	10	10	10
Sole B	1	1	5	3	3	3	3
Sum PF	1	1	1	2	2	2	2
Sum BF	1	1	1	2	2	2	2
Thunnus alalunga cpue	1	1	1	1	1	1	4
Tuna & Swordfish catch	1	1	1	1	1	1	1
WCRL catches (tons)	1	1	1	1	1	1	1
Large Sparids cpue WC	1	1000	1	1	1	X	4

Medium Sparids cpue WC	1	1000	1	1	1	X	4
Sciaenids cpue WC	1	1000	1	1	1	X	4
Sharks & Rays cpue WC	1	1000	1	1	1	X	4
Snoek cpue WC	1	1000	1	1	1	X	4
Yellowtails cpue WC	1	1000	1	1	1	1	4
Large Sparids cpue SC	1	1000	1	1	X	1	4
Medium Sparids cpue SC	1	1000	1	1	X	1	4
Sciaenids cpue SC	1	1000	1	1	X	1	4
Sharks & Rays cpue SC	1	1000	1	1	X	1	4
Anchovy model predicted November total biomass (in '000t)	1	10000	6	10	10	10	10
Anchovy harvest proportion	1	1	1	1	1	1	1
Sardine west component model predicted November recruitment (in billions)	X	X	X	X	X	X	X
Sardine south component model predicted November recruitment (in billions)	X	X	X	X	X	X	X
Sardine west component model predicted November total biomass	X	X	X	X	10	X	X
Sardine south component model predicted November total biomass	X	X	X	X	X	10	X
Sardine (west+south) model predicted November total biomass	1	10000	6	10	X	X	10
Sardine west component harvest proportion	X	X	X	X	1	X	X
Sardine south component harvest proportion	X	X	X	X	X	1	X
Sardine total (west+south) harvest proportion	1	1	1	1	X	X	1
PF demersal catch	1	1	3	10	10	10	10
BF demersal catch	1	1	3	10	10	10	10
relative jig effort	1	1	1	10	10	10	10
Hmack Midwater trawl scaled to invoke fishery of 7480t midwt SA catch in 2000	1	1	2	10	10	10	10
M. par off tr effort WC scaled to 1	1	1	4	10	10	X	10

M. par off tr effort SC scaled to 1	1	1	4	10	X	10	10
M. cap off tr effort WC scaled to 1	1	1	4	10	10	X	10
M. cap off tr effort SC scaled to 1	1	1	4	10	X	10	10
Sole effort scaled to 1	1	1	4	10	10	10	10
Large Sparids Effort WC	1	1	1	10	10	X	10
Medium Sparids Effort WC	1	1	1	10	10	X	10
Sciaenids Effort WC	1	1	1	10	10	X	10
Sharks & Rays Effort WC	1	1	1	10	10	X	10
Snoek Effort WC	1	1	1	10	10	X	10
Tuna & Billfish	1	1	1	10	10	X	10
Yellowtail Effort WC	1	1	1	10	10	X	10
Large Sparids Effort SC	1	1	1	10	X	10	10
Medium Sparids Effort SC	1	1	1	10	X	10	10
Sciaenids Effort SC	1	1	1	10	X	10	10
Sharks & Rays Effort SC	1	1	1	10	X	10	10

9 Exploring model fits to data series across scenarios by means of correlations

Table S9. % change in positive correlations of model predicted versus observed time series data from ***scenario 2*** (equally-weighted time series, upwelling anomaly forcing large phytoplankton) to the ***preferred scenario*** (Table S7 and Table 3); in the preferred scenario, the proportion of sardine biomass surveyed on the west coast in November is used as a forcing function to alter availability of sardine as prey to all predators. *cpue*=catch per unit effort.

Observed data series	Model predicted series	Correlation coefficient in scenario 2	Correlation coefficient in preferred scenario correlation	% change in correlation from scenario 2 to preferred
Anchovy May recruit survey biomass	Anchovy recruit biomass	0.275	0.340	+24
Sardine May recruit survey biomass	Sardine recruit biomass	0.284	0.303	+7
Penguin breeding pairs	Penguin biomass	0.021	0.216	Order of magnitude increase
Gannet breeding pairs	Gannet biomass	0.809	0.751	-7
Stock-assessment model-predicted anchovy November biomass	Adult anchovy biomass	0.294	0.402	+37

Stock-assessment model-predicted sardine November biomass	Adult sardine biomass	0.576	0.714	+24
Stock assessment model-predicted biomass of female *M. paradoxus* spawners	Adult *M. paradoxus* biomass	0.094	0.247	Order of magnitude increase
Stock assessment model-predicted biomass of female *M. capensis* spawners	Adult *M. capensis* biomass	-0.237	0.320	>100
Large sparid *cpue* on the west coast	Large sparid biomass	0.314	0.532	+69
Medium sparid *cpue* on the west coast	Medium sparid biomass	0.198	0.292	+47
Sciaenid *cpue* on the west coast	Sciaenid biomass	0.313	0.684	>100
Sharks & rays *cpue* on the west coast	Pelagic-feeding chondrichthyans	0.150	0.084	-44
Snoek *cpue* on the west coast	Snoek biomass	0.551	0.626	+14
Yellowtail *cpue* on the west coast	Yellowtail biomass	0.439	0.299	-32
Large sparid *cpue* on the south coast	Large sparid biomass	0.213	0.394	+85
Medium sparid *cpue* on the south coast	Medium sparid biomass	0.347	0.206	-41
Sciaenid *cpue* on the south coast	Sciaenid biomass	0.725	0.564	-22
Sharks & rays *cpue* on the south coast	Benthic-feeding chondrichthyans	0.689	0.242	-65

Table S10. % change in positive correlations of model predicted versus observed time series data from ***scenarios 5 to 6*** (Table 3); in scenario 6, the proportion of sardine biomass surveyed on the west coast in November is used as a forcing function to alter availability of sardine as prey to all predators. *cpue*=catch per unit effort.

Observed data series	Model predicted series	Correlation coefficient in scenario 5	% change in correlation from ***scenario 5*** to ***scenario 6***
Anchovy May recruit survey biomass	Anchovy recruit biomass	0.547	-8
Sardine May recruit survey biomass	Sardine recruit biomass	0.332	+7
Penguin breeding pairs	Penguin biomass	0.477	+39
Gannet breeding pairs	Gannet biomass	0.625	-67

Stock-assessment model-predicted anchovy November biomass	Adult anchovy biomass	0.772	+4
Stock-assessment model-predicted sardine November biomass	Adult sardine biomass	0.824	-36
Stock assessment model-predicted biomass of female *M. paradoxus* spawners	Adult *M. paradoxus* biomass	0.140	+80
Large sparid *cpue* on the west coast	Large sparid biomass	0.443	-5
Medium sparid *cpue* on the west coast	Medium sparid biomass	0.350	+11
Sciaenid *cpue* on the west coast	Sciaenid biomass	0.410	-63
Snoek *cpue* on the west coast	Snoek biomass	0.561	-15
Yellowtail *cpue* on the west coast	Yellowtail biomass	0.271	+71
Large sparid *cpue* on the south coast	Large sparid biomass	0.346	-12
Medium sparid *cpue* on the south coast	Medium sparid biomass	0.492	+8
Sciaenid *cpue* on the south coast	Sciaenid biomass	0.441	-60

Table S11. % change in positive correlations of model predicted versus observed time series data from ***scenario 12*** and ***scenario 13*** (below and Table 3) to the ***preferred scenario*** (see Table S9 and Table 3); in all three scenarios tabulated, the proportion of sardine biomass modelled from surveys on the west coast in November is used as a forcing function to alter availability of sardine as prey to all predators; in ***scenario 12***, the proportion of anchovy biomass surveyed on the west coast in November is used as an additional forcing function to alter availability of anchovy as prey to all predators. *Cpue* =catch per unit effort; in **scenario 13**, the latter forcing function applied to anchovy is replaced with one based on the Food Availability Index of Crawford et al. (2019), calculated from seabird diet data. Plots of model fits for scenario 12 and 13 are provided in Figure S3-6.

Observed data series	Model predicted series	Correlation coefficient in ***scenario 12***	% change in correlation: ***scenario 12*** relative to the ***preferred scenario***	Correlation coefficient in ***scenario 13***	% change in correlation: ***scenario 13*** relative to the ***preferred scenario***
Anchovy May recruit survey biomass	Anchovy recruit biomass	0.370	+9	0.244	-28
Sardine May recruit survey biomass	Sardine recruit biomass	0.388	+28	0.254	-16
Penguin breeding pairs	Penguin biomass	-0.684	Negative correlation	0.380	+76
Gannet breeding pairs	Gannet biomass	0.770	+3	0.817	+9
Stock-assessment model-predicted anchovy November biomass	Adult anchovy biomass	0.385	-4	0.375	-7
Stock-assessment model-predicted sardine November biomass	Adult sardine biomass	0.426	-40	0.571	-20
Stock assessment model-predicted biomass of female *M. paradoxus* spawners	Adult *M. paradoxus* biomass	0.193	-22	0.108	-56
Stock assessment model-predicted biomass of female *M. capensis*	Adult *M. capensis* biomass	-0.014	Negative correlation	0.312	-3
Large sparid *cpue* on the west coast	Large sparid biomass	0.281	-47	0.417	-22
Medium sparid *cpue* on the west coast	Medium sparid biomass	0.389	+33	0.280	-4

Sciaenid *cpue* on the west coast	Sciaenid biomass	-0.011	Negative correlation	0.415	-40
Snoek *cpue* on the west coast	Snoek biomass	0.682	+9	0.257	-59
Yellowtail *cpue* on the west coast	Yellowtail biomass	0.667	+123	-0.501	Negative correlation
Large sparid *cpue* on the south coast	Large sparid biomass	0.084	-79	0.198	-50
Medium sparid *cpue* on the south coast	Medium sparid biomass	0.458	+122	0.362	+76
Sciaenid *cpue* on the south coast	Sciaenid biomass	0.386	-32	0.171	-70
Sharks & rays *cpue* on the south coast	Benthic-feeding chondrichthyans	0.326	+35	0.534	+120

Table S12. Types of flow control (vulnerability parameter values, rounded to the nearest whole number; large numbers >10 000 are denoted by >>) estimated to improve fitting of the 1978 southern Benguela model to time series data that were equally weighted with no environmental forcing incorporated. The 40 most sensitive predator-prey interactions were identified for model-estimation of vulnerabilities. Interactions rounded to 1 indicate bottom-up flow control whereas interactions greater than 2 indicate top-down flow control characteristics. All other interactions assumed default vulnerabilities, set at 2.

	Prey \ predator	3	4	5	6	7	8	9	**10**	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Phytoplankton 1	2	2	2	2	2	2	2	**>>**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	Phytoplankton 2	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	Microzooplankton	2	2	2	2	>>	2	1	**1**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	Mesozooplankton	2	2	2	2	2	2	2	**14**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5	Macrozooplankton	2	2	2	2	2	>>	2	**>>**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
6	Gelatinous Zooplankton	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7	Anchovy recruits	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
8	Anchovy spawners	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
9	Juvenile sardine	2	2	2	2	2	2	2	**2**	2	2	2	>>	>>	2	2	>>	2	2	2	1	>>	2	2	2	>>
10	Adult sardine	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	>>	2	2	2	2	2	2	2	2
11	Redeye	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
12	Other small pelagics	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

13	Juvenile Hmack	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Adult Hmack	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
15	Chub mackerel	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
16	Lanternfish	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
17	Lightfish	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
18	Snoek	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
19	Tuna&Swordfish	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
20	Large Sparids	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
21	Medium Sparids	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
22	Sciaenids	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
23	Yellowtail	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2
24	Other linefish	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
25	Mullet	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
26	Chokka Squid	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
27	Other cephalopods	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
28	Small M.capensis	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
29	Large M. capensis	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
30	Small M. paradoxus	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
31	Large M. paradoxus	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
32	PF Demersals	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
33	BF Demersals	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
34	Agulhas Sole	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
35	PF Chondrichthyans	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
36	BF Chondrichthyans	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
37	Apex Chondricthyans	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
38	Seals	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
39	Cetaceans	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
40	African Penguin	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
41	Cape Gannet	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

42	Cape Cormorant	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
43	Other seabirds	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
44	Benthic Producers	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
45	Meiobenthos	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
46	Macrobenthos	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
47	WC rock lobster	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	>>
48	SC rock lobster	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
49	Detritus	2	2	2	2	2	2	2	**2**	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Continued

	Prey \ predator	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	45	46	47	48
1	Phytoplankton 1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	Phytoplankton 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	Microzooplankton	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
4	Mesozooplankton	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
5	Macrozooplankton	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
6	Gelatinous Zooplankton	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
7	Anchovy recruits	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
8	Anchovy spawners	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
9	Juvenile sardine	>>	2	>>	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2	2
10	Adult sardine	2	2	2	2	2	2	2	>>	2	2	2	1	1	1	2	1	2	2	2	2
11	Redeye	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
12	Other small pelagics	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
13	Juvenile Hmack	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
14	Adult Hmack	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
15	Chub mackerel	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
16	Lanternfish	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
17	Lightfish	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
18	Snoek	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

19	Tuna & Swordfish	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
20	Large Sparids	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
21	Medium Sparids	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
22	Sciaenids	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
23	Yellowtail	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
24	Other linefish	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
25	Mullet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
26	Chokka Squid	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
27	Other cephalopods	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
28	Small M.capensis	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
29	Large M. capensis	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
30	Small M. paradoxus	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
31	Large M. paradoxus	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
32	PF Demersals	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
33	BF Demersals	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2
34	Agulhas Sole	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
35	PF Chondrichthyans	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
36	BF Chondrichthyans	2	2	2	2	2	2	2	2	1	>>	2	2	2	2	2	2	2	2	2	2
37	Apex Chondricthyans	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
38	Seals	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2
39	Cetaceans	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
40	African Penguin	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
41	Cape Gannet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
42	Cape Cormorant	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
43	Other seabirds	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
44	Benthic Producers	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	>>	2
45	Meiobenthos	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
46	Macrobenthos	2	2	2	2	2	2	1	2	621	2	2	2	2	2	2	2	2	2	1	2
47	WC rock lobster	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	>>	2	2	2	2

48	SC rock lobster	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
49	Detritus	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2

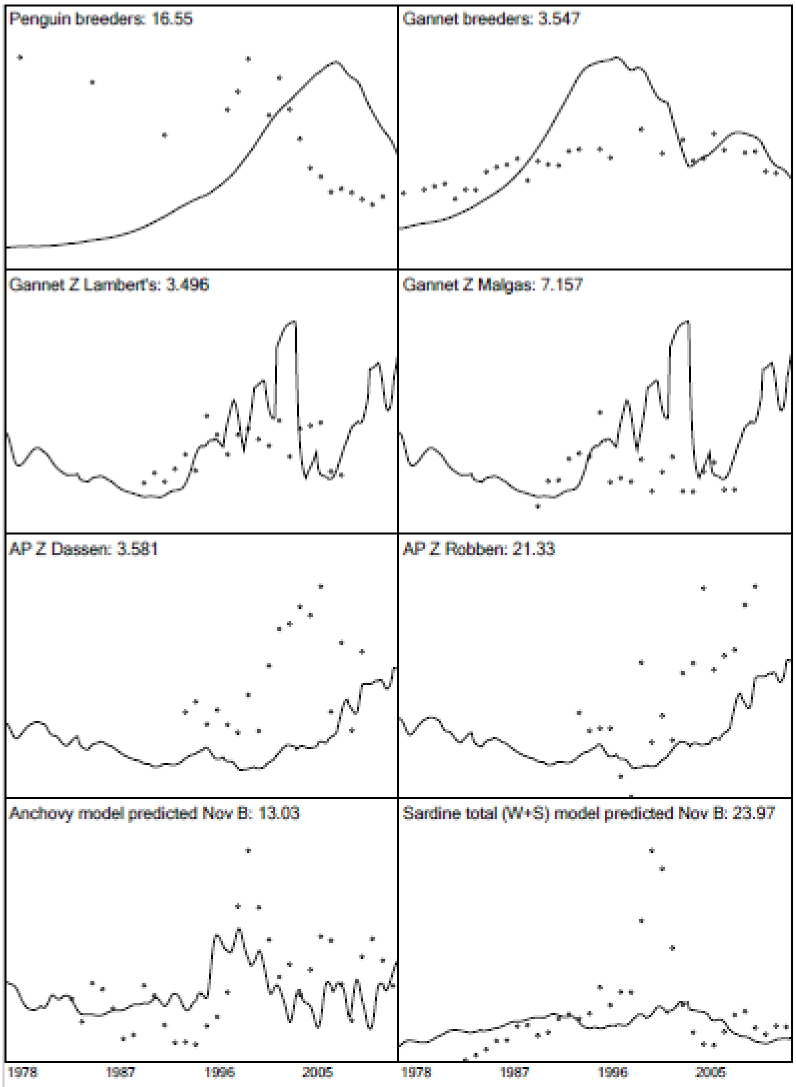

Figure S3. Model fits of anchovy, sardine and African penguins in model fitting scenario 12 in which both anchovy and sardine west coast proportions are incorporated in model fitting attempts (see Table 3 for details of the scenario). The contribution of each group to model sum of squares is provided on the plots.

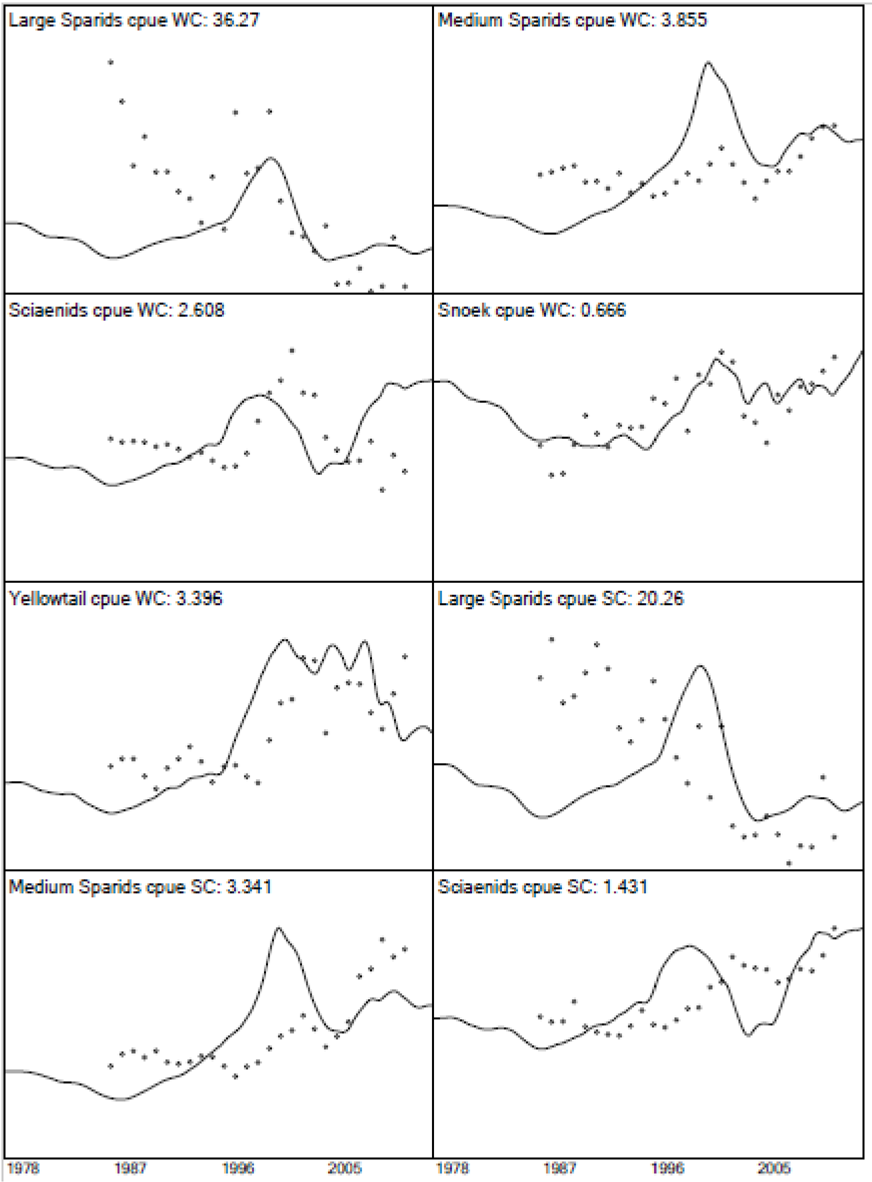

Figure S4. Model fits of key linefish groups in model fitting scenario 12 in which both anchovy and sardine west coast proportions are incorporated in model fitting attempts (see Table 3 for details of the scenario). The contribution of each group to model sum of squares is provided on the plots.

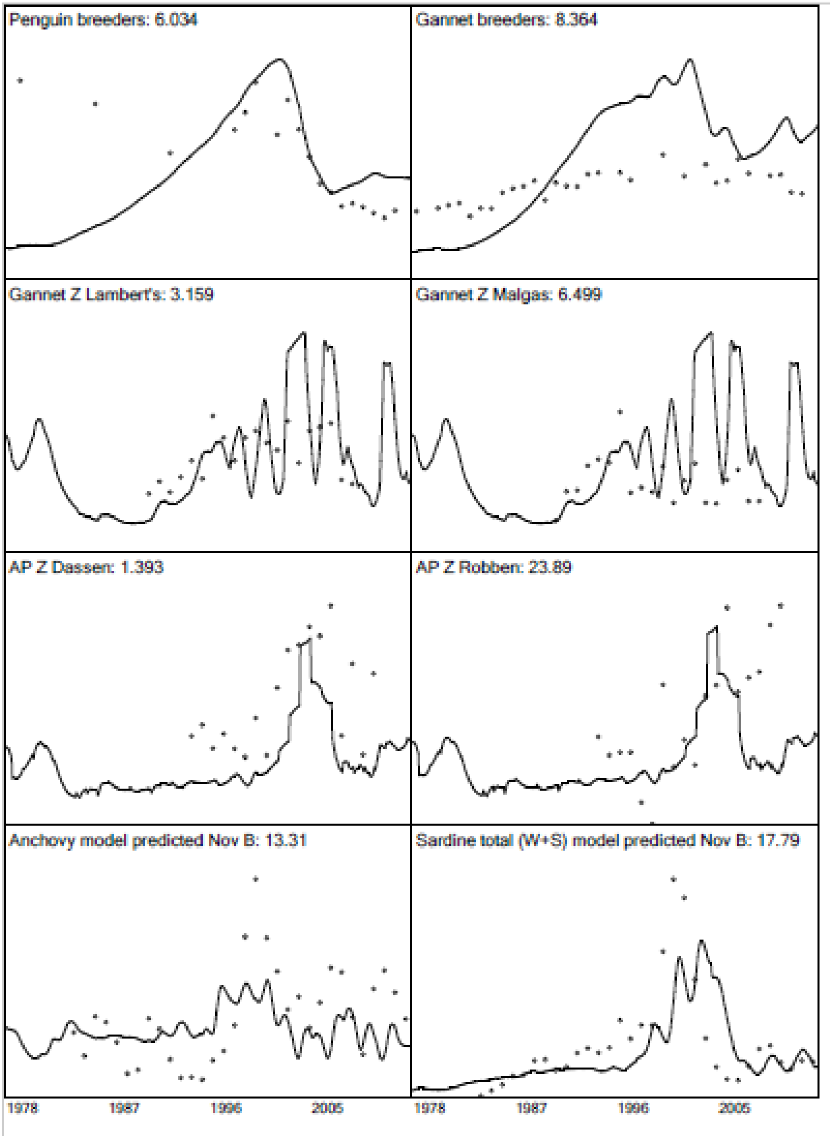

Figure S5. Model fits of anchovy, sardine and African penguins in model fitting scenario 13 in which sardine west coast proportion and Crawford et al.'s (2019) Food Availability Index are incorporated into model fitting attempts (see Table 3 for details of the scenario). The contribution of each group to model sum of squares is provided on the plots.

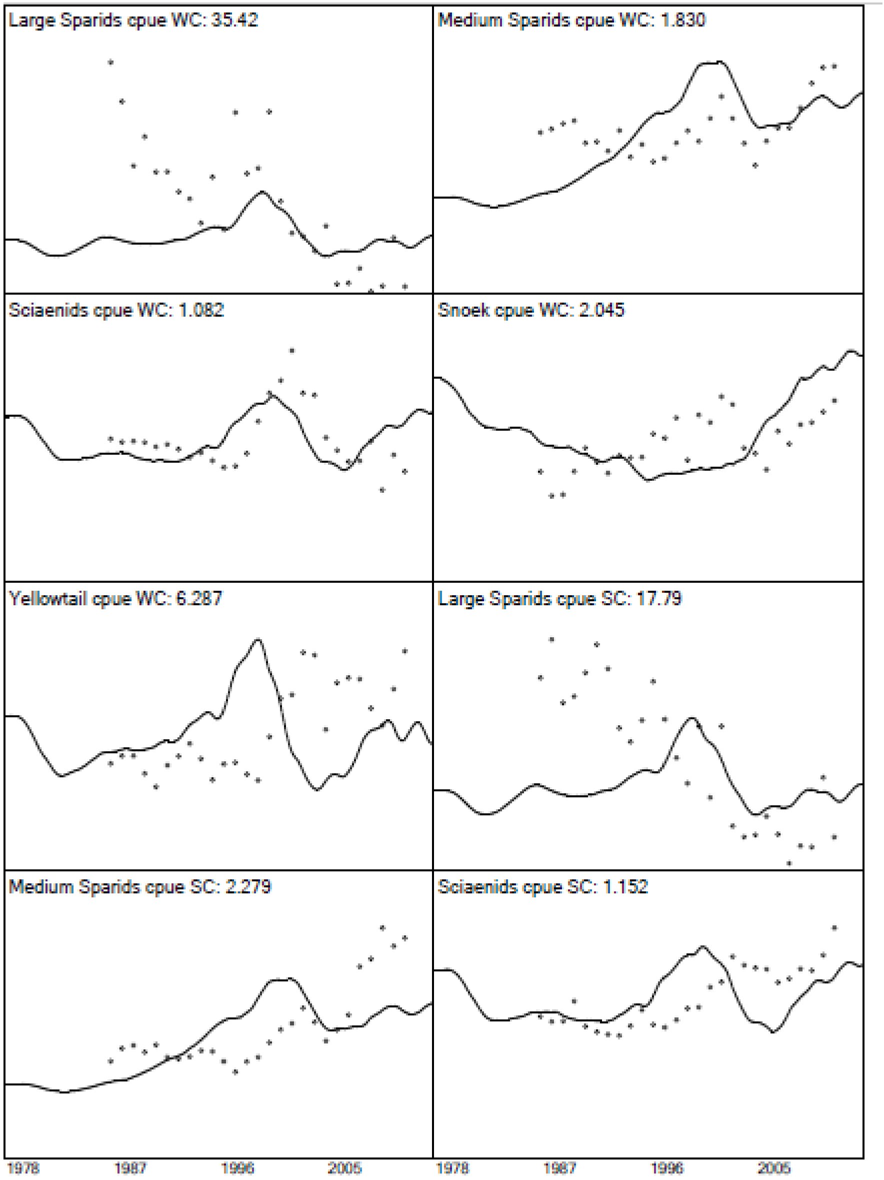

Figure S6. Model fits of key linefish groups in model fitting scenario 13 in which sardine west coast proportion and Crawford et al.'s (2019) Food Availability Index are incorporated into model fitting attempts (see Table 3 for details of the scenario). The contribution of each group to model sum of squares is provided on the plots.

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