APPENDIX 3. Ecosystem modelling: Ecopath model

Ecosystem models attempt to represent ecological systems by quantifying interactions among the ecosystem components, from individual populations to communities and even entire biomes. Among the variety of ecosystem models, Ecopath with Ecosim (EwE), an energy balance model, has been widely applied to inform ecosystem-based management (e.g. Plaganyi and Butterworth year); climate change impacts (e.g. Brown, *et al*., 2010); fishing impacts (e.g. Lozano-Montes *et al.,* 2013), spatial closures (e.g. Lozano-Montes *et al*., 2012); artificial reefs (e.g. Wu *et al*., 2016), and aquaculture impacts (e.g. Han *et al.,* 2017) since its development in 1980s (Polovina, 1984). The EwE software is the most applied tool for modelling marine and aquatic systems globally, with over 800 models published (www.Ecopath.org). Ecopath focuses on trophic interactions and is used more for understanding of whole food webs than individual components of the system. Other models are used for understanding the dynamics of components of an ecosystem, e.g. phytoplankton and biogeochemical models.

In this study, the Ecopath model will be used to assess interactions between different functional groups, including intra- and inter-specific competition and predation of fish (including target fished species) and other species of high conservation and community interest (e.g., Australian Sea Lion, Bottle-nose Dolphin, sharks, Little Penguin, and migratory sea birds). The EwE model developed in this 12-month project provides the quantitative basis needed to explore solutions to manage current and future risks (termed management strategy evaluation), including a better understanding of ecological flow-on effects from impacts associated with port development and climate change in Cockburn Sound. This research would be the focus for future research that is currently not funded.

Objectives

- Characterise the trophic structure, key ecosystem attributes and overall functioning of the Cockburn Sound ecosystem
- Integrate data from other themes into a quantitative ecosystem model to support a synthesis of current knowledge of ecological and ecosystem processes in Cockburn Sound.

Study area

The model developed in this study covers a total area of about 260 km^2 (Fig. 1). The model represents the food web of the key commercial species, key recreational species, key conservation species, demersal and pelagic fish assembles, invertebrates and primary producers of the embayment of Cockburn Sound ecosystem in the depth range from 0 and 20 m.

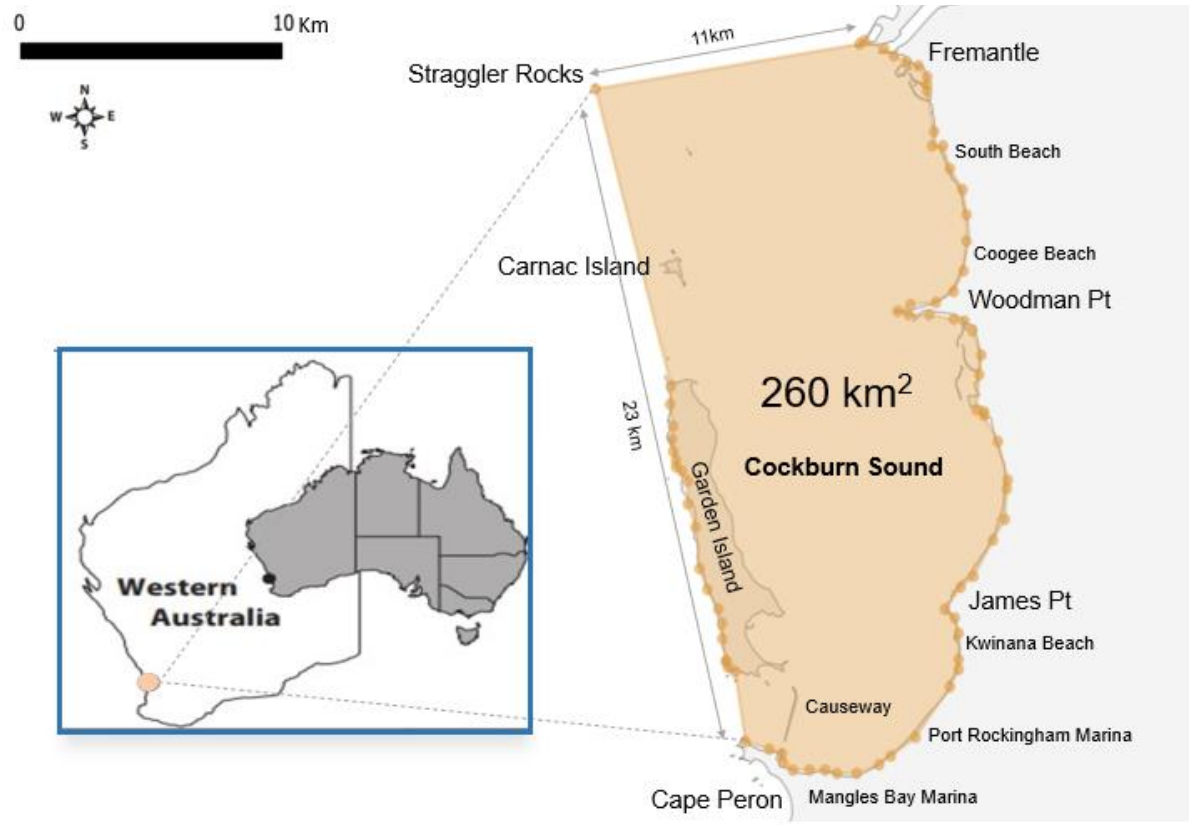

Figure 1. The Model domain for the Ecopath Cockburn Sound model in south-western Australia. The domain extends from Cockburn Sound to Owen Anchorage and covers 260 km^2.

The model

The food web of the Ecopath model is based on two equations describing production and energy balance for each of the 74 functional groups included in the model:

Eq (1): *Production = catch + predation mortality + biomass accumulation + net migration + other mortality,*

Eq (2): *Consumption = production + respiration + unassimilated food.*

Ecopath also calculates:

production utilized = catch + consumption by predators,

or mathematically,

$$B_i(PB^{-1})_i EE_i - \sum_{j=1}^{n} B_j(QB^{-1})_j DC_{ij} - Y_i - E_i - BA_i = 0 \qquad 1.$$

where:

B_i is the biomass of functional group *i*;

PB^{-1}_i is production/biomass ratio and can generally be input as total mortality rate (*Z)*;

EE_i is the ecotrophic efficiency defined as the proportion of production of *i* that is utilized in the system;

B_j is biomass of predator *j*;

QB^{-1}_j is consumption rate for predator *j*;

DC_{ij} is the fraction of group *i* in the diet of predator *j*;

Y_i is the total fishery catch of group *i*;

E_i is the net migration of group *i* (emigration-immigration); and

BA_i is the biomass accumulation rate.

To parameterize the model, estimates for three of the four terms, *B*, PB^{-1}, QB^{-1} or *EE*, must be supplied. If all four of the terms are entered, biomass accumulation or net migration can be estimated. Also required are data on diet composition, assimilation rates, net migration, catches, and biomass accumulation, the last three of which may be zero. The period that our model represents is the early 2020s to estimate the ecosystem state and trophic flows for the current state of Cockburn Sound.

Model groups

The structure of the EwE model is largely subjective, and it was tailored to satisfy specific objectives and requirements of the investigation in this study. The Cockburn Sound ecosystem model contains 74 functional groups, including one non-living group (detritus) (Table 1). The Functional groups were identified based on discussions with experts, different interest groups and feedback from workshop one. These include species of significance to commercial and recreational fishing (e.g. Pink Snapper, Blue Swimmer Crab, Scaley Mackerel), those of conservation significance and those likely to be of ecological significance. The model also represents sharks (small, large and juveniles), Bottlenose dolphin, seabirds (Cormorants, pelicans, gulls, terns, migratory waders), Little Penguin, pelagic fishes (e.g. Skipjack Trevally, Mulloway, Australian Salmon), small pelagic fishes (e.g. Southern Garfish, Sandy Sprat, Pilchard, King George Whiting, Australian Herring), demersal fishes (Wrasses, soldiers, mullets, leatherjackets, boxfishes, flounders, pipefishes), invertebrates (Western King Prawns, cuttlefish, Western Octopus, sea cucumbers, black mussels), and plants (e.g. seagrass, macroalgae, macroalgal epiphytes and microphytobenthos). Because of its significance to commercial and recreational fisheries, Pink Snapper was split into three stanzas: Spawners (>560mm); pre-spawners (250-560mm); and coastal juveniles (60-250mm) to account for specific life history and traits that would affect their

specific growth, predation and fishing within the Sound. Also, two introduced species of concern for DPIRD are included in the model:" the carpet sea squirt" (*Didemnum vexillum*) and "Dead's man fingers" (*Codium fragile* subsp. *fragile*).

Table 1. The functional groups and species contained in the Ecopath model for Cockburn Sound.

Category	#	Ecological group	Representative taxa	Rationale
High commercial fishing species	1	Pink Snapper >560mm	*Chrysophrys auratus*	Commercial and Recreational fishing
	2	Blue Swimmer Crab	*Portunus armatus*	Commercial / conservation interest
	3	Scaly Mackerel	*Sardinella lemuru*	Commercial fishing
	4	Australian Herring	*Arripis georgianus*	Commercial / Recreational fishing
	5	Pilchard	*Sardinops neopilchardus*	Commecial fishing / baitfish
	6	Southern Garfish	*Hyporhamphus melanochir*	Commercial and Recreational fishing
	7	Other Garfishes	*Three-by-two (Hemiramphus robustus)* and other garfishes *(Hyporhamphus spp)*	Commercial and Recreational fishing
	8	Pikes	Long-finned Pike (*Dinolested lewini*), Snook (*Sphyraena novahollandiae*)	Commercial fishing
	9	Squids (Southern Calamari, southern bobtail calamari)	Southern calamari squid (*Sepioteuthis australis*), Southern Bobtail squid (*Euprymna tasmanica*)	Commercial and Recreational fishing
	10	Marray	*Etrumeus jacksoniensis*	Commercial fishing
	11	Butterfishes	*Western Butterfish (Pentapodus vitta),* other butterfishes *(Pampus* spp, *Peprilus* spp, *Stromateus* spp*)*	Commercial and recreational fishing
	12	Trevallies	*Pseudocaranx georgianus*	Commercial /Recreational fishing interest
	13	King George Whiting	*Sillaginodes punctata*	Commercial /Recreational fishing interest
	14	Yellowtail Scad	*Trachurus novaezelandiae*	Commercial fishing
	15	Western Australian Common Octopus	*Octopus djilba*	Commercial fishing
	16	Black mussel	*Mytilus* spp	Aquaculture
High recreational fishing species	17	Wrasses	western king wrasse *Coris auricularis* and brownspotted wrasse *Notolabrus parilus*	Recreational fishing interest
	18	Whiting species (non King George species)	Whiting *(Sillago spp)*	Recreational fishing interest
	19	Flounders and flatheads	Southern bluespotted flathead (*Pseudorhobus speculator*), rock flathead (*P. laevigatus*) and yellowtail flathead (*P. westraliae*) Smalltooth Flounder (*P. jenynsii*), Lefteye Flounder (*Arnoglosus* spp),	Recreational fishing interest
	20	Western Australian Salmon	*Arripis truttaceus*	Recreational fishing interest
	21	Mulloway	*Argyrosomus japonicus*	Conservation / Recreational fishing interest
	22	Western Australia Butterfish	*Pentapodus vitta*	Recreational fishing interest
	23	Western King Prawn	*Penaeus latisulcatus*	Recreational fishing interest
	24	Other crabs	Swimmer (*Portunus rugosus*), Four-lobed swimmer (*Thalamitas sima*)	Recreational fishing interest
High conservation species	25	Large sharks	*White (Carcharodon carcharias), Smooth Hammerhead shark (Shyrna zygaena), Tiger shark (Galeocerdo cuvier), Spinner shark (Carcharhinus brevipinna)*	Conservation interest
	26	Small sharks	*Port Jackson shark (Heterodontus portusjacksoni), Gummy shark (Mustelus antarticus), Wobbegong shark (Orectolobus maculatus)*	Conservation interest
	27	Shark juveniles	Port Jackson *(Heterodontus portusjacksoni),* Spinner *(Carcharhinus brevipinna)*	Conservation interest
	28	Bottlenose dolphin	*Tursiops aduncus*	Conservation interest
	29	Australian Pelican	*Pelecanus conspicillatus*	Conservation interest
	30	Gulls and Terns	Bridled Tern (*Onychoprion anaethetus*), Fairy Tern (*Sternula nereis*), Caspian Tern (*Hydroprogne caspia*), Crested Tern (*Thalasseus bergii*), Pacific Gull *(Larus pacificus*)	Conservation interest
	31	Migratory waders	Sanderling (*Calidris alba*), Grey plover (*Pluvialis squatarola*), Ruddy turnstone (*Arenaria interpres*), bar-tailed godwit (*Limosa lapponica*), Grey-tailed Tattler (*Tringa brevipes*)	Conservation interest
	32	Pink Snapper pre-spawner (250-560mm)	*Chrysophrys auratus*	Conservation interest
	33	Pink Snapper coastal juvenile (60-250mm)	*Chrysophrys auratus*	Conservation interest
	34	Pipefishes	*Smooth Pipefish (Lissocampus caudalis), Western Crested Pipefish (Mitotichthys meraculus)*	Aggregate group
	35	Sponges	*Tedania sp, Ciocalypta sp, Holopsamma sp, Leucosolenida sp, Tethya cf. Ingalli*	Conservation / Indicator species
	36	Australian Sea Lion	*Neophoca cinerea*	Conservation interest

Table 1. Continuation

Category	#	Ecological group	Representative taxa	Rationale
Sentinel Species (biological indicators)	37	Sea cucumbers	*Cercodema anceps, Colochirus quadrangularis*	Conservation / Indicator species
	38	Corals	Faviidae family	Conservation / primary production
	39	Little penguin	*Eudyptula minor*	Conservation interest
	40	Cormorants	Pied Cormorant (*Phalacrocorax varius*), Little Pied Cormorant (*Microcarbo melanoleucos*), Little Black Cormorant (*Phalacrocorax sulcirostris*)	Conservation interest
	41	Rays	Souther Eagle Ray (*Myliobatis australis*), Southern Fiddler Ray (*Trygonorrhia fasciata*), Sparseley-spotted syingaree (Urulophus paucimaculatus) and Rhinobatidae spp	Aggregate group
	42	Ascidians (sea squirts) and sea pens	Ascidian spp colonial *(Herdmania sp*), Ascidian spp solitary (*Herdmania spp*), Sea Pen (*Cavernularia* spp)	Aggregate group
	43	Infaunal polychaetes	*Sabella spallanzanii*	Aggregate group
	44	Introduced species	Dead's man fingers *(Codium fragile subsp. Fragile), The* carpet sea squirt *(Didemnum vexillum)*	introduced species with potential to become invasive
	45	Rabbitfish	*Siganus sp*	Tropicalization of herbivore communities
	46	Phytoplankton	Chain-forming diatoms (e.g. Chaetoceros, Leptocylindrus), other diatoms (e.g. Nitzschia, Cylindrotheca, Rhizosolenia); dinoflagellates (e.g. Gymnodinioids)	Primary production
Other fishes	47	Western Stripped Grunter	*Helotes octolineatus*	Aggregate group
	48	Sea King fish juvenile	*Seriola hippos*	Aggregate group
	49	Blue Sprat	*Spratelloides robustus*	Aggregate group / baitfish
	50	Schooling species	Common Hardyhead (Atherinomorus vaigiensis), Australian anchovy (*Engraulis australis*),	Aggregate group
	51	Weedfish	Aedelaide weedfish *(Heteroclinus adelaidae),* weed-whiting *(Siphonognathus attenuatus), Southern Crested Weedfish (Cristiceps australis)*	Aggregate group
	52	Common Silverbelly	*Paraquula melbournensis*	Aggregate group
	53	Soldier	*Gymnapisters marmoratus*	Aggregate group
	54	Western Dragonet	*Pseudocalliurichthys goodladi*	Aggregate group
	55	Mullets	Yelloweye Mullet *(Aldrichetta forsteri),* Sea Mullet *(Mugil cephalus)*	Aggregate group
	56	Demersal fish	Bass Groper *(* Polyprion americanus), Western Foxfish *(Bodianus frenchii*); Western Blue Groper (*Achoerodus gouldii*), Little Gurnard Perch (*Maxillicosta scabriceps*)	Aggregate group / Minor recreational fishing interest
	57	Leatherjackets and boxfishes	Bridled leatherjack (Acanthaluters spilomelanurus), Rough leatherjack (Scobinichthys granulatus), Fanbelly Leatherjack (Monocanthus chinensis), Yellowstriped Leatherjacket (*Meuschenia flaviolineata*), Western Smooth Boxfish (*Anoplocapros amygdaloides*)	Aggregate group
	58	Sandy Sprat (White bait)	Hyperlophus vittatus	Aggregate group / baitfish
	59	Spiny Gurnard	*Lepidotrigla papilio*	Conservation / Aggregate group
	60	Australian Goatfish	*Upeneus australiae*	Aggregate group
Other invertebrates	61	Bivalves	*Musculista glaberrima, Dosinia incisas, Anomia trigonopsis, Circe sulcate,*	Aggregate group
	62	Cuttlefish	Bragg's (*Sepia braggi*), *Sepia novaehollandie*	Aggregate group
	63	Seastars	Seastar (*Astropecten preissi*), Seastar (*Stellaster inspinosus*), Seastar (*Ludia australiae*), Brittlestar (*Macrophiothrix spongicola*)	Aggregate group
	64	Mantis shrimp	*Belosquilla laevis*	Aggregate group
	65	Other prawns (velvet prawns)	Metapenaeopsis fusca, M. lindae, M. spp	Aggregate group
	66	Urchins	*Temnopleurus michaelseni*	Aggregate group
	67	Sea snails	*Astralium tentorium, Bedeva paive, Bulla botanica, Pervicacia* sp, *Vermetid* sp.	Aggregate group
Nekton	68	Zooplankton	Mainly calanoid copepods	Secondary production
	69	Planktotrophic larvae	Larval stages if fish and invertebrates	Secondary production
Primary producers	70	Seagrass	*Posidonia australis, P. sinuosa*	Conservation / Primary production
	71	Microphytobenthos	microscopic algae on the sediments	Primary production
	72	Macroalgal Epiphytes	Mainly crustose coralline algae and filamentous species of Rhodophyta on seagrass *P. sinuosa*	Conservation / Primary production
	73	Macroalage	*Ecklonia radiatea*	Primary production
Non-living	74	Detritus	Particulate (POM) and Dissolved (DOM) organic matter produced by the decomposition of organisms	Energy cycling

Biological data

Biomasses of fishes and invertebrates estimated from science surveys

Abundance and biomasses of fish and invertebrate communities in Cockburn Sound were obtained from WAMSI sampling of Cockburn Sound (small and large otter trawls, grab sampling, belt transects and rubble collection in 2021 and 2022) by Project 2.4 ("Benthic communities in soft-sediment and hard substrates", Prof. Glenn Hyndes, Dr James Tweedley) and Project 4.2.1 ("Spatial distribution of fish and invertebrates", Dr Danielle Johnston, Dr James Tweedley) are under processing and first season of sampling (November 2021 to March 2022) were delivered at the end of September 2022.

Production (P/B*) and consumption (Q/B) parameters*

The production/biomass (*P/B*) and consumption/biomass (*Q/B*) ratios (year^{-1}) are basic input parameters in EwE. In Ecopath, the *P/B* ratio (year $^{-1}$) for non-target species is equivalent to natural mortality rate (*M*). Unfortunately, the natural mortality rate of fish populations is one of the most difficult parameters to estimate. Direct estimates of *M* (e.g. from tagging studies) are usually difficult to obtain for most fish stocks. Numerous methods have been developed to get estimates of *M* from other more frequently available life history parameters. We used empirical estimators of natural mortality using the Shiny tool (a package of R) available on the website "Barefoot Ecologist's Toolbox" which employs various empirical estimators of natural mortality (http://barefootecologist.com.au/shiny_m.html). This website was originally developed Prince (2003) and further developed by Adrian Hordyk (Institute for the Oceans and Fisheries, University of British Columbia) and Jeremy Prince (Biospherics, Australia). Neil Loneragan has been an important collaborator in the development of the concept and web-based applications of the Barefoot Ecologist's Toolbox.

We select the estimates of *M* based on the von Bertalanffy growth parameters *K* and its relationships with water temperature as proposed by Jensen (1996, 1997) and recommended by Hasmel (2015). For fish species in aggregated groups, an overall *P/B* will be derived by the median value (Table 2). Natural mortality rates for lower trophic invertebrate groups were also obtained from empirical relationships proposed by Optiz (1996). For zooplankton, phytoplankton, macroalgae and seagrass we used parameters of *P/B* (years^{-1}) from the temperate food web model of Jurien Bay (Western Australia) reported by Loneragan *et al*. (2010). The estimates of food consumption rates (*Q/B*, year $^{-1}$) for most fish and invertebrate groups were obtained from empirical equations proposed in Pauly *et al*. (1993); Palomares and Pauly (1998), Optiz (1996), Lasalle *et al*. (2012), and Hill *et al*. (2021). We used these empirical formulae as a proxy for consumption rates (Table 3).

Table 2. Growth and mortality estimates of fish for the Cockburn Sound Ecopath model. Food type: 1 = detritivore; 2 = herbivore; 3 = omnivore; 4 = carnivore.

Functional Group	Species	$L\infty$ (cm)	W_∞ (g)	K (year^{-1})	t_0 (years)	M year^{-1} (Jensen, 1996)	M year^{-1} (Palomares, 1998) at 20°C	F year^{-1}	Food type	Aspect Ratio	Q/B (year^{-1}) at 20°C
Large sharks	*Carcharodon carcharias* Great white shark	676	$2.07x10^6$	0.07	-1.07	0.081	0.09		4	1.6	1.2
	Sphyrna zygaena Smooth Hammerhead	525	$3.9x10^5$	0.07	-1.02	0.083	0.1		4	1.6	1.5
	Galeocerdo cuvier Tiger shark	575	$1.05x10^6$	0.09	-0.87	0.18	0.13		4	1.6	1.7
	Carcharhinus brevipinna Spinner shark	265	$1.29x10^5$	0.21	-0.45	0.289	0.31		4	1.6	2.9
Small sharks	*Heterodontus portusjacksoni* Port Jackson shark	173	$4.3x10^4$	0.06	-1.83	0.102	0.11		4	1.6	2.3
	Mustelus antarticus Gummy shark	202	$4.49x10^4$	0.12	-0.85	0.147	0.16		4	1.6	2.8
	Orectolobus maculatus Wobbegong shark	335	$9.66x10^4$	0.08	-1.13	0.089	0.1		4	1.6	3.1
Shark juveniles	*Heterodontus portusjacksoni* Port Jackson shark	60	760	1.39	-0.09	1.16	1.32		4	1.6	4.2
Rays and Shovelheads	*Myliobatis australis* Souther Eagle Ray	123.1	4.5x104	0.2	-0.48	0.29	0.31		4	1.6	2.8
	Trygonorrhia fasciata Southern Fiddler Ray	123.1	1.8x104	0.14	-0.83	0.203	0.23		4	1.6	5.9
	Urulophus paucimaculatus Sparseley-spotted syingaree	60	784	0.23	-0.6	0.291	0.33		4	1.6	6.4
Pink Snapper *Chrysophrys auratus*	Pink Snapper spawners (>560mm)	136.8	4.1x104	0.04	-2.96	0.082	0.09		3	1.32	2.7
	Pink Snapper pre-spawner (250-560mm)	56		0.26	-0.56	0.39	0.47		3	1.32	4.5
	Pink Snapper coastal juvenile (60-250mm)	25		1.06	-0.16	1.39	1.58		3	1.32	6.7
Wrasses	*Coris sandeyeri* King Wrasse	26.3	181	0.32	-0.54	0.48	0.52		3	1.32	17.9
	Notolabrus parilus Brown Spotted Wrasses	41.5	$1.02x10^3$	0.15	-1.05	0.31	0.34		3	1.32	13
Skipjack Trevally	*Pseudocaranx wrighti*	72.4	$3.07x10^3$	0.44	-0.25	0.47	0.58		2	6.55	4.4
Flounders and flatheads	*Pseudorhobus jenynsii* Smalltooth Flounder	35.6	444	0.48	-0.32	0.76	0.82		3	1.32	6.8
	Arnoglosus spp Lefteye Flounder	18	41	0.56	-0.29	0.81	0.86		3	1.32	11
	Inegocia japonica Rusty Flathead	36.6	361	0.32	-0.49	0.52	0.6		3	1.32	7.1
	Onigocia spinosa Midget Flathead	26.3	107	0.44	-0.39	0.84	0.92		3	1.32	1.5
Demersal fishes	*Polyprion americanus* Bass Groper	215	$1.5x10^5$	0.03	-3.52	0.04	0.06		3	1.32	2.1
	Bodianus frenchii Western Foxfish	47.6	$1.6x10^3$	0.06	-2.6	0.11	0.15		3	1.32	11.6
	Achoerodus gouldii Western Blue Groper	182.6	$1.29x10^5$	0.02	-5.61	0.034	0.05		3	1.32	2.1
	Maxillicosta scabriceps Little Gurnard Perch	12.8	21	0.85	-0.2	1.11	1.28		3	1.32	12.6
Australian Salmon	*Arripis trutta*	91.5	$1.03x10^3$	0.15	-0.84	0.22	0.27		3	1.9	15.5
Mulloway	*Argyrosomus japonicus*	136	$7.5x10^4$	0.16	-0.7	0.21	0.26		3	1.32	2.8

...

Table 2. Continued

Leatherjackets and Boxfishes	*Meuschenia flaviolineata* Yellowstriped Leatherjacket	31.5	312.6	0.34	-0.48	0.58	0.65	3	1.32	16
	Anoplocapros amygdaloides Western Smooth Boxfish	33.5	352	0.36	-0.37	0.56	0.65	3	1.32	16
Spiny Gurnard	*Lepidotrigla papilio*	21.1	93.9	0.53	-0.28	0.76	0.8	3	1.32	9.3
Longspine Dragonet	*Pseudocalliurichthys goodladi*	10.7	12.3	0.88	-0.2	1.13	1.38	3	1.32	31
Yellowtail Scad	*Trachurus novaezelandiae*	42	551	0.31	-0.49	0.44	0.47	3	1.9	4.7
Australian Goatfish	*Upeneus australiae*	16.9	86.1	0.57	-0.33	0.97	1.09	3	1.32	9.5
Scaly Mackerel	*Sardinella lemuru*	19.4	60	1.01	-0.18	1.82	1.99	3	1.9	22.4
Southern Garfish	*Hyporhamphus melanochir*	54	600	0.43	-0.24	0.83	0.9	3	1.9	17.9
Other Garfishes	three-by-two garfish *(Hemiramphus robustus), other garfish (* Hemiramphus *spp)*	31.5	359	0.66	-0.24	1.02	1.19	3	1.32	14.2
Pilchards	*Sardinops neopilchardus*	33.8	486	0.33	-0.49	0.73	0.78	3	1.9	26.6
Blue Sprat	*Spratelloides robustus*	12.8	21	0.57	-0.3	1.09	1.2	3	1.9	31
Maray	*Etrumeus jacksoniensis*	33	117	1.65	-0.1	1.97	2.13	3	1.9	20.2
Australian herring	*Arripis georgiana*	41	169	0.9	-0.19	0.69	0.72	3	1.9	20.3
Pikes	Longfin Pike (*Dinolestes lewini*), Snook (*Sphyraena novahollandiae*)	86.6	6495	0.17	-0.71	0.26	0.27	3	1.32	5
Sandy Sprat (White bait)	*Hyperlophus vittatus*	100	11.7	0.59	-0.3	0.92	0.97	3	1.9	16
Western Stripped Grunter	*Helotes octolineatus*	28	188	0.44	-0.39	0.79	0.83	3	1.32	17.4
Sea King Fish (juvenile)	*Seriola hippos*	80		0.94	-0.11	1.07	1.13	2	6.55	13.3
Whiting species (non King George species)	*Sillago* spp	21.5	250	0.26	-0.63	0.49	0.52	3	1.32	16.3
Weed-Whiting	*Siphonognathus attenuatus*	12.8	21	1.05	-0.19	1.64	1.85	3	1.32	26.3
Schooling species	*Engraulis australis* Australian anchovy	15	40	0.35	-0.38	0.87	0.91	3	1.32	24.4
	Atherinomorus vaigiensis Common Hardyhead	18	52	0.41	-0.39	0.77	0.81	3	1.32	10.2
Western Australia Butterfish	*Pentapodus vitta*	27.3	265	0.51	-0.33	0.71	0.86	2	1.9	16.6
Common Silverbelly	*Paraquula melbournensis*	23.2	124.9	0.66	-0.26	0.91	0.98	2	1.9	19.3
Soldier	*Gymnapisters marmoratus*	21.4	98	0.12	-1.58	0.28	0.33	2	1.32	9.2
Rabbitfish	*Siganus sp*	25	261	0.86	-0.2	1.52	1.66	2	1.32	38.7
Mullets	*Aldrichetta forsteri* Yelloweye Mullet	43	640	0.44	-0.34	0.69	0.73	3	1.9	23.9
Pipefishes	*Lissocampus caudalis* Smooth Pipefish	10.7	12.3	0.44	-0.41	0.77	0.82	3	1.32	31
	Mitotichthys meraculus Western Crested Pipefish	23.4	128	0.39	-0.38	0.71	0.78	3	1.32	19.2

Table 3. Basic input data and sources of information for the Cockburn Sound Ecopath model. Colour code represents the origin of the value and its percentage of confidence interval assigned as proposed by Christensen *et al.* (2000) as shown in Table 6.

		Biomass		*Production*		*Consumption*		Diets
	Group name	Biomass (t/km^2)	Reference	P/B ($Year^{-1}$)	Reference	Q/B ($Year^{-1}$)	Reference	Reference
1	Large sharks	0.054	Braccini. 2022	0.115	Jensen. 1996	16	Palomares and Pauly. 1998	Compagno et al 1998
2	Australian Sea Lion	0.0146	Osterrieder *et al*, 2015	0.08	Lasalle *et al*., 2012	40.69	Lasalle *et al*., 2012	Gales et al 1994
3	Bottlenose Dolphin	0.0823	Chabanne *et al*, 2017	0.08	Lasalle *et al*., 2012	21.67	Lasalle *et al*., 2012	https://australian.museum/learn/animals/mammals/bottlenose-dolphin/
4	Small sharks	0.0018	Braccini. 2022	0.11	Jensen. 1996	2.8	Palomares and Pauly. 1998	Compagno et al 1998
5	Cormorants	0.039	Rippey *et al*, 2002	0.09	Lasalle *et al*., 2012	57.66	Lasalle et al., 2012	https://australian.museum/learn/animals/birds/great-cormorant/
6	Little Penguin	0.0009	BMT, 2018	0.19	Hill *et al*., 2021	30.1	Hill *et al*., 2021	Preston et al., 2007
7	Australian Pelican			0.09	Lasalle *et al*., 2012	69.96	Lasalle *et al*., 2012	https://australian.museum/learn/animals/birds/australian-pelican/
8	Gulls and Terns	0.0106	Dunlop & Storr, 1981	0.14	Lasalle *et al*., 2012	69.96	Lasalle *et al*., 2012	https://australian.museum/learn/animals/birds/terns/
9	Migratory Waders	0.0001	Dunlop & Storr, 1981	0.18	Lasalle *et al*., 2012	42.3	Lasalle *et al*., 2012	Ingrid Tulp & Petra de Goeij.1994
10	Other seabirds			0.19	Lasalle *et al*., 2012	42.3	Lasalle *et al*., 2012	Ingrid Tulp & Petra de Goeij.1994
11	Rays and Shovelheads			0.31	Jensen. 1996	5.9	Palomares and Pauly. 1998	Last et al., 2016
12	Shark juveniles			1.32	Jensen. 1996	4.2	Palomares and Pauly. 1998	Compagno. 1984
13	Skipjack Trevally			0.32	Jensen. 1996	4.9	Palomares and Pauly. 1998	Platell et al. 2001
14	Mulloway			0.26	Jensen. 1996	2.8	Palomares and Pauly. 1998	Anonymous, 1993
15	Australian Salmon			0.27	Jensen. 1996	15.5	Palomares and Pauly. 1998	Paulin. 1993
16	Pink Snapper spawners (>560mm)			0.09	Jensen. 1996	2.7	Palomares and Pauly. 1998	Hayes. 1994
17	Pink Snapper pre-spawner (250-560mm)			0.47	Jensen. 1996	4.5	Palomares and Pauly. 1998	Clough. 2009
18	Pink Snapper coastal juvenile (60-250mm)			1.58	Jensen. 1996	6.7	Palomares and Pauly. 1998	Battaglene and Talbot. 1992
19	Yellowtail Scad			0.44	Jensen. 1996	4.7	Palomares and Pauly. 1998	May and Maxwell. 1986.
20	Wrasses			0.43	Jensen. 1996	15.45	Palomares and Pauly. 1998	Russell.1983
21	Flounders and Flatfishes			0.83	Jensen. 1996	9.5	Palomares and Pauly. 1998	Sainsbury et al., 1985
22	Western Stripped Grunter			0.83	Jensen. 1996	17.4	Palomares and Pauly. 1998	Paxton et al. 1989
23	Sea King Fish (juvenile)			1.13	Jensen. 1996	13.3	Palomares and Pauly. 1998	Paxton et al. 1989
24	Common Silverbelly			0.98	Jensen. 1996	19.3	Palomares and Pauly. 1998	Iwatsuki et al., 2012
25	Soldiers			0.33	Jensen. 1996	9.2	Palomares and Pauly. 1998	Scott et al., 1974
26	Western Dragonet			1.38	Jensen. 1996	31.5	Palomares and Pauly. 1998	Masuda et al., 1984
27	Mullets			0.73	Jensen. 1996	23.9	Palomares and Pauly. 1998	Kailola et al., 1993
28	Demersal fish			0.105	Jensen. 1996	6.85	Palomares and Pauly. 1998	Kuiter. 1993
29	Leatherjackets and Boxfishes			0.65	Jensen. 1996	16	Palomares and Pauly. 1998	Hoschke et al., 2019
30	Pipefishes			0.8	Jensen. 1996	25.1	Palomares and Pauly. 1998	Dawson. 1985
31	Buttlefishes			0.86	Jensen. 1996	16.6	Palomares and Pauly. 1998	Russell. 1990
32	Southern Garfish			0.9	Jensen. 1996	13.6	Palomares and Pauly. 1998	Kailola et al., 1993
33	Other Garfishes			1.02	Jensen. 1996	14.2	Palomares and Pauly. 1998	Kailola et al., 1993
34	Scaly Mackerel			1.99	Jensen. 1996	22.4	Palomares and Pauly. 1998	Whitehead.1985
35	Blue Sprat			1.2	Jensen. 1996	31	Palomares and Pauly. 1998	Whitehead.1985
36	Sandy Sprat (white bait)			0.96	Jensen. 1996	14.4	Palomares and Pauly. 1998	Whitehead.1985
37	Pilchard			0.78	Jensen. 1996	26.6	Palomares and Pauly. 1998	Matarese et al., 1989
38	Maray			1.97	Jensen. 1996	20.2	Palomares and Pauly. 1998	Whitehead and Rodriguez-Sanchez. 1995
39	Australian Herring			0.79	Jensen. 1996	20.3	Palomares and Pauly. 1998	Anonymous, 1988
40	King George Whiting			0.41	Jensen. 1996	11.4	Palomares and Pauly. 1998	Hyndes et al., 1997
41	Pikes			0.26	Jensen. 1996	5	Palomares and Pauly. 1998	Coleman and Mobley, 1984
42	Whiting Species (non King George spp)			0.52	Jensen. 1996	16.3	Palomares and Pauly. 1998	McKay.1992
43	Schooling species			0.86	Jensen. 1996	17.3	Palomares and Pauly. 1998	Whitehead et al., 1988
44	Spiny Gurnard			0.8	Jensen. 1996	9.3	Palomares and Pauly. 1998	Neira et al., 1998
45	Weedfish			1.85	Jensen. 1996	26.3	Palomares and Pauly. 1998	Hoese et al., 2006
46	Rabbitfish (*Siganus* sp)			1.52	Jensen. 1996	38.7	Palomares and Pauly. 1998	
47	Australian Goatfish			1.09	Jensen. 1996	9.5	Palomares and Pauly. 1998	Kim and Nakaya. 2002
48	Introduced species			2.3	Pauly *et al*., 1993	24	Pauly *et al*., 1993	Munoz and McDonald. 2014
49	Squid			0.84	Pauly *et al*., 1993	16.64	Pauly *et al*., 1993	Yeoh et al., 2021
50	Cuttlefish			0.84	Pauly *et al*., 1993	16.64	Pauly *et al*., 1993	Yeoh et al., 2021
51	Western Australian Octopus			1.1	Pauly *et al*., 1993	7.3	Pauly *et al*., 1993	https://fish.gov.au/report/414-Western-Rock-Octopus-2020
52	Blue Swimmer Crab			0.52	Hall. 2003	21.6	Pauly *et al*., 1993	Johnston et al., 2020
53	Other crabs			0.52	Hall. 2003	21.6	Pauly *et al*., 1993	Johnston et al., 2020
54	Western King Prawn			0.52	Pauly *et al*., 1993	28.94	Pauly *et al*., 1993	Anonimous. 2022
55	Other Prawns			7.57	Pauly *et al*., 1993	28.94	Pauly *et al*., 1993	Anonimous. 2022
56	Mantis shrimp			7.57	Pauly *et al*., 1993	28.94	Pauly *et al*., 1993	www.barrierreef.org/mantis_shrimp
57	Seastars			0.49	Optiz. 1996	3.24	Optiz. 1996	www.museum.wa.gov.au
58	Sea snails			3.9	Optiz. 1996	26.9	Optiz. 1996	www.museum.wa.gov.au
59	Urchins			7.51	Pauly *et al*., 1993	3.58	Pauly *et al*., 1993	www.museum.wa.gov.au
60	Black Mussels			2.23	Optiz. 1996	9.5	Optiz. 1996	www.museum.wa.gov.au
61	Infaunal Polychaetes			4.85	Pauly *et al*., 1993	24.2	Optiz. 1996	www.awe.gov.au
62	Corals			0.08	Optiz. 1996	3	Optiz. 1996	www.barrierreef.org/corals
63	Sea Cucumbers			4.45	Pauly *et al.*, 1993	3.83	Pauly *et al.*, 1993	Hart et al., 2018
64	Ascidians			2.3	Optiz. 1996	24	Optiz. 1996	Munoz and McDonald. 2014
65	Sponges			1.7	Optiz. 1996	4.2	Optiz. 1996	www.museum.wa.gov.au
66	Bivalves			1.35	Optiz. 1996	9	Optiz. 1996	www.museum.wa.gov.au
67	Planktotrophic larvae			3	Liew and Chan. 1987	12	Liew and Chan. 1987	Liew and Chan. 1987
68	Zooplankton			29.6	Loneragan *et al*., 2010	55	Loneragan *et al*., 2010	www.water.wa.gov.au
69	Phytoplankton			50.97	Loneragan *et al*., 2010			
70	Seagrass			7.3	Loneragan *et al*., 2010			
71	Macroalgae			2	Loneragan *et al*., 2010			
72	Macroalgal Epiphytes			2	Loneragan *et al*., 2010			
73	Microphytobenthos			706.5	Loneragan *et al*., 2010			
74	Detritus							

Diets

The diet composition matrix was assembled as percentage weight or volume of the annual fraction that each prey contributes to the overall diet of the predator (following the methodology recommended by Christensen *et al*., 2004, 2008). Wherever available, dietary information was taken from local studies on Cockburn Sound. As some data from Cockburn Sound were not available, data were taken for the relevant species from adjacent areas (e.g. Perth area, Jurien Bay), assuming that this would provide a reasonable approximation for the diet composition in Cockburn Sound. When no data were available locally, or in adjacent areas, diets were deduced from information on FishBase (Froese and Pauly, 2000). If no specific prey were identified, the aggregated diet group was re-apportioned across possible prey that would be available to the predator according to proportions in the diets of predators in the same functional group. The diet matrix assembled was reviewed by experts in the main components of the food web as shown in Table 4. EwE will use this diet matrix to estimate trophic interactions and predation rates based on Equations 1 and 2.

Table 4. Reviewers of the diet matrix of the EwE Cockburn Sound model.

Functional Groups	Diet matrix reviewer
Sharks and Rays	Matias Braccini (DPIRD)
Australian Sea Lion	Chandra Salgado-Kent (ECU)
Bottlenose Dolphin	Delphine Chabanne (Murdoch)
Little Penguin	Belinda Cannell (UWA)
Sea birds (Cormorants, pelicans, terns, waders)	Jeffrey Norris (DPIRD) Nic Dunlop (CCWA)
Pink Snapper (adults, pre-spawners, juveniles)	David Fairclough (DPIRD)
Pelagic fish (Mulloway, Skipjack trevally, Sea King fish)	Kurt Krispyn (Murdoch)
Small Pelagic fish (Scaly Mackerel, Blue Sprat, Sandy Sprat)	Jeffrey Norris (DPIRD)
Demersal fish (Mullets, Soldiers, Wrasses, Flounders)	Mitchell Haywood (Murdoch) Kurt Krispyn (Murdoch)
Squid and Cuttlefish	Daniel Yeoh (DPIRD)
Blue Swimmer Crab	Daniel Yeoh (DPIRD)
Invertebrates (crabs, prawns, urchins, seastars)	Daniel Yeoh (DPIRD) Sorcha Cronin-O'Reilly (Murdoch)

Fishery data

Commercial data

The ecosystem modelling project was introduced to fisheries researchers during a brief seminar at the Department of Primary Industries and Regional Development (DPIRD) on June 22nd, 2022. The seminar provided information on the background and methods of the study, and the data required to develop the models. This served as a basis for subsequent group discussions with fisheries experts to gain an in-depth understanding of commercially and recreationally targeted species and those of conservation significance. All available data specific to Cockburn Sound were discussed and provided in the form of resource assessment reports and total commercial catch and catch per unit effort (CPUE) summaries by fisheries researchers following the discussions.

Data on fishing method and gear type, total catch (kg) and CPUE, where available, were acquired for the main targeted species in Cockburn Sound. The fisheries operating within Cockburn Sound from which catches were obtained include the following fleets: the Cockburn Sound Crab Fishery, the Cockburn Sound Line and Pot Fishery, the Cockburn Sound Fish Net Fishery, and the Cockburn Sound Mussel Fishery.

Ecopath Catch statistics

Commercial catch values for the Ecopath with Ecosim (EwE) model were calculated using a three-year average annual total catch for species caught between 2019 and 2021, where available. The average annual catch value was divided by the area of the model domain (260 km^2) to convert catches to catch in tonnes per area per year – i.e. the standard unit for the EwE model (t/km^2/year) (Table 5). Recent catch statistics were not available for blue swimmer crabs, black mussels, and southern garfish. However, as they are commercially and recreationally important species, the most recent available catch values were used (Figure 2). Time series were built using available CPUE data to be used for the EwE model calibration.

Blue swimmer crab *(Portunus armatus)*

Total annual commercial catches from 2012, 2013 and 2014 (42,116 kg, 60,687kg and 21,859kg respectively) were used. The 3-year average annual total catch was 41.554 tonnes. This catch value was divided by the model domain (260 km^2) to estimate the total commercial catch 0.1598 t/km^2/year. Commercial operators captured crabs in Cockburn Sound using purpose designed “hourglass” crab traps when the fishery was operating. This commercial fishery has been closed since 2014.

Black mussel *(Mytilus spp.)*

The total commercial catch values for mussels were 12,464 kg in 2002, 0 kg in 2003 and 23,120 kg in 2004. The total average catch was estimated to be 0.0456 t/km^2/year.

Southern Sea Garfish *(Hyporhamphus melanochir)*

The most recent annual commercial catch statistics for the Southern Sea Garfish were from 2015 (1,721 kg), 2016 (2,066 kg) and 2017 (538 kg). The total annual garfish catch was estimated to be 0.0055 t/km^2/year. In Cockburn Sound, all garfish are taken with a 'garfish net' (hauling).

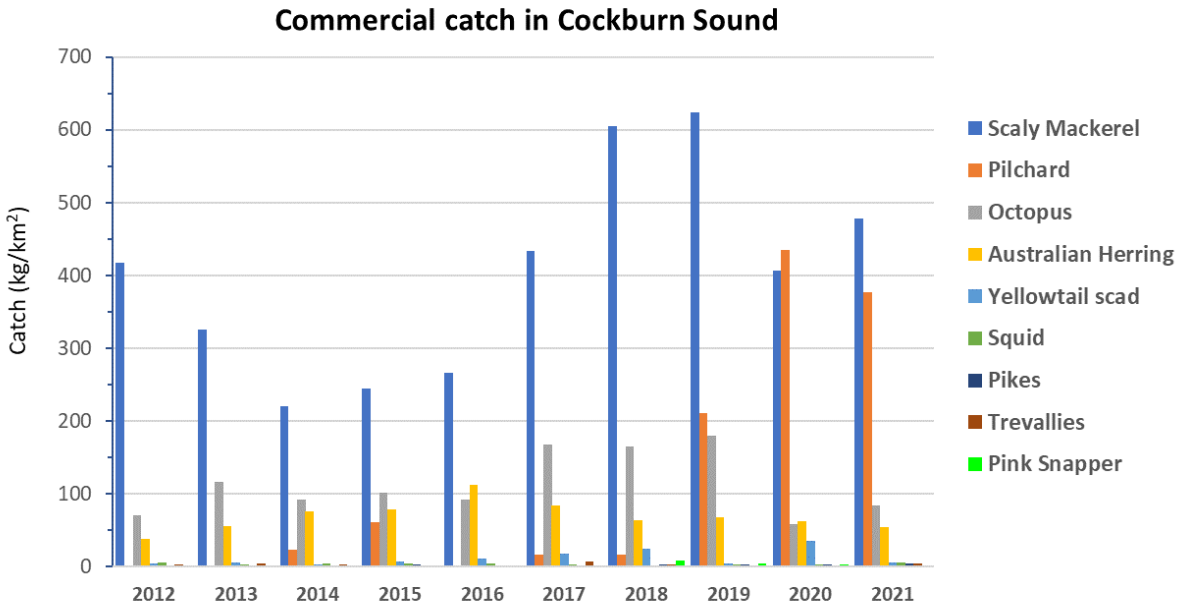

Figure 2. Commercial catch (kg/km^2/year) estimated for the Cockburn Sound Ecopath model using a model domain area of 260 km^2. Catch data provided by the Department of Primary Industries and Regional Development.

Table 5: Total commercial catch (kg) of species in Cockburn Sound in 2019, 2020 and 2021, and the total commercial catch within the EwE model domain (t/km^2/year). Data provided by DPIRD.

Functional Group	Commercial Catch (kg) 2019	2020	2021	Total catch (t/km^2/year
Squid	984	943.74	1375	0.0042
Australian Herring	17669	16227	14116.24	0.0616
Octopus	46896.2	15044.39	21863.7	0.1074
Pilchard	54920	113150	98100	0.3412
Scaly Mackerel	105690	124160	34150	0.3384
Australian Anchovy	0	300	220	0.0006
Yellowtail Scad	1284	9346	1399	0.0154
Pink Snapper	1079	840	484	0.0030
Yellowfin Whiting	389	100	0	0.0006
Maray	0	3300	0	0.0042
King George whiting	85	78	237	0.0005
Trevallies	393	343	1015.3	0.0022
Rabbitfish	167	185	159	0.0007
Cuttlefish	103	43.51	127	0.0011
Whitings	10	12	6	0.00004
Pikes	754	994	1071	0.0036
Butterfishes	20	10	0	0.00004
Other Garfishes	30	27	0	0.00007

Data quality of the model: "*Pedigree of the data*"

The pedigree of an Ecopath input represents the origin of a given input data. The 'pedigree' routine in Ecopath, functions as a sensitivity analysis for documenting the effect of different quality of data inputs on estimated parameters and their quality. The pedigree index (*P*) measures the amount of local data used (i.e., minor uncertainty in the inputs) among the five basic categories of models: Biomass (*B*), Production to biomass (*P/B*), the ratio of consumption to biomass (*Q/B*), and diets and catches for each of the functional groups. The range of *P* is from 0 for data not rooted locally to 1.0 for data that are fully rooted in local data (Christensen *et al*., 2004). The pedigree Index for the Northwest Shelf Ecopath model (reference) was calculated using the following expression:

$$P = \sum_{i=1}^{n} \frac{I_{ij}}{n}$$

Where I_{ij} is the pedigree index value for group *I* and parameter *j* for each of the living groups in the ecosystem; *j* can represent either *B*, *P/B*, *Q/B*, catch and diet. The confidence intervals associated with each of these input parameters attributed in the pedigree was defined as shown in Table 6. When the

pedigree table is completed, Ecopath models are then implemented with this "quality footprint' that is unique for the study ecosystem. The model pedigree can be compared between models based on single parameters pedigree, or overall pedigree indices (Christensen and Walters, 2004).

Table 6. Default options for pedigree routine for each input parameter used in the Ecopath Cockburn Sound model. Default (percentage confidence intervals [CI]) are defined based on values proposed by Christensen *et al.,* (2000).

Parameter	Pedigree index	Default CI (± %)	Colour assigned
Biomass			
Sampling based, high precision	1	10	
Sampling based, low precision	0.7	40	
Approximate or indirect method	0.4	50-80	
Guesstimate	0	80	
From other model	0	80	
Estimated by Ecopath	0	n.a.	
P/B and Q/B ratios			
Same group/species, same system	1	10	
Same group/species, similar system	0.8	20	
Similar group/species in same system	0.7	30	
Similar species in similar system	0.6	40	
Empiral relationship	0.5	50	
From other Ecopath model	0.2	80	
Guesstimate	0.1	90	
Estimated by Ecopath	0	n.a.	
Diet compostions			
Quantitative, detailed, diet composition study	1	30	
Quantitative but limited diet composition study	0.7	40	
Qualitative diet composition study	0.5	50	
General knowledge for same group/species	0.2	80	
From other Ecopath model	0	80	
General knowledge of related group/species	0	80	
Catches			
Local study, high precision/complete	1	10	
Local study, low precision/incomplete	0.7	30	
National statistics	0.5	50	
FAO statistics	0.2	80	
From other Ecopath model	0	90	
Guesstimate	0	90	

Next steps

Work will now focus on completing the quantitative models for key recreational fish species (e.g. Australian Herring), and species of conservation interest (Bottlenose Dolphin and sea birds). In regards of the Ecopath model is planned to complete its parameterization (biomass estimations) by the end of December 2022. After that the Ecopath model is mass-balanced, calibrated (using CPUE data) and sensitivity analysis is run. The results from these analyses will be presented in the 3rd project workshop, planned for late-January to early-February 2023 (Table 6). The planned activities for this project from October until the end of the project (March 2023) are summarised in Table 6.

Table 6. Planned project activities from October 2022 to March 2023 (end of the project) to complete conceptual, qualitative and Ecopath models.

		2022					2023		
	Activity	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
Conceptual models	Final seagrass models for 1960s, 1980s, 2020								
Qualitative models	Use of Maple for existing models								
	Building models for Whiting, Australian Herring, Dolphins, Seabirds								
Ecopath model	Estimates of P/B and Q/B rates								
	Diet matrix (revised by experts)								
	Estimates of biomass								
	Run model initial conditions and Pre-balance diagnostics								
	Balancing and tunning								
	Sensitivity analysis								
	Ecopath results								
3rd Workshop and Final report	3rd Workshop: Results								
	Final report								

References

Anonymous. (1988). Australian herring. Fisheries Department of Western Australia. Fishing WA No. 3. 4 p.

Anonymous. (1993). Mulloway. Fisheries Department of Western Australia. Fishing WA No. 2. 4 p.

Anonymous. (2022). Western king prawn *Penaeus latisulcatus*. Natural Resources. Government of South Australia.

Battaglene, S. C., & Talbot, R. B. (1992). Induced spawning and larval rearing of snapper, *Pagrus auratus* (Pisces: Sparidae), from Australian waters. *New Zealand Journal of marine and freshwater research*, *26*(2), 179–183.

BMT Western Australia Pty Ltd. (2018). *Cockburn Sound - Drivers, Pressures, State, Impacts, Responses Assessment*. Prepared for Department of Water and Environmental Regulation, the Kwinana Industries Council, the City of Rockingham, and the City of Kwinana by BMT Western Australia Pty Ltd, Report No. 1362_001/Rev1, Perth, Western Australia, July 2018.

Chabanne, D. B. H., Finn, H., & Bejder, L. (2017). Identifying the relevant local population for environmental impact assessments of mobile marine fauna. Frontiers in Marine Science, 4, 148.

Clough, J. M. (2011). Demersal fish assemblages of South Passage and Blind Strait, Western Australia: a unique subtropical embayment in a World Heritage Property. [Unpublished raw data]. The University of Western Australia.

Cockburn Sound Management Council. (2018). State of Cockburn Sound marine area report.

Coleman, N., and M. Mobley, 1984. Diets of commercially exploited fish from Bass Strait and adjacent Victorian waters, southeaster Australia. Aust. J. Mar. Freshwater. Res. 35: 549-560.

Compagno, L. J. V. (1984). FAO species catalogue. Vol. 4. Sharks of the world. An annotated and illustrated catalogue of shark species known to date. Part 1. *Hexanchiformes to Lamniformes*. FAO Fish. Synop. 125(4/1): 1-249. Rome, FAO.

Compagno, L. J. V., & Niem. V. H. (1998). Carcharhinidae. Requiem sharks. In Carpenter, K. E. & Niem, V. H. (Eds.). (1998), FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, Vol. 2. Cephalopods, crustaceans, holothurians, and sharks (pp. 1312-1360). Rome, FAO.

DPIRD. 2018. A study of Western Australia's 2010/11 marine heatwave. Newsletter 38. Department of Primary Industries and Regional Development. Perth. WA. Australia

Dunlop, J. N., & Storr, G. M. (1981). Seabird Islands: Carnac Island, Western Australia. Corella, 5, 71-4.

Gales, N. J., Shaughnessy, P. D., & Dennis, T. E. (1994). Distribution, abundance, and breeding cycle of the Australian sea lion *Neophoca cinerea* (Mammalia: Pinnipedia). Journal of Zoology, 234(3), 353–370.

Gaughan, D. J., & Mitchell, R. W. (2000). The biology and stock assessment of the tropical sardine, *Sardinella lemuru,* off the mid-west coast of Western Australia. Department of Primary Industries and Regional Development, Perth. Report No. 119.

Hall, N. G. (2009). Estimation of natural and fishing mortality using length-composition data. Centre for Fish and Fisheries Research, Murdoch University.

Hart, A. (2020). Western Rock Octopus *(2020)*. Fisheries Research and Development Corporation. https://fish.gov.au/report/414-Western-Rock-Octopus-2020

Hart, A. M., Murphy, D. V, Caputi, N., Hesp, A., & Fisher, E. A. (2018). Western Australian Marine Stewardship Council Report Series No. 12: Resource Assessment Report Western Australian Sea Cucumber Resource. Department of Primary Industries and Regional Development, Western Australia. 89pp.

Hart, Hart, D. M., Murphy, D., Harry, A., & Fisher, E. A. (2018). Resource Assessment Report Western Australian Octopus Resource. Department of Primary Industries and Regional Development, Perth. Report No. 14.

Hasmel, O.S. 2015. A method for calculating a meta-analytical prior for the natural mortality rate using multiple life history corelates. ICES Journal of Marine Science 72: 62-69

Hayes, E. (1994). Snapper in New South Wales. NSW Fisheries Fishnote DF/37. 4 p.

Hill, S. L., Pinkerton, M. H., Ballerini, T., Cavan, E. L., Gurney, L. J., Martins, I., & Xavier, J. C. (2021). Robust model-based indicators of regional differences in food-web structure in the Southern Ocean. Journal of Marine Systems, 220, 103556.

Hoese, D. F., Bray, D. J., Paxton, J. R., Allen, G. R. (2006). Fishes. In Beasley, O.L., & A. Wells (Eds.). Zoological Catalogue of Australia. Vol. 35. Australia: ABRS & CSIRO Publishing, 2178 p.

Hoschke, A., Whisson, G., & Moore, G. (2019). Complete list of fishes from Rottnest Island. In Whisson, G., & Hoschke, A. (2017) The Rottnest Island Fish Book (pp. 150-161). Aqua Research & Monitoring Service.

Hyndes, G. A., Platell, M. E., & Potter, I. C. (1997). Relationships between diet and body size, mouth morphology, habitat, and movements of six sillaginid species in coastal waters: implications for resource partitioning. *Marine Biology, 128*(4), 585–598.

Iwatsuki, Y., Pogonoski, J. J., & Last, P. (2012). Revision of the genus *Parequula* (Pisces: Gerreidae) with a new species from southwestern Australia. Zootaxa, *3425*(1), 42–54.

Jensen, A. L. (1996). Beverton and Holt life history invariants result from optimal trade-off of reproduction and survival. Canadian Journal of Fisheries and Aquatic Sciences, 53(4), 820–822.

Jensen, A. L. 1997. Origin of the relation between K and Linf and synthesis of relationships among life history parameters. Canadian Journal of Fisheries and Aquatic Sciences, 54: 987–989

Johnston, D., Yeoh, D., Harris, D., & Fisher, E. (2020). Blue Swimmer Crab (*Portunus armatus*) and Mud Crab *Scylla serrata* and *Scylla olivacea*) Resources in the North Coast and Gascoyne Coast Bioregions, Western Australia. Department of Primary Industries and Regional Development, Perth. Report 306.

Johnston, D., Yeoh, D., Harris, D., & Fisher, E. (2020). Blue Swimmer Crab (*Portunus armatus*) Resource in the West coast Bioregion, Western Australia Part 1: Peel Harvey Estuary, Cockburn Sound and Swan Canning Estuary. Department of Primary Industries and Regional Development, Perth. Report 307.

Last, P. R., White, W. T., de Carvalho, M. R., Séret, B., Stehmann, M. F. W., & Naylor, G. J. P. (2016). Rays of the World. CSIRO publishing.

Liew, H. C., & Chan, E. H. (1987). ECOPATH Model of a Tropical Shallow-water Community in Malaysia. Report of the International Development Research Centre (IDRC), Singapore.

Loneragan, N. R., Russell, C.B., Lozano-Montes, H.M., and J. M. Dambacher. 2010. Evaluating how food webs and the fisheries they support are affected by fishing closures in Jurien Bay, temperate Western Australia. FRDC Report 2006/038. Perth, WA. Australia.

Masuda, H., Amaoka, K., Araga, C., Uyeno, T., & Yoshino, T. (1985). The fishes of the Japanese Archipelago. (Vol. 1). Tokai University Press.

Matarese, A. C., Kendall, A. W., Blood, D. M., & Vinter, B. M. (1989). Laboratory Guide to Early Life History Stages of Northeast Pacific Fishes. NOAA Tech. Rep. NMFS 80: 1-652.

May, J.L. and J.G.H. Maxwell, 1986. Trawl fish from temperate waters of Australia. CSIRO Division of Fisheries Research, Tasmania. 492 p.

Mckay, R. J. (1992). FAO species catalogue. Vol. 14. Sillaginid fishes of the world (Family Sillaginidae). An annotated and illustrated catalogue of the Sillago, Smelt or Indo-Pacific whiting species known to date. FAO Fish. Synop. 125(14):87p. Rome, FAO.

Muñoz, J., & Mcdonald, J. (2014). Potential Eradication and Control Methods for the management of the ascidian *Didemnum perlucidum* in Western Australia. Fisheries Research Report No. 252. Department of Fisheries, Western Australia. 40pp.

Neira, F. J., Miskiewicz, A. G., & Trnski, T. (1998). Larvae of temperate Australian fishes: laboratory guide for larval fish identification. University of Western Australia Press.

Nicholson, K., Loneragan, N., Finn, H., & Bejder, L. (2021). Social, spatial, and isotopic niche partitioning identify an estuarine community of bottlenose dolphins as a discrete management unit. Aquatic Conservation: Marine and Freshwater Ecosystems, 31(12), 3526–3542.

Opitz, S. (1996). Trophic Interactions in Caribbean Coral Reefs. ICLARM Tech. Rep. 43. 341 p.

Osterrieder, S. K., Kent, C. S., & Robinson, R. W. (2015). Variability in haul-out behaviour by male Australian sea lions *Neophoca cinerea* in the Perth metropolitan area, Western Australia. Endangered Species Research, 28(3), 259–274.

Palomares, M. L. D., & Pauly, D. (1998). Predicting food consumption of fish populations as functions of mortality, food type, morphometrics, temperature and salinity. Marine and Freshwater Research, 49(5), 447–453.

Paulin, C. (1993). Review of the Australian fish family Arripididae (Percomorpha), with the description of a new species. Marine and Freshwater Research, *44*(3), 459–471.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal de Conseil International pour l'Exploration de la Mer, 39: 175–192.

Pauly, D., Sambilay, V. J., & Opitz, S. (1993). Estimates of relative food consumption by fish and invertebrate populations, required for modelling the Bolinao reef ecosystem, Philippines. WorldFish Center Conference Proceedings. 1993, 390.

Paxton, J. R., Hoese, D. F., Allen, G. R., & Hanley, J. E. (1989). Pisces Petromyzontidae to Carangidae. Australian Biological Resources Survey.

Platell, M. E., & Potter, I. C. (2001). Partitioning of food resources amongst 18 abundant benthic carnivorous fish species in marine waters on the lower west coast of Australia. Journal of Experimental Marine Biology and Ecology, 261(1), 31–54.

Preston, T. J., Ropert-Coudert, Y., Kato, A., Chiaradia, A., Kirkwood, R., Danń, P., & Reina, R. D. (2008). Foraging behaviour of little penguins Eudyptula minor in an artificially modified environment. Endangered Species Research, *4*(1–2), 95–103.

Prince, J.D. 2003. The barefoot ecologist goes fishing. Fish and Fisheries 4, 359-371.

Rippey, E., Rippey, J. J., & Dunlop, J. N. (2002). Increasing numbers of pied cormorants breeding on the islands off Perth, Western Australia, and consequences for the vegetation. Corella, 26(3), pp. 61–64.

Russell, B. C. (1990). FAO species catalogue. Vol.12. Nemipterid fishes of the world (Threadfin breams, Whiptail breams, Monocle breams, Dwarf monocle breams and Coral breams), family Nemipteridae. An annotated and illustrated catalogue of nemipterid species known to date. FAO Fish. Synop. *125*(12). 149 p. Rome, FAO.

Russell, B. C., & Leigh, R. D. (1983). The food and feeding habits of rocky reef fish of north-eastern New Zealand. Zealand Journal of Marine and Freshwater Research, *17*, 121–145.

Sainsbury, K. J., Kailola, P. J., & Leyland, G. G. (1985). Continental shelf fishes of Northern and North-western Australia: an illustrated guide. CSIRO Division of Fisheries Research; Clouston & Hall and Peter Pownall Fisheries Information Service, Canberra, Australia. 375 p.

Scott, T. D., Glover, C. J. M., & Southcott, R. V. (1974). The marine and freshwater fishes of South Australia. SA Government Printer Adelaide.

Smith, K. A., Brown, J., Lewis, P., Dowling, C., Howard, A. Lenanton, R., & Malony, B. (2013). Status of nearshore finfish stocks in south-western Western Australia: Part 1: Australian herring. Government of Western Australia Department of Fisheries, Perth. Fisheries Research Report No. 246.

Smith, K., Dowling, C., Mountford, S., Hesp, A., Howard, A., & Brown, J. (2017*). Status of southern garfish (Hyporhamphus melanochir)* in Cockburn Sound, Western Australia. Department of Primary Industries and Regional Development, Perth. Report 271.

Sumner, N., & Lai, E. (2012). Boat-based Recreational Fishing Catch and Effort in Cockburn Sound and Owen Anchorage during 1996/97, 2001/02 and 2005/06. Fisheries research contract report No. 23. Department of Fisheries, Western Australia. 16p.

The Australian Museum. (2020). *Australian Pelican*. https://australian.museum/learn/animals/birds/australian-pelican/

The Australian Museum. (2022a). *Bottlenose Dolphin*. https://australian.museum/learn/animals/mammals/bottlenose-dolphin/

The Australian Museum. (2022b). *Great Cormorant*. https://australian.museum/learn/animals/birds/great-cormorant/

Tulp, I., & de Goeij, P. (1994). Evaluating wader habitats in Roebuck Bay (north-western Australia) as a springboard for northbound migration in waders, with a Ffocus on Great Knots. *Emu*, *94*(2), 78–95.

Whitehead, P. J. P. (1985). FAO species catalogue, Vol. 7. Clupeoid fishes of the world (suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, anchovies, *and wolf herrings.* FAO Fish. Synop. 125(7/1):1-303. Rome, FAO.

Whitehead, P. J. P., Nelson, G. J., & Wongratana, T. (1988). FAO species catalogue. Vol. 9. Clupeoid fishes of the world. (Suborder Clupeoidei). An annotated and illustrated catalogue of the herrings, sardines, pilchards, sprats, shads, anchovies, and wolf-herrings. FAO Fish. Synop. 125(7/2):305-579.

Whitehead, P.J.P. and Y.R. Rodriguez-Sánchez, 1995. Clupeidae. Sardinas, sardinetas, machuelos, sábalos, piquitingas. p. 1015-1025. In W. Fischer, F. Krupp, W. Schneider, C. Sommer, K.E. Carpenter, and V. Niem (eds.) Guia FAO para identification de Especies para lo Fines de la Pesca. Pacifico Centro-Oriental. 3 Vols. FAO, Rome.

Yeoh, D. E., Johnston, D. J., & Harris, D. C. (2021). *Squid and cuttlefish resources of Western Australia Squid and cuttlefish resources of Western Australia*. Department of Primary Industries and Regional Development, Perth. Book 314.

Appendix A. Diet matrix showing proportion of the diet biomass used in the pre-balance Ecopath Cockburn Sound model.

Prey \ predator	Large sharks	Australian Sea Lion	Bottlenose Dolphin	Small sharks	Shark juveniles	Rays and Shovelheads	Cormorants	Australian Pelican	Little Penguin	Gulls and Terns	Migratory waders	Pikes	Trevallies
Large sharks	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Sea Lion	0.0216	0	0	0	0	0	0	0	0	0	0	0	0
Bottlenose Dolphin	0.0108	0	0	0	0	0	0	0	0	0	0	0	0
Small sharks	0.0216	0.0099	0	0	0	0	0	0	0	0	0	0	0
Shark juveniles	0.0108	0	0	0	0	0	0	0	0	0	0	0	0
Rays and Shovelheads	0.0108	0	0	0.0487	0	0	0	0	0	0	0	0	0
Cormorants	0	0.001	0	0	0	0	0	0	0	0	0	0	0
Australian Pelican	0	0.001	0	0	0	0	0	0	0	0	0	0	0
Little Penguin	0.0011	0	0	0	0	0	0	0	0	0	0	0	0
Gulls and Terns	0	0.001	0	0	0	0	0	0	0	0	0	0	0
Migratory waders	0	0	0	0	0	0	0	0	0	0	0	0	0
Pikes	0	0.0194	0.0196	0	0	0	0.0093	0	0	0.0094	0	0	0
Trevallies	0	0	0.017	0	0	0	0.0179	0	0	0	0	0	0
Mulloway	0	0.01	0.0087	0	0	0	0	0.0175	0	0	0	0	0
Western Australian Salmon	0	0.01	0.0087	0	0	0	0	0	0	0	0	0	0
Pink Snapper adult	0.1609	0.0201	0.0255	0	0	0	0	0	0	0	0	0	0
Pink Snapper pre-spawner	0.1609	0.0201	0.0255	0	0	0	0	0	0	0	0	0	0
PInk Snapper coastal juvenile	0	0.01	0.0255	0	0	0	0	0	0	0	0	0	0
Yellowtail Scad	0	0	0	0	0	0	0	0	0	0	0	0.0347	0
Flounders and flatheads	0	0.0198	0	0.0885	0	0	0	0	0	0	0	0	0
Western Stripped Grunter	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea King Fish juvenile	0	0	0.0174	0	0	0	0	0.0087	0	0	0	0	0
Common Silverbelly	0	0	0	0	0	0	0.0179	0.0087	0	0	0	0	0
Demersal fish	0	0.0502	0	0.2921	0	0.0495	0	0	0	0	0	0	0
Wrasses	0	0.01	0.017	0	0	0	0	0	0	0	0	0	0
Soldiers	0	0	0	0.0974	0	0.0297	0	0	0	0	0	0.0116	0
Western Dragonet	0	0	0	0	0	0.0099	0.009	0	0	0	0	0	0
Mullets	0	0.0099	0.026	0	0	0	0.0355	0.0437	0.0445	0	0	0.0693	0
Leatherjackets and Boxfishes	0	0	0	0	0	0	0	0	0	0	0	0	0
Pipefishes	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australia Butterfish	0	0.0192	0	0.037	0	0	0	0	0	0	0	0.0291	0
Butterfishes	0	0.0192	0	0.037	0	0	0	0	0	0	0	0.0231	0
Southern Garfish	0	0	0.0174	0	0	0	0.0449	0.0874	0.1513	0.0286	0	0.0347	0
Other Garfish	0	0	0.0199	0	0	0	0.0565	0.0998	0.0925	0.019	0	0.0693	0
Marray	0	0	0	0	0	0	0	0	0	0	0	0	0
Scaly Mackerel	0	0.0301	0.0434	0	0	0	0.0449	0.0874	0.0712	0	0	0.0578	0
Blue Sprat	0	0.0301	0.0434	0	0	0	0.0449	0.0175	0.4272	0.1886	0	0.0809	0
Sandy Sprat (white bait)	0	0.0301	0.0434	0	0	0	0.0449	0.0175	0.1192	0	0	0.0578	0
Pilchard	0	0.0301	0.0434	0	0	0	0.0449	0.0874	0.0267	0	0	0.0231	0
Australian Herring	0	0.0301	0.0434	0	0	0	0.0449	0.0874	0.0178	0	0	0.0116	0
King George Whiting	0	0.0301	0.0434	0	0	0	0.0897	0.0173	0.0159	0.1886	0	0.0231	0
Whiting Species (non King George spp)	0	0.0301	0.0434	0	0	0	0.0897	0.0173	0.0159	0.1886	0	0.0462	0
Schooling species	0	0.0301	0.0868	0	0	0	0.0897	0.0519	0.0178	0.0943	0	0	0
Spiny Gurnard	0	0	0	0.0779	0	0.0297	0.0178	0.0173	0	0	0	0	0
Weedfish	0	0	0	0	0	0.0297	0.0178	0.0173	0	0	0	0	0
Australian Goatfish	0	0	0	0.0195	0	0.0198	0	0	0	0	0	0	0
Rabbitfish (Siganus sp)	0	0	0	0.0097	0	0.0099	0.02	0.0101	0	0	0	0	0
Introduced species	0	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	0.1491	0.0868	0	0	0	0.0089	0	0	0	0	0.289	0
Cuttlefish	0.0216	0.0398	0.0868	0	0	0	0	0	0	0	0	0.1387	0
Western Australian Octopus	0.0216	0.0803	0.017	0.0195	0.0202	0.0495	0	0	0	0	0	0	0
Mantis shrimp	0	0	0	0	0.0505	0.0198	0	0.0087	0	0	0	0	0.05
Blue Swimmer Crab	0	0.0099	0	0.0195	0.0202	0.099	0.009	0.0087	0	0	0	0	0.01
Other crabs	0.0216	0.0502	0.0174	0.0974	0.303	0.198	0.0179	0.0437	0	0	0	0	0.07
Western King Prawn	0	0	0	0.0097	0	0.0198	0	0.0087	0	0.0471	0	0	0.03
Other Prawns	0	0	0	0.0487	0.303	0.099	0	0.0175	0	0.0471	0.05	0	0.2
Seastars	0	0	0	0	0	0	0	0	0	0	0	0	0.08
Sea snails	0	0	0	0	0.0808	0.0495	0	0	0	0	0	0	0.07
Urchins	0	0	0	0	0.1212	0.1386	0	0	0	0	0	0	0.08
Black Mussels	0	0	0	0	0	0.0495	0	0	0	0	0	0	0.04
Infaunal Polychaetes	0	0	0	0.0487	0	0.099	0	0	0	0.1886	0.2	0	0.05
Corals	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Cucumbers	0	0	0	0	0	0	0	0	0	0	0	0	0.02
Ascidians	0	0	0	0	0	0	0	0	0	0	0	0	0
Sponges	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalves	0	0	0	0.0487	0	0	0	0	0	0	0	0	0
Planktotrophic Larvae	0	0	0	0	0	0	0	0	0	0	0	0	0
Zooplankton	0	0	0	0	0	0	0	0	0	0	0	0	0
Phytoplankton	0	0	0	0	0	0	0	0	0	0	0	0	0
Seagrass	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroalgae	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroalgal Epiphytes	0	0	0	0	0	0	0	0	0	0	0	0	0
Microphytobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	0	0	0	0	0.101	0	0	0	0	0	0.05	0	0
Import (food adquired out of Cockburn sound)	0.5364	0.1989	0.1735	0	0	0	0.2243	0.2185	0	0	0.7	0	0.3
Sum	1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix A. Continuation.

Prey \ predator	Mulloway	Western Australian Salmon	Pink Snapper adult	Pink Snapper pre-spawner	Pink Snapper coastal juvenile	Yellowtail Scad	Flounders and flatheads	Western Stripped Grunter	Sea King Fish juvenile	Common Silverbelly	Demersal fish	Wrasses	Soldiers
Large sharks	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Sea Lion	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottlenose Dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0
Small sharks	0	0	0	0	0	0	0	0	0	0	0	0	0
Shark juveniles	0	0	0	0	0	0	0.0143	0	0	0	0	0	0
Rays and Shovelheads	0	0	0	0	0	0	0	0	0	0	0	0	0
Cormorants	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Pelican	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Penguin	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulls and Terns	0	0	0	0	0	0	0	0	0	0	0	0	0
Migratory waders	0	0	0	0	0	0	0	0	0	0	0	0	0
Pikes	0	0	0	0	0	0	0	0	0	0	0	0	0
Trevallies	0	0	0	0	0	0	0	0	0	0	0	0	0
Mulloway	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australian Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Snapper adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Snapper pre-spawner	0	0	0	0	0	0	0	0	0	0	0	0	0
PInk Snapper coastal juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail Scad	0	0	0	0	0	0	0	0	0	0	0	0	0
Flounders and flatheads	0	0	0	0	0	0	0	0	0	0	0.0388	0	0
Western Stripped Grunter	0	0	0	0	0	0	0.0857	0	0	0	0.0384	0	0
Sea King Fish juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Silverbelly	0	0	0	0	0	0	0	0	0	0	0	0	0
Demersal fish	0	0	0	0	0	0	0.0857	0	0	0	0	0	0
Wrasses	0	0	0	0	0	0	0.0286	0	0	0	0.0288	0	0
Soldiers	0	0	0.02	0	0	0	0.0429	0	0	0	0.0288	0	0
Western Dragonet	0	0	0.02	0	0	0	0.0286	0	0	0	0	0	0
Mullets	0.3	0	0.01	0	0	0	0.1286	0	0	0	0	0	0
Leatherjackets and Boxfishes	0	0	0	0	0	0	0	0	0	0	0.0096	0	0
Pipefishes	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australia Butterfish	0	0	0	0	0	0	0	0	0	0	0.0192	0	0
Butterfishes	0	0	0	0	0	0	0	0	0	0	0.0192	0	0
Southern Garfish	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Garfish	0	0	0	0	0	0	0	0	0	0	0	0	0
Marray	0	0	0	0	0	0	0	0	0	0	0	0	0
Scaly Mackerel	0	0	0	0	0	0.0952	0	0.06	0	0	0	0	0
Blue Sprat	0	0	0	0	0	0.0952	0	0.05	0	0	0	0	0
Sandy Sprat (white bait)	0	0.1	0	0	0	0.0952	0	0.1	0	0	0	0	0
Pilchard	0	0.1	0	0	0	0.0952	0	0	0	0	0	0	0
Australian Herring	0	0.05	0	0	0	0.0476	0	0	0	0	0	0	0
King George Whiting	0.1	0.1	0	0	0	0.0952	0	0	0	0	0	0	0
Whiting Species (non King George spp)	0.1	0.1	0	0	0	0.0952	0	0	0	0	0	0	0
Schooling species	0.1	0.05	0	0	0	0.0952	0	0	0	0	0	0	0
Spiny Gurnard	0	0	0.02	0.02	0	0	0.0714	0	0	0	0.0288	0	0
Weedfish	0	0	0.01	0.02	0	0	0.0429	0	0	0	0.0192	0	0
Australian Goatfish	0	0	0.01	0.02	0	0	0.0143	0	0	0	0.0192	0	0
Rabbitfish (Siganus sp)	0	0	0	0	0	0	0	0	0	0	0.0096	0	0
Introduced species	0	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	0	0	0	0	0	0	0.05	0	0	0	0	0
Cuttlefish	0	0	0	0	0	0	0	0	0	0	0.0481	0	0
Western Australian Octopus	0	0	0.02	0.02	0	0	0.0286	0	0	0	0.0961	0	0
Mantis shrimp	0.05	0	0.01	0.01	0	0	0.0571	0.02	0.02	0.02	0.0192	0.1	0
Blue Swimmer Crab	0	0	0.03	0.05	0.05	0	0.0143	0	0.02	0.01	0.1442	0.01	0
Other crabs	0	0	0.15	0.16	0.25	0	0.0714	0	0.2	0.1	0.1922	0.1	0.4
Western King Prawn	0	0	0.02	0.02	0.05	0	0.0286	0.05	0.03	0.03	0.0769	0.03	0
Other Prawns	0.1	0	0.1	0.01	0.15	0	0.0857	0.1	0.2	0.3	0.1442	0.2	0.3
Seastars	0	0	0.1	0.1	0	0	0	0	0.01	0.01	0	0.02	0
Sea snails	0	0	0	0.02	0	0	0.0286	0.02	0.03	0.05	0.0096	0.04	0
Urchins	0	0	0.1	0.15	0.1	0	0.0143	0.03	0.08	0.05	0.0096	0.08	0
Black Mussels	0	0	0.03	0	0	0	0.0286	0	0	0	0	0.04	0
Infaunal Polychaetes	0.15	0	0.05	0.1	0.3	0	0.0429	0.1	0.08	0.3	0	0.15	0
Corals	0	0	0	0	0	0	0	0.02	0	0	0	0	0
Sea Cucumbers	0	0	0	0	0	0	0	0	0.01	0.03	0	0	0
Ascidians	0	0	0	0	0	0	0	0.04	0	0	0	0	0
Sponges	0	0	0	0	0	0	0	0.02	0	0	0	0	0
Bivalves	0	0	0	0	0	0	0.0571	0	0	0	0	0.03	0
Planktotrophic Larvae	0	0	0	0	0	0	0	0.02	0	0	0	0	0
Zooplankton	0	0.2	0	0	0	0.2857	0	0.1	0	0	0	0	0
Phytoplankton	0	0	0	0	0	0	0	0	0	0	0	0	0
Seagrass	0	0	0	0	0	0	0	0.02	0	0	0	0	0
Macroalgae	0	0	0	0	0	0	0	0.05	0	0	0	0	0
Macroalgal Epiphytes	0	0	0	0	0	0	0	0.05	0	0	0	0	0
Microphytobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	0	0	0	0	0.1	0	0	0.1	0.02	0.1	0	0.2	0.2
Import (food adquired out of Cockburn sound)	0.1	0.3	0.3	0.3	0	0	0	0	0.3	0	0	0	0.1
Sum	1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix A. Continuation

Prey \ predator	Australian Herring	King George Whiting	Whiting Species (non King George spp)	Schooling species	Spiny Gurnard	Weedfish	Australian Goatfish	Rabbitfish (Siganus sp)	Introduced species	Squid	Cuttlefish	Western Australian Octopus	Mantis shrimp
Large sharks	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Sea Lion	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottlenose Dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0
Small sharks	0	0	0	0	0	0	0	0	0	0	0	0	0
Shark juveniles	0	0	0	0	0	0	0	0	0	0	0.018	0	0
Rays and Shovelheads	0	0	0	0	0	0	0	0	0	0	0	0	0
Cormorants	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Pelican	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Penguin	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulls and Terns	0	0	0	0	0	0	0	0	0	0	0	0	0
Migratory waders	0	0	0	0	0	0	0	0	0	0	0	0	0
Pikes	0	0	0	0	0	0	0	0	0	0	0	0	0
Trevallies	0	0	0	0	0	0	0	0	0	0.0192	0.018	0	0
Mulloway	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australian Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Snapper adult	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Snapper pre-spawner	0	0	0	0	0	0	0	0	0	0	0	0	0
PInk Snapper coastal juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail Scad	0	0	0	0	0	0	0	0	0	0	0	0	0
Flounders and flatheads	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Stripped Grunter	0	0	0	0	0	0	0	0	0	0	0.018	0	0
Sea King Fish juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Silverbelly	0	0	0	0	0	0	0	0	0	0.0192	0.018	0	0
Demersal fish	0	0	0	0	0	0	0	0	0	0	0.009	0	0
Wrasses	0	0	0	0	0	0	0	0	0	0.0192	0	0.0182	0
Soldiers	0	0	0	0	0	0	0	0	0	0	0.018	0	0
Western Dragonet	0	0	0	0	0	0	0	0	0	0	0	0	0
Mullets	0	0	0	0	0	0	0	0	0	0.0192	0.018	0	0
Leatherjackets and Boxfishes	0	0	0	0	0	0	0	0	0	0	0	0	0
Pipefishes	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australia Butterfish	0	0	0	0	0	0	0	0	0	0.0097	0.0196	0.037	0
Butterfishes	0	0	0	0	0	0	0	0	0	0.0194	0.0359	0.037	0
Southern Garfish	0	0	0	0	0	0	0	0	0	0.0192	0.018	0	0
Other Garfish	0	0	0	0	0	0	0	0	0	0.0288	0.0286	0	0
Marray	0	0	0	0	0	0	0	0	0	0	0	0	0
Scaly Mackerel	0	0	0	0	0	0	0	0	0	0.0673	0	0	0
Blue Sprat	0	0	0	0	0	0	0	0	0	0.0481	0	0	0
Sandy Sprat (white bait)	0	0	0	0	0	0	0	0	0	0.0481	0	0	0
Pilchard	0	0	0	0	0	0	0	0	0	0.0288	0.018	0	0
Australian Herring	0	0	0	0	0	0	0	0	0	0.0192	0.018	0	0
King George Whiting	0	0	0	0	0	0	0	0	0	0.0769	0	0	0
Whiting Species (non King George spp)	0	0	0	0	0	0	0	0	0	0.0961	0	0	0
Schooling species	0.3	0	0	0	0	0	0	0	0	0.1923	0.0359	0	0
Spiny Gurnard	0	0	0	0	0	0	0	0	0	0	0.0269	0	0
Weedfish	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Australian Goatfish	0	0	0	0	0.01	0	0	0	0	0.0192	0.018	0	0
Rabbitfish (Siganus sp)	0	0	0	0	0	0	0	0	0	0	0	0	0
Introduced species	0	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	0	0	0	0	0	0	0	0	0	0.009	0	0.0375
Cuttlefish	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australian Octopus	0	0	0	0	0.02	0	0	0	0	0.0192	0.009	0	0
Mantis shrimp	0.05	0.0505	0.05	0	0.04	0	0	0	0	0	0.009	0	0
Blue Swimmer Crab	0	0	0	0	0.05	0	0	0	0	0	0.0269	0.0454	0
Other crabs	0	0.3535	0	0	0.11	0	0	0	0	0	0.0898	0.1816	0
Western King Prawn	0.05	0.0505	0	0	0.03	0	0.2	0	0	0.0192	0.018	0	0
Other Prawns	0.15	0.2525	0.5	0	0.2	0.05	0.6	0	0	0.0192	0.0898	0.1816	0.1
Seastars	0	0.0202	0	0	0	0	0	0	0	0	0	0	0
Sea snails	0	0.0505	0	0	0.07	0	0	0	0	0	0	0.1816	0.1
Urchins	0	0.0202	0	0	0.01	0	0	0	0	0	0.0449	0	0.05
Black Mussels	0	0	0	0	0	0	0	0	0	0	0.0269	0.0454	0.0625
Infaunal Polychaetes	0	0.101	0.3	0	0.3	0.6	0	0	0	0	0.1347	0	0.375
Corals	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea Cucumbers	0	0	0	0	0	0	0	0	0	0	0	0	0
Ascidians	0	0	0	0	0	0	0	0	0	0	0	0	0
Sponges	0	0	0	0	0	0	0	0	0	0	0	0	0.025
Bivalves	0	0	0	0	0	0	0	0	0	0	0.0269	0.2723	0.25
Planktotrophic Larvae	0.05	0	0	0.05	0	0	0	0	0	0	0	0	0
Zooplankton	0.15	0	0	0.4	0	0	0	0	1	0	0	0	0
Phytoplankton	0.05	0	0	0.3	0	0	0	0	0	0	0	0	0
Seagrass	0	0	0	0	0	0	0	0.7	0	0	0	0	0
Macroalgae	0	0	0	0	0	0	0	0.2	0	0	0	0	0
Macroalgal Epiphytes	0	0	0	0	0	0	0	0.1	0	0	0	0	0
Microphytobenthos	0	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	0	0	0	0.1	0.15	0.35	0.2	0	0	0	0	0	0
Import (food adquired out of Cockburn sound)	0.2	0.101	0.15	0.15	0	0	0	0	0	0.1923	0.1796	0	0
Sum	1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix A. Continuation

Prey \ predator	Blue Swimmer Crab	Other crabs	Western King Prawn	Other Prawns	Seastars	Sea snails	Urchins	Black Mussels	Infaunal Polychaetes	Corals	Sea Cucumbers	Ascidians	Sponges	Bivalves	Planktotrophic Larvae	Zooplankton
Large sharks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Sea Lion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottlenose Dolphin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small sharks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shark juveniles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rays and Shovelheads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cormorants	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Pelican	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Penguin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulls and Terns	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Migratory waders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pikes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trevallies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mulloway	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australian Salmon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Snapper adult	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink Snapper pre-spawner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PInk Snapper coastal juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail Scad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flounders and flatheads	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Stripped Grunter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea King Fish juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Silverbelly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Demersal fish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wrasses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soldiers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Dragonet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mullets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leatherjackets and Boxfishes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pipefishes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australia Butterfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butterfishes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern Garfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Garfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marray	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scaly Mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue Sprat	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sandy Sprat (white bait)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pilchard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Herring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
King George Whiting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Whiting Species (non King George spp)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schooling species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spiny Gurnard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weedfish	0.0097	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Australian Goatfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rabbitfish (Siganus sp)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Introduced species	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuttlefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Australian Octopus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mantis shrimp	0.0485	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue Swimmer Crab	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other crabs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western King Prawn	0.0097	0.01	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0
Other Prawns	0.0485	0.05	0.03	0	0	0.1	0	0	0	0	0	0	0	0	0	0
Seastars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sea snails	0.0097	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0
Urchins	0.0291	0.03	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0
Black Mussels	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0	0
Infaunal Polychaetes	0.2913	0.3	0.1	0.1	0	0.1	0	0	0	0	0	0	0	0	0.1	0
Corals	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0
Sea Cucumbers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ascidians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sponges	0.0194	0.02	0.01	0.01	0	0	0.1	0	0	0	0	0	0	0	0	0
Bivalves	0.0291	0	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0
Planktotrophic Larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zooplankton	0	0	0	0	0	0	0	0.2	0	0.2	0.3	0.5	0.3	0	0.8	0.1
Phytoplankton	0	0	0	0	0	0	0	0.8	0	0	0.2	0.1	0.2	0.3	0	0.9
Seagrass	0.0194	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroalgae	0.1942	0.2	0.1	0.1	0	0	0.4	0	0	0	0	0	0	0	0	0
Macroalgal Epiphytes	0.0971	0.1	0.1	0.1	0	0	0.2	0	0	0	0	0	0	0	0	0
Microphytobenthos	0	0	0.05	0.05	0	0	0	0	0	0	0	0	0	0	0	0
Detritus	0	0	0.6	0.6	0	0	0.25	0	1	0.1	0.5	0.4	0.5	0.7	0.1	0
Import (food adquired out of Cockburn sound)	0.1942	0.2	0	0	0	0	0	0	0	0.7	0	0	0	0	0	0
Sum	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1