Table 1: The ecological issues discussed in the text for the small pelagics fishery, and corresponding indicators and research approaches that may be useful in addressing each issue. Issues are those in the category 'Ecological Well-being', identified and prioritised (see methods) by stakeholders attending the Pelagic Fishery Risk Assessment for Sustainable Fishery (see Nel 2005a). Research approaches or monitoring studies currently underway are given, and those proposed for the future are also indicated. For each issue, technical management measures are proposed and, where possible and applicable, ways in which their performance could be evaluated, and South Africa's ability to manage each issue is rated using asterisks

Issues	Indicators	Research approaches and proposed studies	Technical management measures and evaluation	Implementation[1]
Extreme risk category				
Impacts of removal of forage fish on species bound to breeding sites on land (seabirds) (ECOSYSTEM)	Bird population sizes; breeding success (fledgling weight, fledglings raised per breeding pair, breeding proportion), seabird diet composition, spatial indicators (e.g. overlap of seabird foraging and pelagic fisheries)	Routine monitoring of seabird colonies; satellite tracking to assess foraging ranges; minimum realistic models; spatialised models of pelagic fish around seabird colonies Future: quantify and formalise the link between the pelagic fishery and seabirds; quantify functional responses of seabirds to small pelagic prey and identify thresholds below which there are serious negative implications for seabirds	Avoid populations falling below levels that exceed limit reference points according to IUCN conservation criteria by reducing TACs or closing areas within foraging ranges; allow sufficient escapement of forage fish for predators; avoid threshold levels of pelagic fish below which the implications for seabirds are detrimental	***
High risk category				
Implications for pelagic fisheries and their management of spatial shifts in sardine distribution (southward distributional shift of sardine and low occurrence of sardine on the West Coast) (ECOSYSTEM)	Biomass and ichthyoplankton distribution; distribution of catches (e.g. centre of gravity of catches); limit reference points exceeded if more than half the sardine stock (in terms of biomass) west of Cape Agulhas or if 20% or more of fish >18cm west of Cape Agulhas	Routine acoustic surveys of pelagic fish stocks (biomass, fish size); catch distributions monitored by means of GIS Future: genetic studies required to check whether separate sardine stocks exist on South vs West coasts	Close areas to fishing (i.e. spatial management of fishing effort)	*
Coping with changes in productivity of sardine stock (indicators suggest a recent decline) (SINGLE SPECIES)	Growth rate; standardised gonad mass; condition factor; length at age; length at maturity; ISPR; ASP	Routine monitoring of biological characteristics of sardine in surveys and catches; determination of sardine ISPR and ASP; ongoing sardine age determination; comparison of indicators with those in 'threshold periods' Future: forecasting of 'productivity states/regimes' for management of the fishery	Set fishing mortality appropriate to current productivity state/regime, identified using indicators of changes in productivity. Reduce fishing when indicators suggest ecosystem is entering a low productivity regime	*
Moderate risk category				
Poor understanding of decade-scale fluctuations in abundance of small pelagic fish and thus availability to fisheries (ECOSYSTEM)	Biomass; catches; trophic replacement index; diet of predators (e.g. seabirds)	Develop indicators to track ecosystem changes; hindcast to pre-fishing period to provide information on ecosystem effects of fishing; develop expert system models to detect ecosystem changes (using indicators); compare ecosystem functioning over different periods and between systems; quantify trophic controls (bottom-up, top-down, wasp-waist) Future: time-series analyses	Manage catches within productivity states/regimes, as identified using indicators of ecosystem state/change Benefit: optimisation of catches while keeping the risk low that catch levels will accelerate stock decline	**

Table 1: cont.

Issues	Indicators	Research approaches and proposed studies	Technical management measures and evaluation	Implementation[1]
Implications of removal of forage fish for top predators other than seabirds (e.g. Bryde's whale, linefish including hake, seals) (ECOSYSTEM)	Population sizes of predators, diet composition, catches of linefish; indicators of temporal and spatial overlap of predators and pelagic fishery	Undertake intensive hake diet study; expand trophic models including spatialized models to assess importance of forage fish for predators; continue to monitor catches of linefish; continue to monitor seal population trends; quantify functional responses of predators to small pelagic prey and identify thresholds below which there are serious negative implications for predator stocks	Holistic management of small pelagic fishery, linefishery and hake fishery (trade-offs may be required depending on objectives set to optimise catches per fishery). Avoid threshold levels (limit reference levels) of pelagic fish below which the implications for predator stocks are detrimental	**
Benefit to seals of artificial food concentration (or discarded dead fish) that may cause an imbalance in the predator suite (ECOSYSTEM)	Population sizes of opportunistic versus specialist predators; seal diet composition	Seal diet studies were undertaken in the 1980s and 1990s, but need updating for current period Future: expand current observer programme to record pelagic fishery-seal interactions; quantify effects of artificial food aggregations on seal populations dynamics; undertake updated study of seal diet and feeding behaviour (to assess the role of dumped fish)	Reduce incidences of discarding (increase observer coverage). Investigate mitigation measures to reduce seal-fishery interactions Extreme action: if seal population shown to be unsustainable high, culling may be considered	*
Ecosystem impacts of an expanded round herring fishery (ECOSYSTEM)	Diet of predators such as snoek and hake; proportion of bycatch species including adult sardine taken in round herring fishing; snoek, hake and tuna catches	Monitor adult sardine bycatch in round herring fishery (currently 5% sardine bycatch in round herring fishery); diet studies of hake (limited) and snoek (more comprehensive) have been completed and could provide a baseline against which additional fishing effects on round herring could be gauged; extend trophic modelling (EwE, OSMOSE); use GIS data to derive indicators of spatial overlap etc. Future: expand acoustic surveys to cover the full distribution of round herring (need to extend surveys farther offshore beyond shelf); undertake full stock assessment of round herring; improve monitoring snoek and hake diet; assess trophic role of round herring (as forage fish for predators, as predators on anchovy and sardine larvae, as competitors of hake, anchovy and juvenile horse mackerel for zooplankton prey)	Current PUCL in place (100 000 tons); consider separate round herring TAC if round herring fishery expanded; adapt management measures to handle increased risk to the sardine resource (such as closing fishing areas if sardine bycatch in round herring fishery is considered too high); trade-offs may be required between sardine and round herring fisheries Holistic management of snoek, hake and other linefish and round herring fishery required (trade-offs may be necessary)	***

[1] Ease of implementation of management response/ability to manage
* Limited
** Fair
*** Good potential