Australian Government

Department of the Environment

2011 NOMINATION – *Lamna nasus*

Section 1 - Legal Status, Distribution, Biological, Ecological

Conservation Theme

1. Not applicable - there is no conservation theme for the 2011 assessment period.	**N/A**

Taxonomy

2. *What are the* ***currently accepted scientific and common name/s*** *for the species (please include Indigenous names, where known)?* *Note any other scientific names that have been used recently. Note the species authority and the Order and Family to which the species belongs (Family name alone is sufficient for plants, however, both Order and Family name are required for insects).*	**Scientific name** **Order:** Lamniformes **Family:** Lamnidae **Species:** *Lamna nasus* (Bonnaterre, 1788) **Synonyms:** *Lamna cornucubis* (Gmelin, 1789); *Lamna whitleyi* (Phillipps, 1935); *Squalus nasus* (Bonnaterre, 1788). **Common name** **English:** Porbeagle, Mackerel Shark **Danish:** Sildehaj **Swedish:** Hábrand, sillhaj **German:** Heringshai (market name: Kalbsfisch, See-Stör) **Italian:** Talpa (market name: smeriglio) **Spanish:** Marrajo sardinero; cailón marrajo, moka, pinocho **French:** Requin-taupe commun (market name: veau de mer) **Japanese:** Mokazame
3. *Is this* ***species conventionally accepted****? If not, explain why. Is there any controversy about the taxonomy?*	*Lamna nasus* is a conventionally accepted species.
4. *If* ***the species*** *is* ***NOT conventionally accepted****, please provide:* *(i) a taxonomic description of the species in a form suitable for publication in conventional scientific literature;* ***OR*** *(ii) evidence that a scientific institution has a specimen of the species and a written statement signed by a person who has relevant taxonomic expertise (has worked, or is a published author, on the class of species nominated)****,*** *that the person thinks the species is a new species.*	Not applicable.
5. *Is this species* ***taxonomically distinct*** *(Taxonomic distinctiveness – a measure of how unique a species is relative to other species)?*	Although porbeagle is taxonomically distinct, there are a number of similarities with the shortfin mako (*Isurus oxyrinchus*) – however the identification of whole sharks is straightforward using existing keys (Francis, 1998). Compagno (2001) also notes that *Lamna nasus* does not engage in spectacular leaps like the shortfin mako when hooked. It should be noted that the shortfin mako was placed on the 2009 Finalised Priority Assessment List (FPAL) to be assessed under EPBC Act criteria, with an assessment completion time of 30 September, 2011.

Australian Government

Department of the Environment

Legal Status

6. *What is the species' **current conservation status** under Australian and State/Territory Government legislation?*	*Lamna nasus* has not been listed under the Australian EPBC Act as a threatened species, nor any specific State/Territory Government legislation. However, the porbeagle is listed under the EPBC Act Migratory Species List due to its presence on Appendix II of the Bonn Convention. State fisheries management plans and anti-finning legislation applying more broadly to large sharks as a group might in practice affect the conservation status of porbeagle sharks. Nonetheless directed commercial and recreational fishing and/or unintended bycatch continues legally in some form in every state. No stock assessments exist for this species in Australian fisheries and the exploitation status is generally 'undefined'.
7. *Does the species **have specific protection** (e.g. listed on an annex or appendix) under other legislation or intergovernmental arrangements, e.g. Convention on International Trade in Endangered Fauna and Flora (CITES), Convention on Migratory Species (CMS).*	The IUCN Red List status assessment for porbeagle is Vulnerable globally, Critically Endangered in the Northeast Atlantic and the Mediterranean (past, ongoing and estimated future reductions in population size exceeding 90%), Endangered in the Northwest Atlantic (estimated reductions exceeding 70% that have now ceased through management) and Near Threatened in the Southern Ocean (Stevens *et al.*, 2005). 'Family Isurida' (now Lamnidae, including *L. nasus*) is listed in Annex 1 (Highly Migratory Species) of the UN Convention on the Law of the Sea (UNCLOS), and therefore should be subject to its provisions concerning fisheries management in international waters (CITES, 2010), effectively conveying the encouragement of cooperation among States but not formally or authoritatively ascribing management action. *Lamna nasus* is included in Appendix II of the Convention of Migratory Species (CMS). In 2009, CMS members agreed to a Memorandum of Understanding (MoU) on the Conservation of Migratory Sharks that went into effect in March 2010. The MoU applies to species listed in the CMS Appendices, including porbeagle. A conservation plan, which will form an annex to the MoU and may in due course stimulate conservation actions for the species, is currently in draft form and has yet to be agreed to by a meeting of the signatories (Lack and Sant, 2011). Nine Regional Fisheries Management Organisations (RFMOs) as well as several fishing nations and international unions have imposed bans on the practice of shark finning, which may in effect help to reduce the harvesting of hammerhead species; these include the tuna commissions in the Atlantic (i.e. ICCAT), Eastern Pacific and Indian Oceans, Australia, the USA, Brazil, and the EU (CITES, 2009). Additionally, ICCAT (The International Commission for the Conservation of Atlantic Tunas) requires its members to reduce mortality in fisheries targeting porbeagle until sustainable levels of harvest can be determined. NEAFC (The North East Atlantic Fisheries Commission) has banned directed fisheries in the international waters of the NEAFC regulatory area for porbeagle.

Description

8. *Give a brief description of the species'* ***appearance****, including size and/or weight, and sex and age variation if appropriate; social structure and dispersion (e.g. solitary/clumped/flocks).*	Compagno (2001) details *Lamna nasus* as having a heavy spindle-shaped body, moderately long conical snout, moderately large blade-like teeth with lateral cusplets, long gill slits, large first dorsal fin with an abruptly white free rear tip, minute, pivoting second dorsal and anal fins, strong keels on caudal peduncle, short secondary keels on caudal base and a crescentic caudal fin. The porbeagle is grey or bluish grey to blackish above and white below, with white abdominal colour terminating at rear end of pectoral bases. In some Southern Hemisphere adults the underside of the head is dark and abdomen blotched, but both may be white without dusky blotches. The first dorsal fin has an abruptly white or greyish white free rear tip. The size of porbeagles varies with sex, with average size at maturity for Southwest Pacific males and females being 165cm and 195cm respectively (Francis *et al.*, 2007), while an approximate maximum size for both sexes is 240cm (Dulvy *et al.*, 2008). Size at birth in the Southwest Pacific is between 72cm and 82cm (Dulvy *et al.*, 2008). *Figure 1 deleted due to copyright* Figure 1. Diagram of *Lamna nasus* (Compagno, 2001). The porbeagle may occur singly, in schools or in feeding aggregations. Fisheries catches in Europe indicate that the species has populational segregation by size (age) and sex (Compagno, 2001). Stock structure information specific to the southern hemisphere population is unknown (Fowler *et al.*, 2004).
9. *Give a brief description of the species'* ***ecological role*** *(for example, is it a 'keystone' or 'foundation' species, does it play a role in processes such as seed dispersal or pollination).*	The porbeagle feeds mainly on small to moderate-sized pelagic schooling fishes, including mackerel, pilchards and herring, also on demersal fishes including gadoids and other sharks, for instance spiny dogfish (Compagno, 2001). As with many other large shark species, the porbeagle is an apex predator, occupying a position near the top of the marine food web, but does not prey on marine mammals (Compagno, 2001; Joyce *et al.*, 2002). Other than humans *Lamna nasus* has few predators, although orcas and great white sharks may take them (Compagno, 2001). Stevens *et al.* (2000) warn that the removal of populations of top marine predators may have a disproportionate and counter-intuitive impact on trophic interactions and fish population dynamics, including by causing decreases in some prey species. Substantial evidence indicates that large assemblages of sizeable and efficient predators exert considerable influence on food web structure, diversity and ecosystem regulation, thus performing some keystone functions (Baum and Myers, 2004; Paine, 2002; Myers *et al*., 2007). For instance, having few natural predators, sharks help to regulate and maintain the balance of marine ecosystems as they feed on mid-trophic level predators and omnivores, directly limiting their populations, in turn affecting the lower trophic prey species of those animals, and so on to grazers, plants and algae (Griffin *et al*., 2008; Bascompte *et al*., 2005; Stevens *et al*., 2000; Myers *et al*., 2007). ECOSIM models of the Venezuelan shelf, the Alaska Gyre and the Grench Frigate shoals in Hawaii indicate the removal of sharks would significantly alter the relative abundances of species from lower trophic levels (Stevens *et al*., 2000). As switch predators, sharks may vary their prey targets when abundance is low, thereby allowing multiple prey species' populations to persist concurrently (Sergio *et al*., 2006; Griffin *et al*., 2008).

	Furthermore, sharks tend to target the sick and the weak members of prey populations, removing weaker genes from the pool, thereby maintaining the overall genetic fitness of prey populations. Apex predators have also been documented to influence the spatial distribution of potential prey as fear of predation causes some species to alter their behaviours regarding habitat use and activity level, leading to shifts in abundance in lower trophic levels, ultimately maintaining or enhancing biodiversity. They exert additional influence by providing essential food sources for scavengers (Frid *et al*., 2007; Griffin *et al*., 2008).

Australian Distribution

10. *Describe the species' **current and past distribution in the Australian distribution** and, if available, attach a map noting the source and the datasets used to create these.*	*Lamna nasus* has a circumglobal distribution in the Southern hemisphere, mainly in temperate and subantarctic waters between latitudes 30-55-^{0} S (Last and Stevens, 2009; Compagno, 2001). *Figure 2 deleted due to copyright* Figure 2. Distribution of *Lamna nasus* around Australia (FAO, 2011). The porbeagle is known to occur off southern Australia from southern Queensland to southern Western Australia, mainly on the continental shelf but also oceanic, occurring from the surface down to 370 m (Last and Stephens, 2009). *Figure 3 deleted due to copyright* Figure 3. Distribution of *Lamna nasus* in the Australian EEZ (Last and Stevens, 2009). There is not sufficient data available to enable reliable estimates on past declines in the extent of occurrence of the porbeagle within Australian waters, primarily due to the lack of data establishing baseline abundances of naturally occurring populations of the species (and other large sharks) in Australia's waters prior to the onset of industrialized commercial fishing (Baum and Myers 2004; Castro et al 1999; Walker 2007).
11. *What is the* **extent of occurrence** *(in km^2) for the species (described in Attachment A); explain how it was calculated and provide information on data sources.*	
a. *What is the **current** extent of occurrence?*	*Lamna nasus* is an active, warm-blooded epipelagic species inhabiting boreal and temperate waters, usually in sea temperatures of less than 18^{0}C and has been caught in high latitudes in 1^{0}C. Its distribution ranges from close inshore (especially in summer) to far offshore, where it is often associated with submerged banks and reefs (Campana and Joyce, 2004). However as a highly mobile species, the porbeagle does not necessarily remain in distinct geographical locations or habitat types within its range. Thus, its current extent of occurrence within Australian waters is potentially identical to its range of distribution, which has been described as occurring off southern Australia from southern Queensland to southern Western Australia, mainly on the continental shelf but also oceanic, occurring from the surface down to 370 m (Last and Stephens, 2009). The porbeagles extent of occurrence has not been determined in terms of square kilometers. Figures 2 and 3 (Q10) indicate the Australian distribution of the species.

b. *What data are there to indicate **past declines** in extent of occurrence (if available, include data that indicates the percentage decline over the past 10 years or 3 generations whichever is longer)?*	There is not sufficient data available to enable reliable estimates to be inferred on past declines in the extent of occurrence within Australia's EEZ due to the lack of data establishing baseline abundances of naturally occurring populations of *Lamna nasus* (and other large sharks) in Australia's waters prior to the onset of industrialized commercial fishing (Baum and Myers, 2004; Castro *et al*., 1999; Walker, 2007). Further, as a wide-ranging epipelagic species capable of roaming vast distances over its lifetime, it is not likely that declines will be readily observed in a spatial or geographical context, as the steep population declines being documented are not driven by loss of habitat as such, but rather by targeted capture and bycatch mortality. Thus declines are reflected in the *density* of the population occurring *within* its spatial/geographical extent of occurrence, rather than in the spatial extent of occurrence itself. Nonetheless, evidence reflecting declines in population density exists, but is limited within Australian waters. Due to overfishing the species now appears to be scarce, if not absent, in areas where it was formerly commonly reported, such as in the Western Mediterranean (Alen Soldo in litt. 2003).
c. *What data are there to indicate **future changes** in extent of occurrence (if available, include data that indicates the percentage decline over 10 years or 3 generations whichever is longer (up to a maximum of 100 years in the future) where the time period is a continuous period that may include a component of the past)*?	Despite a lack of information on the status of the Southern Ocean population of *Lamna nasus* it is caught by fisheries, and its meat and fins, for which there is huge demand, enter international trade (Fowler *et al.*, 2004). Porbeagle shark products include fresh, frozen and dried-salted meat for human consumption, oil and fishmeal for fertilizer, and fins for shark-fin soup (Compagno, 2001). The commercial value of the species has been documented through present and past market surveys (Fleming and Papageorgiou, 1997; Rose, 1996), with findings indicating that the demand for fresh, frozen or processed meat, as well as fins and other products of porbeagle is sufficiently high to justify the existence of an international market, in addition to national utilisation. Despite the high value of its meat, and unlike other high-priced fish such as swordfish, bluefin tuna and spiny dogfish, trade in porbeagle is not documented at species level. This makes it difficult to assess the importance and scale of its utilisation worldwide (Fowler *et al.*, 2004). Although porbeagle landings from the Southern Hemisphere are only reported to FAO by New Zealand, NZ catch data for the Pacific southwest, primarily bycatch in tuna longlines, but also trawl and bottom longline catches, sometimes exceed FAO's total Southern Ocean catch records (FAO FishSTAT, 2008). Porbeagle landings reported to FAO by New Zealand in the Pacific southwest are minor in comparison with those in the North Atlantic, although actual catches are likely to be much higher than this. The only trend data identified for southern stocks are records of declining captures of porbeagle by the Uruguayan pelagic tuna longline fleet during 1981-1998 (Domingo, undated). During the 1980s, only the two most valuable shark species were retained for their meat by this fleet: porbeagle and mako (*Isurus oxyrinchus*), representing about 10% of the total catch. By 1991, the abundance of these two species had fallen considerably (Fowler *et al.*, 2004).
12. *What is the **area of occupancy** (in km^2) for the species (described in Attachment A); explain how it was calculated and provide information on data sources*	
a. *What is the **current** area of occupancy?*	As an active, warm-blooded epipelagic species inhabiting boreal and temperate waters, *Lamna nasus* does not necessarily remain in distinct

	geographical locations or habitat types within its range. *Lamna nasus* moves throughout the extent of occurrence described previously in item 11, and therefore its area of occupancy within Australian waters is potentially identical to its range of distribution, which has been described as occurring off southern Australia from southern Queensland to southern Western Australia, mainly on the continental shelf but also oceanic, occurring from the surface down to 370 m (Last and Stephens, 2009). There is insufficient data regarding potential unoccupied habitats within the extent of occurrence, creating difficulties in accurately determining the current area of occupancy.
*b. What data are there to indicate **past declines** in area of occupancy (if available, include data that indicates the percentage decline over the past 10 years or 3 generations whichever is longer)?*	There are no readily available data that demonstrate past declines in the geographical area of the species' occupancy within Australian waters due to the absence of reliable baseline estimates of abundances of naturally occurring populations of *Lamna nasus* and other large sharks prior to the onset of industrialized commercial fishing (Baum and Myers, 2004; Castro *et al*., 1999; Walker, 2007). However the porbeagle now appears to be scarce, if not absent, in areas where it was formerly commonly reported (e.g. in the Western Mediterranean, Alen Soldo *in litt.* 2003).
*c. What data are there to indicate **future changes** in area of occupancy (if available, include data that indicates the percentage decline over 10 years or 3 generations whichever is longer (up to a maximum of 100 years in the future) where the time period is a continuous period that may include a component of the past)?*	There is insufficient data to indicate or predict with any accuracy future changes in the area of occupancy of the porbeagle in Australian waters. Due to the broad tolerance of environmental conditions, it is unlikely that there will be future changes in the area of occupancy of *Lamna nasus*, but without drastic and immediate changes to worldwide management practice, the population declines currently being documented with such frequency can only reasonably be expected to continue.
13. *How many **natural locations** do you consider the species occurs in and why? Where are these located? Provide latitude, longitude, map datum and location name, where available, in an attached table.* *The term 'location' defines a geographically or ecologically distinct area.*	*Lamna nasus* has a broad range of habitat within its area of occupancy, and thus the species does not occur within any number of specific 'natural locations'. There are separate stocks in the Northeast and Northwest Atlantic, and in the Southeast and Southwest Atlantic. The latter two stocks extend into the Southwest Indian Ocean and Southeast Pacific, respectively (Compagno *et al.,* 2001). The southern hemisphere population is known to occur off southern Australia from southern Queensland to southern Western Australia (Lack and Stephens, 2009). See Figures 2 and 3 for the species' Australian distribution, and Figure 4 for global.
14. *Give **locations of other populations**: captive/propagated populations; populations recently re-introduced to the wild; and sites for proposed population re-introductions. Note if these sites have been identified in recovery plans. Provide latitude, longitude, map datum and location name, where available, in an attached table.*	Porbeagle sharks have never been maintained in captivity and are probably unsuitable candidates for aquaria. Their life history traits also preclude captive breeding for commercial purposes (Fowler *et al.*, 2004).
15. *Is the species' **distribution severely fragmented?** What is the cause of this fragmentation? Describe any biological, geographic, human-induced or other barriers causing this species' populations to be fragmented.* *Severely fragmented refers to the situation in*	Very little is known about porbeagle shark spatial ecology, movement and habitat preference to inform conservation (Pade *et al.*, 2009). However, due to the wide distribution and habitat tolerance of *Lamna nasus* it is highly unlikely that the species' distribution within Australian waters is severely fragmented. Although, due to the cohabitation of sharks and humans in coastal environments, human induced fishing pressures may have some impact on localised genetic isolation.

which increased extinction risk to the taxon results from most individuals being found in small and relatively isolated subpopulations (in certain circumstances this may be inferred from habitat information). These small subpopulations may go extinct, with a reduced probability of recolonisation.	Globally, the species is fragmented with separate porbeagle stocks in the Northeast and Northwest Atlantic, and in the Southeast and Southwest Atlantic. The latter two stocks extend into the Southwest Indian Ocean and Southeast Pacific, respectively (Compagno *et al.,* 2001). Genetic studies identified two isolated populations, in the North Atlantic and Southern oceans (Pade *et al.* 2006). Mark-recapture in the North-West Atlantic since the 1960s has revealed seasonal migration in Canadian waters, with porbeagles captured by fisheries found mainly in northeastern waters during the spring, and more south-westerly in the summer and autumn, with some individuals caught 500-1000 km from their tagging location (Campana *et al*., 2003). It was concluded that these animals moved short to moderate distances along the continental shelves, and only one individual was observed to move far off the shelf (Francis *et al*., 2008). There is another record of one individual travelling 4,260km over open ocean (Francis *et al.,* 2008), although this was the only instance of 1,850 tagged individuals, indicating that trans-oceanic movement, or at least migration between continental margins and mid-oceanic islands, is possible but extremely rare. However, while *Lamna nasus* does not regularly roam across large distances, the circumglobal distribution of the species (at least in the Southern Hemisphere) implies some degree of historical trans-oceanic dispersal. Therefore, the available data from tagging and genetic studies are congruous in their conclusion that *Lamna nasus* appears to disperse readily across continuous habitat (continental shelves), and rarely across open oceans. The specific locations of groups of the species is still unknown, and whether they are in fact a) subpopulations connected by corridors between which some dispersal exists, thus comprising metapopulations; or b) subpopulations between which there is no reproductive exchange, and which in fact are in the process of speciation – are subjects for further study, as such information carries important implications for conservation.
16. *Departmental Use Only:*	

Global Distribution

17. *Describe the species' **global distribution**.*	The porbeagle shark is a large, fast-swimming, cold-temperature pelagic species that occurs on both sides of the North Atlantic Ocean, as well as in the South Atlantic and South Pacific Oceans, or more succinctly at high latitudes in both hemispheres (Campana and Joyce, 2004; Campana *et al.* 2008). Porbeagles grow to over 3m total length, inhabiting waters between 5 and 20^{0}C (Campana and Joyce, 2004) in temperate seas of the North and South Atlantic, as well as the Mediterranean and the Baltic seas (Compagno, 2001). In the Southern hemisphere the porbeagle has a circumglobal distribution in temperate and subantarctic waters, mainly in latitudes 30-55-^{0} S (Last and Stevens, 2009; Compagno, 2001). They are common in oceanic waters around New Zealand. Tagging data suggest that north-east and north-west Atlantic stocks of Porbeagles are essentially separate, and there appears to be no genetic exchange between Northern and Southern Hemisphere populations (Last and Stevens, 2009). *Figure deleted due to coyright* Figure 4. Global distribution of *Lamna nasus* (IUCN Red List).

18. *Give an overview of the **global population**'s size, trends, threats and security of the species outside Australia.*	The conservation status of the porbeagle is of major concern because of the drastic decline in catches from targeted fisheries in the North Atlantic and continuing exposure of the species to intensive high-seas pelagic longline fisheries (with finning and capture trauma contributing to mortality) wherever it occurs. The porbeagle's wide distribution in coastal and shelf waters subjects the species to intensive domestic fisheries pressure – both as targeted catch and bycatch - within EEZs throughout the world; while its occurrence in pelagic habitat exposes it to exploitation by multinational fisheries occupying international waters (Camhi *et al.*, 2009). A contributing factor to declines such as those recorded in the Atlantic (Camhi *et al.,* 2009) may be the propensity of porbeagles to aggregate for seasonal feeding opportunities in coastal areas where they become readily available to fisheries. North Atlantic fisheries are relatively well-documented and under regulation, but not those of the Southern Hemisphere with the exception of New Zealand (Compagno, 2001). In what may be the clearest management advice yet given for a pelagic shark, in 2006 ICES (the International Council for the Exploration of the Sea) recommended that "no targeted fishing for [Northeast Atlantic] porbeagle should be permitted on the basis of their life history and vulnerability to fishing (Camhi *et al.*, 2009). The structure of exploited populations is highly unnatural, with very few large mature females present. This results in an extremely low reproductive capacity in heavily fished, depleted stocks (e.g. Campana *et al.* 2001), and could be due to the larger females being more valuable as a byproduct. *Lamna nasus* meets the guidelines suggested by FAO for the listing of commercially exploited aquatic species. It falls into FAO's lowest productivity category of the most vulnerable species; those with an intrinsic rate of population increase of <0.14 and a generation time of >10 years (FAO, 2001). Some documented stock declines of *Lamna nasus* have clearly exceeded the qualifying level of 20% or less of historic baseline, or are declining so rapidly as to qualify for Appendix I listing under the FAO guidelines (Fowler *et al.*, 2004). Meat of *Lamna nasus* is highly valued, particularly in the European Union (EU). The large fins of the porbeagle increase their catch value. *Lamna nasus* is taken in target fisheries and is a retained and utilised economically-important component of multispecies fisheries. Its meat and fins enter international trade, but are generally not recorded at species level. Other products (liver oil, cartilage, jaws, teeth and skin) are less fully utilised (Fowler *et al.*, 2004).
19. *Explain the **relationship** between the Australian population and the global population, including:*	
*a. What **percentage** of the global population occurs **in Australia**;*	As there is no data reliably defining populations of *Lamna nasus* either globally or in Australian waters, it is not possible to quantify the percentage of the global population, or even the Southern hemisphere population, found strictly within Australian waters.
*b. Is the Australian population **distinct**, geographically **separate** or does part or all of the population move in/out of Australia's jurisdiction (give an overview; details in Movements section);*	Due to the ambiguity surrounding the species' transoceanic migratory movements, the lack of definitive knowledge concerning specific locations of subpopulations, and the degree to which these subpopulations naturally interact, it is unknown whether there are any populations which occur entirely within Australia's EEZ for any given period of time. The southern oceans porbeagle population is highly migratory and occupies a circumglobal band around the southern hemisphere (Last and Stevens, 2009; Compagno, 2001), and genetic information has demonstrated that this population is geographically separate from that of

	the North Atlantic (Pade *et al.* 2006). However, mark-recapture in the North-West Atlantic since the 1960s has revealed seasonal migration in Canadian waters, with porbeagles captured by fisheries found mainly in northeastern waters during the spring, and more south-westerly in the summer and autumn, with some individuals caught 500-1000 km from their tagging location (Campana *et al*., 2003). It was concluded that these animals moved short to moderate distances along the continental shelves, and it is therefore likely that the majority of *Lamna nasus* occuring in Australian waters will remain within the relative bounds of the Australian continental shelf, although there is no specific scientific data to indicate this.
c. *Do **global threats** affect the Australian population*?	As previously stated, due to ambiguity surrounding possible transoceanic migratory movements, the lack of definitive knowledge concerning specific locations of subpopulations and the degree of natural interaction among them, the extent to which any populations are exclusively "Australian" in jurisdiction is unknown. Thus the effect the major worldwide threats of overfishing from directed fisheries or as bycatch from intensive international fisheries has specifically on Australian populations of *Lamna nasus* is unable to be quantified at this time. It is however likely that the same threats facing *Lamna nasus* globally threaten the species in Australian waters. The most severe global threat to *Lamna nasus* is overfishing by directed fisheries, and although there are no directed porbeagle fisheries operating within the Australian EEZ, it is possible that the directed porbeagle fishery in New Zealand affects the species' occurrence in Australian waters due to its relative proximity. New Zealand catch data for the Pacific southwest, primarily bycatch in tuna longlines, but also trawl and bottom longline catches, sometimes exceed FAO's total Southern Ocean catch records (FAO FishSTAT, 2008). In the Southern Hemisphere, most of the porbeagle catch comes as bycatch in tuna longline fisheries, where landings are small but may be underreported (Francis *et al*., 2001, 2008). Porbeagle is also a target for anglers in countries such as Australia, Canada, Ireland, New Zealand, the United Kingdom and the United States (Babcock, 2008). The domestic longline fishery operating off the east coast of Australia incidentally takes over 80 non-target species, and a significant amount of this non-target catch is retained as byproduct. Due to the difficult economic outlook faced by these fisheries (resulting from overcapacity, localized depletions, increased fuel prices, lowered availability of target species and reduced access to export markets) byproduct has become a relatively more important part of some fishers' catch and income (Bromhead *et al.*, 2005). Fowler *et al.* (2004) state that the high value of porbeagle shark meat means that it is not appropriate to describe these exploited incidental captures as 'bycatch'. To cite just one example, logbook data from the Australian Eastern Tuna and Billfish Fishery (Lynch, 2003; 2004; 2005; Evans, 2007) indicates the number of porbeagle caught as bycatch in the fishery dropped significantly between 2002 – 2006, despite bycatch of species with little commercial value, such as manta rays, remaining constant.

Data Range	No. Kept	No. Discarded	Retained KG	Total Caught
2002-2003	61	121	1,159	182
2003-2004	69	84	1,770	153
2004-	14	16	765	30

2005				
2005-2006	12	11	505	23
Total	**156**	**232**	**4,199**	**388**

Table 1. Reported longline retained and non-retained porbeagle catch from the Eastern Tuna and Billfish Fishery.

These figures could be indicative of a population collapsing under the combined pressure of bycatch from multiple longline (and other) fishing operations within Australian waters. With the survival rates of unprocessed discarded sharks being unknown (MFSC, 2008), the kept and discarded catch from 2003-2004 alone, bycatch from just one Australian fishery, may have exceeded the entire porbeagle annual catch limit in place in the United States (1.7t) by a significant factor (Lack and Sant, 2011).

Surveys and Monitoring

20. *Has the species been* ***reasonably well surveyed****?*

Provide an overview of surveys to date and the likelihood of the species' its current known distribution and/or population size being its actual distribution and/or population size. Include references documenting the current known distribution and location records and survey methodology where available.

Like many other species of elasmobranch, the global population of *Lamna nasus* has not been well surveyed, and their management is characterized by a debilitating lack of quality biological data and baseline abundance estimates. While many gaps in bycatch data for sharks in general exist, Bonfil (1994) estimated that by the end of the 1980s approximately 12 million elasmobranchs (up to 300,000t) were taken as bycatch annually on the high seas alone, with 4 million taken in driftnet fisheries and over 8 million on tuna fishery longlines primarily from Asia. The species composition of these catches is virtually unknown, other than that most were sharks (Camhi *et al.*, 2009).

However, Camhi *et al.* (2009) state that fisheries for porbeagle in the North Atlantic are among the best-studied shark fisheries in the world and offer the most complete picture to date of the effect that fishing can have on a highly migratory, wide-ranging shark (Camhi, 2008; Campana *et al.*, 2008).

The Northwest Atlantic porbeagle population has been subject to a full stock assessment – the first for any pelagic shark. The target fishery for Northeast Atlantic porbeagles began in the 1930s. Fisheries were intense and unregulated, and collapsed in the 1960s, and in 1961 much of the effort shifted to the virgin Northwest Atlantic population, which also collapsed within a decade: Landings peaked at over 9,000t in 1964, but declined to about 200t in 1970 and hovered below 500t through the 1980s (Campana *et al.*, 2002b, 2008; FAO, 2009).

The target fishery (almost exclusively of Canadian vessels) expanded once again in the early 1990s, and once again collapsed: Catches in 1995 peaked at 1,395t, but declined by almost 90% to 146t by 2003 (FAO, 2009). A Canadian quota of 250t, imposed in 2002, was inadequate to allow population recovery.

Despite implementation of increasingly stringent Canadian management since 1994 in the Northwest Atlantic, the population hovers at about 11% of its 1961 virgin biomass. Scientists estimate that even if target fisheries were closed and strict limits placed on porbeagle bycatch, it could take at least 30–60 years for this population to recover. Scientists with the Committee on the Status of Endangered Species Wildlife in Canada (COSEWIC) declared porbeagle Endangered in 2004 and recommended the species for listing under Canada's Species at Risk Act, but the proposal was rejected for economic and monitoring reasons. In 2008, the Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) warned that mortality from a new porbeagle fishery in international waters just outside the Canadian EEZ, when added to Canadian landings, would

	lead to a population "crash" (NAFO, 2008).
21. *For species nominated as extinct or extinct in the wild, please provide details of the* ***most recent*** *known* ***collection****, or authenticated* ***sighting*** *of the species, and whether additional populations are likely to exist and the basis for this assertion. Provide latitude, longitude, map datum and location name, where available.*	Not applicable.
22. *Is there an ongoing* ***monitoring programme****? If so, please describe the extent and length of the programme.*	Monitoring of catch records is by far the most common type of monitoring occurring for shark species globally; however for reasons previously discussed it does not consistently provide accurate data and in fact a great deal of mortality is intentionally never recorded. Shark fisheries in general suffer from a debilitating lack of baseline information from which to base assessments. Data for fisheries that impact on shark populations in general through bycatch, such as Australian Tuna and Billfish Longline Fisheries, is collected mainly through logbooks, catch disposal records and observer data. The Australian Fisheries Management Authority (AFMA) logbook provides for the recording of information on the location, time and method of fishing as well as the resultant catch for each fishing operation, but while logbook information has proved reasonably reliable for target species, information on byproduct, bycatch and fishing practices has been less reliable (AFMA, 2008). Although catches are reported to ICES, there is no monitoring of porbeagle populations in the Northeast Atlantic. In the Northwest Atlantic, monitoring of porbeagle catches is undertaken by Canadian and US scientific observer programs, which trigger management decision when the quota is reached (Campana *et al.*, 2003). The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) does not monitor porbeagle catches in the southern ocean (Fowler *et al.*, 2004). There are no known formal, ongoing, large-scale, species-specific, fisheries-independent population monitoring programs for which information is readily available at present.

Life Cycle and Population

23. *What is the species' total population size in terms of* ***number of mature individuals****? How were population estimates derived and are they reliable? Are there other useful measures of population size and what are they?* In the absence of figures, terms such as common, abundant, scarce can be of value.	There is insufficient data to reliably define the total population size of *Lamna nasus* due to a lack of species-specific population estimates undertaken to date. However, the status of the Northwest Atlantic porbeagle population was assessed using an age- and sex-structured, forward projecting population model that used the landings, catch-per-unit-effort, proportions-at-length in the catch, and tagging data to estimate population size. Three variants of the model were used, each with a different assumed productivity scenario (DFO, 2005). Estimates of the Northwest Atlantic population size in 2005 are similar among the models: 188,000 to 195,000 fish. The estimated number of mature females was in the range of 9,000 to 13,000 fish, or about 15% of the population. Based on the model estimates, the population was 12% to 24% its size in 1961, and female spawner abundance had declined to about to 12% to 15% of its 1961 level (DFO, 2005).
24. *Does the species occur in a* ***number***	There is insufficient data to indicate the presence of distinct

<table>
<tr><td>of smaller populations? How many? For each population give the locality, numbers and trends in numbers and tenure of land (include extinct populations). Can these be considered to be subpopulations and why?
Subpopulations are defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange.</td><td>subpopulations of Lamna nasus in Australian waters, however geographically isolated populations such as those of the Southern Oceans and the North Atlantic can be differentiated using genetic techniques (Pade et al. 2006).

The IUCN Red List status assesses the porbeagle as three smaller populations as well as globally, these being the Northeast Atlantic and the Mediterranean, the Northwest Atlantic, and the Southern Ocean (Stevens et al., 2005).

<table><tr><th>Population</th><th>Threat Category</th></tr><tr><td>Global</td><td>Vulnerable</td></tr><tr><td>Northeast Atlantic and the Mediterranean</td><td>Critically Endangered</td></tr><tr><td>Northwest Atlantic</td><td>Endangered</td></tr><tr><td>Southern Ocean</td><td>Near Threatened</td></tr></table>Table 2. Threat categories of porbeagle populations (Stevens et al., 2005).</td></tr>
<tr><td>25. Provide details on ages of the following:</td><td></td></tr>
<tr><td>a. sexual maturity;</td><td>In the Southern hemisphere age at maturity for males is 8-11 years and for females it is 13-18 years (Last and Stevens, 2009).</td></tr>
<tr><td>b. life expectancy;</td><td>The life expectancy of Lamna nasus is between 26 and 45 years in the Northern Atlantic (Campana et al., 2003), but longevity may be about 65 years in the Southern Hemisphere population (Last and Stevens, 2009).</td></tr>
<tr><td>c. natural mortality.</td><td>Prior to the intensive fishery that greatly reduced the numbers of this shark in European waters, the annual mortality for the species was an estimated 18% under low human exploitation and probably minimal predation pressure from other species. Recent research in Atlantic Canada indicates that the instantaneous natural mortality rate of the porbeagle is about 0.1 (Campana et al., 1999).</td></tr>
<tr><td>26. Reproduction</td><td></td></tr>
<tr><td>For plants: When does the species flower and set fruit? What conditions are needed for this? What is the pollinating mechanism? If the species is capable of vegetative reproduction, a description of how this occurs, the conditions needed and when. Does the species require a disturbance regime (e.g. fire, cleared ground) in order to reproduce?</td><td>Not applicable.</td></tr>
<tr><td>For animals: provide overview of breeding system and of breeding success, including: when does it breed; what conditions are needed for breeding; are there any breeding behaviours that may make it vulnerable to a threatening process?</td><td>Young are probably born from April to September, with a peak in the winter months of June and July in the southern hemisphere. An extended mating period (in comparison to the late summer in European waters) seems to exist for southern hemisphere populations around Australia and New Zealand, with breeding likely to occur every year (Compagno, 2001).

The porbeagle is ovoviviparous, and reproduction is oophagous with 1-5 (usually 4) pups born in winter in the Australasian region. The gestation period is 8-9 months with a one year reproductive cycle. Age at maturity for males is 8-11 years and for females it is 13-18 years; longevity may be about 65 years. Individuals off Australasia reach a smaller maximum size than their Atlantic counterparts, with males maturing at about 165cm and females at 200cm (Last and Stevens, 2009). Foetuses grow enormously by feeding on fertilized eggs, and develop grotesquely expanded abdomens and branchial regions (Compagno, 2001).</td></tr>
</table>

	Although segregation by sex and age is common among sharks and other vertebrates, including the porbeagle in at least some regions (Fowler *et al.*, 2004), it is possible that sex-biased exploitation may occur for porbeagle shark in European waters which may exacerbate declines already observed (Wearmouth and Sims, 2008).
27. *What is the* ***population trend*** *for the entire species?*	
a. *What data are there to indicate* ***past decline*** *in size (if available, include data on rate of decline over past 10 years or 3 generations whichever is longer)?*	In light of the comparable intensity of longline and other pelagic fisheries in all oceans and the similar catch composition, serious declining trends in Northwest Atlantic shark abundances are most likely reflective of a common global phenomenon (Baum *et al*., 2003). Furthermore, it is likely that these trends are underestimated, as researchers' conclusions were based on reported catch data, which thus disregard illegal and unreported catch. The IUCN Red List assesses the global population trend for *Lamna nasus* to be declining (Stevens *et al.*, 2006), and logbook data from the Australian Eastern Tuna and Billfish Fishery (Lynch, 2003; 2004; 2005; Evans, 2007) indicates the number of porbeagle caught as bycatch in the fishery dropped significantly between 2002 – 2006, despite bycatch of species with little commercial value, such as manta rays, remaining constant (see Table 1 for a summary of this data). These figures could be indicative of a population collapsing under the combined pressure of bycatch from multiple longline (and other) fishing operations within Australian waters. The target fishery for Northeast Atlantic porbeagles began in the 1930s. Fisheries were intense and unregulated, and collapsed in the 1960s, and in 1961 much of the effort shifted to the virgin Northwest Atlantic population, which also collapsed within a decade: Landings peaked at over 9,000t in 1964, but declined to about 200t in 1970 and hovered below 500t through the 1980s (Campana *et al*., 2002b, 2008; FAO, 2009). The target fishery (almost exclusively of Canadian vessels) expanded once again in the early 1990s, and once again collapsed: Catches in 1995 peaked at 1,395t, but declined by almost 90% to 146t by 2003 (FAO, 2009). A Canadian quota of 250t, imposed in 2002, was inadequate to allow population recovery. Furthermore, population declines of porbeagle of up to 90% of their historical biomass have been suggested for the Northeast Atlantic (Stevens et al., 2006). The species now appears to be scarce, if not absent, in areas where it was formerly commonly reported (e.g. in the Western Mediterranean, Alen Soldo in litt. 2003). There is no trend data identified for Australian porbeagle stocks, and very few for southern ocean stocks in general. One example lies in records of declining captures of porbeagle by the Uruguayan pelagic tuna longline fleet during 1981-1998 (Domingo, undated). During the 1980s, only the two most valuable shark species were retained for their meat by this fleet: porbeagle and mako (Isurus oxyrinchus), representing about 10% of the total catch. By 1991, the abundance of these two species had fallen considerably.
b. *What data are there to indicate* ***future changes*** *in size (if available, include data which will indicate the percentage of decline over 10 years or 3 generations whichever in longer (up to a maximum of 100 years in the future) where the time period is a continuous period that may include a*	There is no data readily available that indicates future changes in the size of *Lamna nasus* populations, however if there is no reduction in fishing exploitation of the porbeagle (targeted catch, bycatch, legal and illegal), no improvement in management processes and/or mitigative measures implemented, population declines of the species can only be expected to continue and there is a risk of population crashes such as those aforementioned occurring.

component of the past)?	
28. *Does the species undergo **extreme natural fluctuations** in population numbers, extent of occurrence or area of occupancy? To what extent and why?* **Extreme fluctuations** can be said to occur in a number of taxa when population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude (i.e. a tenfold increase or decrease).	There is insufficient data to show that *Lamna nasus* undergoes extreme natural fluctuations in population size, and given its slow growth rate, low natural mortality and low fecundity it is highly unlikely that such fluctuation would occur.
29. *What is the **generation length** and how it is calculated?* **Generation length** is the average age of parents of the current cohort (i.e. newborn individuals in the population). Generation length therefore reflects the turnover rate of breeding individuals in a population. Generation length is greater than the age at first breeding and less than the age of the oldest breeding individual, except in taxa that breed only once. Where generation length varies under threat, the more natural, i.e. pre-disturbance, generation length should be used.	Generation length calculations necessarily incorporate age at maturity and life expectancy values; neither has been definitively determined for *Lamna nasus* as yet. Estimates of age at maturity vary widely but for the Southwest Pacific are thought to be approximately 13-18 years for females and 8-11 for males (Last and Stevens, 2009). Natural mortality values could only be found for the Northwest Atlantic population in the literature, and were 0.10, 0.15 and 0.20 for immatures, mature males and mature females respectively (Campana *et al.*, 2001). Using these figures generation length can be approximated with the formula GL = age of first reproduction + (1/natural mortality rate). Assuming natural mortality rate is similar in the Southwest Pacific and Northwest Atlantic, this can be given as: GL = ((15.5+9.5)/2) + (1/((0.15+0.20)/2) = 12.5 + (1/0.175) = approximately 18.214 years However, these generation time approximations have a high element of error, as much information is unknown, such as whether the species remains reproductively active throughout its mature years or whether it undergoes senescence or at what age. Furthermore, the best approximations of natural mortality used may be exaggerated, as measures of longevity for individuals in the Northwest Atlantic (29-45 years, Campana *et al.*, 2008) are significantly lower than those in the Southwest Pacific, thought to be approximately 65 years (Dulvy *et al.*, 2008). Regardless, a generation length of approximately 18 years as a best estimate is an appropriate figure, and one agreed upon for the IUCN Red List for porbeagle stocks worldwide (Stevens *et al.*, 2006).
30. *Identify **important populations** necessary for the species' long-term survival and recovery? This may include: key breeding populations, those near the edge of the species' range or those needed to maintain genetic diversity.*	There are no data readily available identifying populations of particular importance to the survival of *Lamna nasus*. However, genetic studies identified two isolated populations, in the North Atlantic and Southern oceans (Pade *et al.* 2006), and the IUCN has differing classifications for three smaller populations as well as globally, these being the Northeast Atlantic and the Mediterranean, the Northwest Atlantic, and the Southern Ocean (Stevens *et al.*, 2005). From a conservation perspective, each subpopulation is potentially as important as the next, since strong population structure built by a high degree of reproductive isolation suggests that regional populations, if depleted, may not replenish themselves rapidly through immigration, but more likely slowly through reproduction. Therefore, practical management for sharks like *S. lewini* should include not only population-specific protection in the adult phase, but also access to regional nurseries (Bowen and Roman, 2005).
31. *Describe any **cross-breeding** with other species in the wild, indicating how*	There is no evidence to suggest the occurrence of cross-breeding with other species in the wild. To date this behaviour has not been observed or

frequently and where this occurs.	recorded.
32. *Departmental Use only:*	

Populations In Reserve

<table>
<tr>
<td>33. Which populations are in reserve systems? Which of these are actively managed for this species? Give details.</td>
<td>

No species-specific mechanisms are currently in place to manage *Lamna nasus*, though sharks in general may be afforded some protection in reserve areas.

In Australian waters, the porbeagle is likely found within Marine Protected Areas in the species' range, occurring either permanently or occasionally. However, none of these are actively managed for *Lamna nasus*.

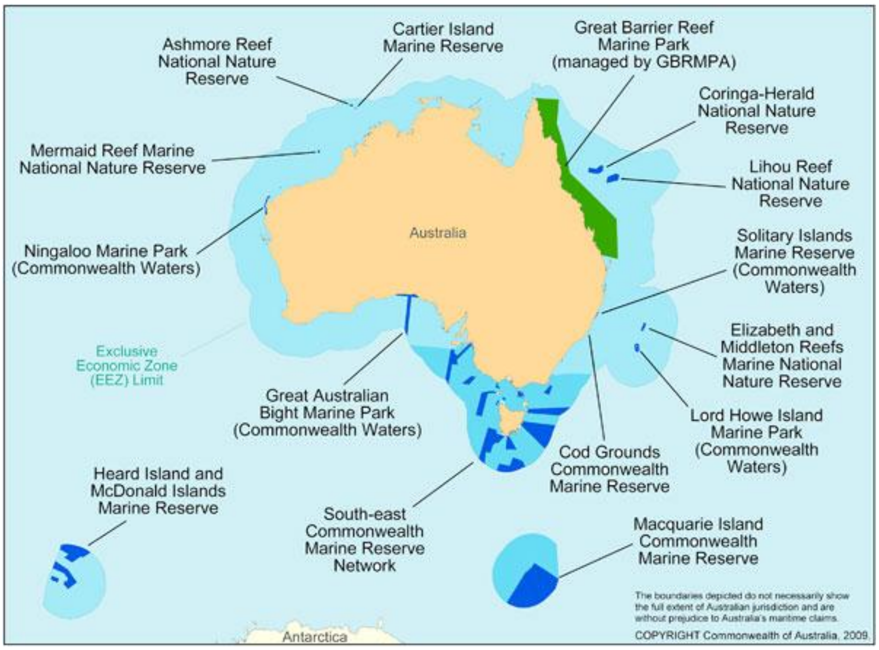

Figure 5. Australian Marine Protected Areas (DSEWPaC, 2010).

A contributing factor to declines such as those recorded in the Atlantic (Camhi *et al.,* 2009) may be the propensity of porbeagles to aggregate for seasonal feeding opportunities in coastal areas where they become readily available to fisheries. The purpose of localised aggregations of porbeagle shark in shallow coastal waters is not known but most likely relate to feeding opportunities (Pade *et al.,* 2009).

Given that declines of porbeagle of up to 90% of their historical biomass have been suggested in the North-East Atlantic (Stevens *et al.*, 2006), identifying aggregation areas occupied seasonally by this species will be important in the context of marine protected areas (Pade *et al.*, 2009).

</td>
</tr>
</table>

Habitat

34. *Describe the **species' habitat** (e.g. aspect, topography, substrate, climate, forest type, associated species, sympatric species). If the species uses different habitats for different activities (e.g. breeding, feeding, roosting, dispersing, basking), then describe each habitat.*	*Lamna nasus* is an active, warm-blooded epipelagic species inhabiting boreal and temperate waters, sea temperatures 1-18^{0}C. Its distribution ranges from close inshore (especially in summer) to far offshore, where it is often associated with submerged banks and reefs (Campana and Joyce, 2004). However as a highly mobile species, the porbeagle does not necessarily remain in distinct geographical locations or habitat types within its range. The porbeagle is found in waters of the continental shelf as well as offshore down to depths of 200m, sometime even deeper (Fowler *et al.*, 2004). They have occasionally been caught at depths of 350-700m (Campana and Joyce, 2004; Compagno, 2001).

	In Pade *et al.*, 2009, four porbeagles were tagged and tracked in the Northeast Atlantic. The tagged sharks demonstrated a wide vertical distribution occupying depths from the surface to 552 m, and a water temperature range from 9.8 to 18.5^{0}C. The maximum depths of sharks tagged largely reflected the sea bottom depths of the shelf/shelf-edge habitats they occupied. When occupying shelf waters the sharks appeared to utilize much of the water column available to them. Based on data collected in Northwest Atlantic fisheries in 1999 and 2000, Campana *et al.* (1999) found that porbeagle were caught at a mean temperature of 7.4^{0}C, with 50% being caught between 5-10^{0}C. There was no significant seasonal pattern in temperature, suggesting that the porbeagle adjusted their location to occupy the preferred temperature range.
35. *Does the species use* ***refuge habitat****, e.g. in times of fire, drought or flood? Describe this habitat.*	As an active swimmer, *Lamna nasus* is likely capable of retreating to zones of lesser impacted water in times of flood or storm.
36. *Is the* ***extent or quality*** *of the species' habitat* ***in decline****? If the species uses different habitats, specify which of these are in decline.*	Critical habitats for *Lamna nasus* and threats to these habitats are unknown. High levels of heavy metals (particularly mercury) in such habitats would be of concern because of their bioaccumulation and bio-magnification in top oceanic predators, but their impacts on population fitness is unknown. Potential effects of climatic changes on world ocean temperatures and related biomass production could impact porbeagle food sources (Fowler *et al.*, 2004). Moreover, climate change and its many associated effects (e.g. ocean acidification, water temperature rise, altered current flows, limited nutrient availability and coral bleaching) may potentially result in any number of implications for sharks; however it is inappropriate to speculate about such implications at present, as management of such potential outcomes is far beyond the scope of this document.
37. *Is the species part of, or does it rely on, a* ***listed threatened ecological community****? Is it associated with any other* ***listed threatened species****?*	*Lamna nasus* is not solely part of and does not solely rely on a listed Threatened Ecological Community. Additionally the porbeagle is not associated with any listed threatened species in particular, but as an apex predator likely interacts with one or more of these species as part of a balanced ecosystem.

Feeding

38. *Summarize the species'* ***food*** *items or sources and timing/seasonality.*	The diet of porbeagles of all sizes, and at all times of the year, is almost exclusively fish and cephalopods. Other elasmobranchs were occasionally eaten by large porbeagle sharks, but marine mammals and birds were never found in the stomachs (Campana *et al.*, 1999). Stomach content analyses of 533 porbeagle collected over a yearly period demonstrated that their diet was dominated by fish (91% by weight), primarily alepisaurids, gadids, pleuronectids and clupeids (S.E. Campana, unpublished data, in Campana *et al.*, 2002a). Compagno (2001) specified further by stating that *Lamna nasus* feeds on small to moderate-sized pelagic schooling fishes, including mackerel and pilchards and herring, but also feeds on demersal fishes including various gadoids such as cod, haddock, cusk, whiting and hake, icefishes and John Dory. Chondrichthyan prey includes dogfish and tope sharks, while cephalopod prey includes squid and cuttlefish.
39. *Briefly describe the species'* ***feeding behaviours****, including those that may make the species vulnerable to a threatening process.*	The porbeagle is a proverbially voracious feeder and is known to scavenge hooked fishes, including cod from longlines (Compagno, 2001). This behaviour makes *Lamna nasus* further vulnerable to the threatening process of 'bycatch' from longline fisheries.

	The porbeagle is the second most common shark as bycatch of the New Zealand longline fishery (Compagno, 2001). A considerable bycatch fishery for porbeagle by Japanese longliners and likely the pelagic fishing fleets of other countries has existed in the southern Indian Ocean and probably elsewhere in the southern hemisphere. Although the catch is poorly known and may be little-utilized except for fins, *Lamna nasus* has figured as complimentary bycatch of the Japanese longline fishery for southern bluefin tuna off Tasmania (Compagno, 2001).

Movement Patterns (fauna species only)

40. *Describe any relevant* ***daily and seasonal pattern of movement*** *for the species, or other irregular patterns of movement, including relevant arrival/departure dates if migratory.*	Pade *et al.* (2009) document that mark-recapture in the North-West Atlantic since the 1960s has revealed seasonal migration in Canadian waters, with porbeagles captured by fisheries found mainly in northeastern waters during the spring, and more south-westerly in the summer and autumn, with some individuals caught 500-1000 km from their tagging location (Campana *et al.*, 2003). It was concluded that these animals moved short to moderate distances along the continental shelves. Number tag returns from commercial fisheries in the North-East Atlantic reported *L. nasus* recaptures occurring mainly in the same area as they were released off southwest England and northern France, with only one individual being recaptured far to the north (2,370km straight line distance) (Stevens, 1976, 1990). Of some 1,850 tags deployed, only one individual is known to have crossed the Atlantic, from Ireland to Canada, traversing some 4,260 km (Francis *et al.*, 2008) suggesting ocean-basin-scale movements are possible but likely rare. Very little is known about porbeagle shark spatial ecology, movement and habitat preference to inform conservation (Pade *et al.*, 2009). The porbeagle has a propensity to aggregate for seasonal feeding opportunities in coastal areas, the purpose of these localised aggregations in shallow coastal waters is not known but most likely relate to feeding opportunities (Pade *et al.,* 2009).
41. *Give details of the species'* ***home ranges/territories***.	Very little is known about porbeagle shark spatial ecology, movement and habitat preference to inform conservation (Pade *et al.*, 2009), and specific locations of home ranges/territories within Australia are unknown. In the North-West Atlantic, porbeagles are believed to be present in the shallower waters of the shelf during the spring and summer, before heading into deeper water during the winter (Campana *et al.*, 2002b), a pattern consistent with the findings of Pade *et al.* (2009) in the North-East Atlantic.

Survey Guidelines

42. *Give details of the* ***distinctiveness and detectability*** *of the species.*	The porbeagle is a taxonomically distinct species. Although there are a number of similarities with the shortfin mako (*Isurus oxyrinchus*), the identification of whole sharks is straightforward using existing keys (Francis, 1998). Compagno (2001) also notes that *Lamna nasus* does not engage in spectacular leaps like the shortfin mako when hooked. Being a marine species, the detectability of the porbeagle is reliant on water conditions.
43. *Describe* ***methods for detecting species*** *including when to conduct surveys (e.g. season, time of day, weather conditions); length, intensity and*	In the case of fisheries-derived studies from direct capture fisheries, management should require landing carcasses with fins intact or naturally attached, as landing only fins makes identification to species-level extremely difficult (Musick *et al.*, 2000). Field guides highlighting

pattern of search effort; and limitations and expert acceptance; recommended methods; survey-effort guide.	morphological distinctions among similar species should be provided onboard fishing vessels to facilitate accurate identification and improve record-keeping and statistics, and observer programs employing professionals properly trained in identification techniques, should be encouraged and utilized wherever possible. Furthermore, given the quantities of shark biomass entering the fin trade – the vast majority of which is illegally-obtained or unrecorded – genetic identification methods are emerging as an important source of data for estimating species composition and catch. Polymerase chain reaction assays and DNA sequencing methods (Clarke *et al*., 2006) have successfully been applied to products appearing in the Hong Kong fin market to identify the species comprising the catch composition of shark-derived products for sale in such markets.

Section 2 - Threats and Threat Abatement

Threats

44. *Identify* ***past, current and future threats****, to the species indicating whether they are actual or potential. For each threat, describe:*	
a. ***how and where*** *it impacts on this species;*	The porbeagle is found most often on the continental shelf, but also in oceanic waters (Last and Stephens, 2009), thus the species is susceptible to intensive domestic fisheries within the EEZs of coastal nations, as well as multinational fisheries on the high seas. A further contributing factor to declines such as those recorded in the Atlantic (Camhi *et al.,* 2009) may be the propensity of porbeagles to aggregate for seasonal feeding opportunities in coastal areas where they become readily available to fisheries. Intensive directed fishing for the valuable meat of porbeagle sharks has been the major threat to populations during the twentieth century, and resulting population collapses have occurred as a result on several occasions (e.g. Campana *et al*., 2002b, 2008; FAO, 2009). The porbeagle shark is a valuable secondary target of many fisheries, particularly longline fisheries, but also gill nets, driftnets, pelagic and bottom trawls, and handlines. Examples include the demersal longlines for Patagonian toothfish (*Dissostichus eleginoides*) in the southern Indian Ocean and by the Argentinian fleet (Victoria Lichtstein, CITES Management Authority of Argentina, *in litt.* to TRAFFIC Europe, 27 October 2003), and longline swordfish and tuna fisheries in international waters off the coasts of Argentina and Uruguay (Domingo, undated). Despite the large amount of fishing activity that will result in porbeagle captures in the Southern Hemisphere, New Zealand is the only country that reports landings to FAO, indicating that the southern catch is largely unreported (Fowler *et al.*, 2004). The high value of porbeagle shark meat means that it is not appropriate to describe these exploited incidental captures as 'bycatch'. The exception is in those high seas tuna and billfish fisheries where vessels holding space is too limited to enable even valuable shark carcasses to be retained; in these cases the fins alone may be retained (e.g. the Japanese longline fishery for southern bluefin tuna off Tasmania and New Zealand, the pelagic fishing fleets of other countries in the southern Indian Ocean and probably elsewhere in the Southern Hemisphere (Compagno, 2001). Its meat and fins, for which there is huge demand, enter international trade (Fowler *et al.*, 2004). Porbeagle shark products include fresh, frozen and dried-salted meat for human consumption, oil and fishmeal for fertilizer, and fins for shark-fin soup (Compagno, 2001). The commercial value of

	the species has been documented through present and past market surveys (Fleming and Papageorgiou, 1997; Rose, 1996), with findings indicating that the demand for fresh, frozen or processed meat, as well as fins and other products of porbeagle is sufficiently high to justify the existence of an international market, in addition to national utilisation. In the Southern Hemisphere, most of the porbeagle catch comes as bycatch in tuna longline fisheries, where landings are small but may be underreported (Francis *et al*., 2001, 2008). Porbeagle is also a target for anglers in countries such as Australia, Canada, Ireland, New Zealand, the United Kingdom and the United States (Babcock, 2008). The domestic longline fishery operating off the east coast of Australia incidentally takes over 80 non-target species, and a significant amount of this non-target catch is retained as byproduct. Due to the difficult economic outlook faced by these fisheries (resulting from overcapacity, localized depletions, increased fuel prices, lowered availability of target species and reduced access to export markets) byproduct has become a relatively more important part of some fishers' catch and income (Bromhead *et al.*, 2005). Macbeth *et al*. (2009) state that the capture and subsequent retention of large oceanic sharks such as blue shark, shortfin mako and porbeagle in pelagic longline fisheries primarily targeting billfish and tuna has historically been extensively practiced by multi-national commercial fishing fleets operating in the North Atlantic and Pacific oceans (ie. Holts *et al*., 1998; Matsunaga and Nakano, 1999; Francis *et al*., 2001). It has been estimated that this byproduct probably accounts for a significant proportion – possibly up to 50% – of the commercial catch of sharks worldwide (Bonfil, 1994). This emphasises the need for protection, which is reinforced by the porbeagle being nominated for listing under CITES Appendices at each of the last two meetings, although these nominations have not been successful to date. Furthermore, as *Lamna nasus* is listed under Appendix II of the CMS, it is correspondingly listed as a migratory species under the EPBC Act. Being listed as a threatened species would be an appropriate way to complement the CMS inclusion, and be a proactive demonstration of support for such conventions.
*b. what its **effect** has been **so far** (indicate whether it is known or suspected; present supporting information/research; does it only affect certain populations);*	Porbeagle is a shark species more vulnerable than most to over-exploitation by fisheries because of their late maturity, longevity, low reproductive capacity, and a very low intrinsic rate of population increase (5-7% per annum) (Fowler *et al.*, 2004). Camhi *et al.* (2009) report that the Northwest Atlantic porbeagle population has been subject to a full stock assessment – the first for any pelagic shark. The target fishery for Northeast Atlantic porbeagles began in the 1930s. Fisheries were intense and unregulated, and collapsed in the 1960s, and in 1961 much of the effort shifted to the virgin Northwest Atlantic population, which also collapsed within a decade: Landings peaked at over 9,000t in 1964, but declined to about 200t in 1970 and hovered below 500t through the 1980s (Campana *et al*., 2002b, 2008; FAO, 2009). The target fishery (almost exclusively of Canadian vessels) expanded once again in the early 1990s, and once again collapsed: Catches in 1995 peaked at 1,395t, but declined by almost 90% to 146t by 2003 (FAO, 2009). A Canadian quota of 250t, imposed in 2002, was inadequate to allow population recovery. Despite implementation of increasingly stringent Canadian management since 1994 in the Northwest Atlantic, the population hovers at about 11% of its 1961 virgin biomass. Scientists estimate that even if target fisheries

	were closed and strict limits placed on porbeagle bycatch, it could take at least 30–60 years for this population to recover. Scientists with the Committee on the Status of Endangered Species Wildlife in Canada (COSEWIC) declared porbeagle Endangered in 2004 and recommended the species for listing under Canada's Species at Risk Act, but the proposal was rejected for economic and monitoring reasons. In 2008, the Scientific Council of the Northwest Atlantic Fisheries Organization (NAFO) warned that mortality from a new porbeagle fishery in international waters just outside the Canadian EEZ, when added to Canadian landings, would lead to a population "crash" (NAFO, 2008). Furthermore, population declines of porbeagle of up to 90% of their historical biomass have been suggested for the Northeast Atlantic (Stevens et al., 2006). The species now appears to be scarce, if not absent, in areas where it was formerly commonly reported (e.g. in the Western Mediterranean, Alen Soldo in litt. 2003). There is no trend data identified for Australian porbeagle stocks, and very few for southern ocean stocks in general. One example lies in records of declining captures of porbeagle by the Uruguayan pelagic tuna longline fleet during 1981-1998 (Domingo, undated). During the 1980s, only the two most valuable shark species were retained for their meat by this fleet: porbeagle and mako (Isurus oxyrinchus), representing about 10% of the total catch. By 1991, the abundance of these two species had fallen considerably. These effects have been documented and are thus known, and although the most severe effects have occurred in certain non-Australian populations, the vulnerability to the causes is even more pronounced in the southern hemisphere due to the populations life history characteristics (Francis *et al.*, 2007).
c. *what is its **expected effect in** the **future** (is there supporting research/information; is the threat only suspected; does it only affect certain populations);*	Without drastic and immediate changes to worldwide management practice, the population declines currently being documented with such frequency can only reasonably be expected to continue. Such necessary measures include regulation fishing practices and enforced reductions in effort; mitigating the capture of non-target species in pelagic longline fisheries; curbing international demand for the trade of fins and other shark products; improving efforts to obtain reliable biological and ecological data to form reliable stock assessments, and improving the accuracy of fisheries catch data.
d. *what is the **relative importance or magnitude** of the threat to the species.*	As indicated by the substantial rates of declines of *Lamna nasus* described throughout this document, the threat to the species from global and domestic fisheries - both as targeted catches and bycatch - is severe.
45. *If not included above, identify **catastrophic threats**, i.e. threats with a low predictability that are likely to severely affect the species. Identify the threat, explain its likely impact and indicate the likelihood of it occurring (e.g. a drought/cyclone in the area every 100 years).*	As an active swimmer with broad distribution and habitat tolerance, *Lamna nasus* is unlikely to be directly impacted across its total population by a catastrophic threat as defined in this question. While it is recognised that climate change and global warming are likely to have serious implications for the vast majority of shark species and ecosystems (Walker, 2007), in light of the lack of biological and behavioural data documented for *Lamna nasus*, and the uncertain magnitude of the effects of climate change, it is beyond the scope of this document to attempt to speculate at length about possible changes to the species' habitat and ecology. However it is reasonable to assume that a broad range of components will come into play, including increased water temperature, altered rainfall patterns, salinity and turbidity, rising sea level, increased storm length and frequency, coastal erosion, changed ocean currents and upwelling, increased ultraviolet light from reduced ozone, and

	reduced pH (Walker, 2007; Harley *et al*., 2006).
46. *Identify and explain any* ***additional biological characteristics*** *particular to the species that are threatening to its survival (e.g. low genetic diversity)?*	Like most pelagic sharks the porbeagle is particularly prone to over exploitation by fisheries due to relatively slow growth rates, a late age at sexual maturity (Natanson *et al.*, 2002) and low fecundity (Jensen *et al.*, 2002). It has been cited as a notable example of stock collapse in a chondrichthyan species (Stevens *et al.*, 2000). In what may be the clearest management advice yet given for a pelagic shark, in 2006 ICES (the International Council for the Exploration of the Sea) recommended that "no targeted fishing for [Northeast Atlantic] porbeagle should be permitted on the basis of their life history and vulnerability to fishing (Camhi *et al.*, 2009). *Lamna nasus* meets the guidelines suggested by FAO for the listing of commercially exploited aquatic species. It falls into FAO's lowest productivity category of the most vulnerable species; those with an intrinsic rate of population increase of <0.14 and a generation time of >10 years (FAO, 2001). Some documented stock declines of *Lamna nasus* have clearly exceeded the qualifying level of 20% or less of historic baseline, or are declining so rapidly as to qualify for Appendix I listing under the FAO guidelines (Fowler *et al.*, 2004). Campana *et al.* (1999) conducted a life table analysis for porbeagle, with results indicating that the intrinsic rate of population growth (r) in an unfished population varied between 0.05-0.07 depending on the natural mortality assumptions which were made. This value indicates that the porbeagle population is intrinsically unproductive and slow to recover from stock depletion. The structure of exploited populations is highly unnatural, with very few large mature females present. This results in an extremely low reproductinve capacity in heavily fished, depleted stocks (e.g. Campana *et al.* 2001), and could be due to the larger females being more valuable as a byproduct. Southern Hemisphere porbeagles have even slower growth rates and greater longevity than porbeagles in the North Atlantic, indicating that this species is biologically more vulnerable to overexploitation (Francis *et al.*, 2007).

47. *Identify and explain any **quantitative measures or models** that address the probability of the species' extinction in the wild over a particular timeframe.*	There are currently no such species-specific models or measures which have been undertaken for *Lamna nasus* specifically to quantify the probability of its extinction. However a number of studies have attempted to shed some light on the subject. Campana *et al.* (1999) noted that porbeagle sharks produce few offspring and mature at a late age compared to the average age of first capture by fisheries. This combination of life history characteristics makes porbeagle highly susceptible to over-exploitation. Average catches of about 4500t per year in the early 1960s resulted in a fishery which collapsed after only 6 years, and which did not recover for another 25 years. However, the fishery appeared sustainable during the 1970s and 1980s when landing averaged 350t annually, and the population slowly recovered. Catches of 1000-2000t throughout much of the 1990s appear to have once again reduced population abundance, resulting in lower catch rates and disturbingly low numbers of mature females. The TAC (Total Allowable Catch) of 850t introduced in 1999, based on preliminary scientific information and with excellent cooperation from industry, resulted in preliminary estimates of $F_{0.1}$ yield, mortality and stock abundance. Nevertheless, it was acknowledged at the time that the $F_{0.1}$ yield was probably not sustainable. The current assessment confirms the unsustainability of fishing at $F_{0.1}$ for porbeagle, and indicates that a fishing mortality above 0.08 will cause the population to decline. A fishing mortality of 0.04-0.05 corresponds to MSY (Maximum Sustainable Yield), and is required if the population is to be allowed to recover.
48. *Is there **other information** that relates to the survival of this species that you would like to address?*	The conservation status of the porbeagle is of major concern because of the drastic decline in catches from targeted fisheries in the North Atlantic and continuing exposure of the species to intensive high-seas pelagic longline fisheries (with finning and capture trauma contributing to mortality) wherever it occurs. North Atlantic fisheries are relatively well-documented and under regulation, but not those of the Southern Hemisphere with the exception of New Zealand (Compagno, 2001).

Threat Abatement and Recovery

49. *Give an overview of how broad-scale **threats** are **being abated**/could be abated and **other recovery actions** underway/ proposed. Identify who is undertaking these activities and how successful the activities have been to date.*	The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) would provide a means for regulating the trade of fins and other products obtained from the porbeagle. Such a listing under CITES appendices could be a useful mechanism for curbing their continued under-regulated exploitation. As previously mentioned, *Lamna nasus* has been nominated for such a listing at each of the last two meetings, although these nominations have not been successful to date. The International Plan of Action (IPOA) for the Conservation and Management of Sharks, adopted by the FAO at the 23rd Session of the Conference on Fisheries (COFI) in February 1999, urges states with active shark fisheries to implement conservation and management plans. However, this initiative is voluntary and, although 116 countries reported shark landings for 2001 to FAO, members of FAO reported to the 25th session of COFI in February 2003 that only six countries had developed a National Plan of Action (NPOA) while a further 11 have partially developed a NPOA for sharks (Fowler *et al.*, 2004). In 1991, Australia brought in legislation that prevented Japanese longliners fishing in the EEZ from landing shark fins unless they were accompanied by the carcass. Since 1996, these vessels have not fished in the Australian EEZ. Finning is currently prohibited on domestic Australian tuna longliners. A small regulated fishery is permitted by New Zealand

	(Compagno, 2001), which has been quota managed for porbeagle shark since October 2004. Currently there are no other management measures applicable to the Antarctic and Southern Ocean, since CCAMLR appears not to be monitoring or managing this species (Fowler *et al.*, 2004). However, because porbeagles are primarily killed for their meat, finning bans alone will not improve their population status. Mandatory release of porbeagles taken as bycatch could help, as an estimated 54% are still alive on gear retrieval in the French Atlantic fishery (Jung, 2008), and 25–68% arrive at the boat alive in the New Zealand fishery (Francis *et al.*, 2001).
50. *For species nominated as extinct in the wild, provide details of the locations in which the* ***species*** *occurs* ***in captivity*** *and the level of human intervention required to sustain the species.*	Not applicable.

Mitigation Approach

51. *Describe any* ***mitigation measures or approaches*** *that have been developed specifically for the species at identified locations. Identify who is undertaking these activities and how successful the activities have been to date.*	European Union (EU) Total Allowable Catches (TACs) are in force for porbeagle, and were set at zero in 2010. These TACs apply to several of the top 20 “shark catchers” identified from shark catch data provided to the FAO including Spain (7.3% of global reported shark catch), France (2.6%), Portugal (1.9%) and the United Kingdom (1.6%). Furthermore, Council Regulation (EU) No. 23/2010 prohibits EU vessels from retaining on board, transshipping or landing porbeagle in international waters (Lack and Sant, 2011). The United States (responsible for 3.7% of global reported shark catch) has catch limits in place for Atlantic porbeagle, and reduced the porbeagle quota in 2008 from 91t to 1.7t and implemented a rebuilding plan. In New Zealand (2.2%), TACs for porbeagle are set without regard for Maximum Sustainable Yield (Lack and Sant, 2011). Pade *et al.* (2009) suggest that the application of archival tags that measure stomach temperature in the endothermic porbeagle (where drops in temperature occur after ingestion of cold-bodied fish prey) may shed further light on the interaction between movements and feeding success (Austin *et al.*, 2006; Bestley *et al.*, 2008). A number of countries including Australia, the US, Mexico, Canada, Brazil, Ecuador, the EU, India and South Africa have some form of legislation preventing the practice of finning and discarding carcasses at sea (HSI, 2009), or have management plans dealing with pelagic sharks or elasmobranchs more broadly; however such legislation does not specifically target *Lamna nasus*.
52. *Departmental use only:*	

Major Studies

53. *Identify major studies on the species that might relate to its taxonomy or management.*	Campana, S. E., Joyce, W., Marks, L., Natanson, L. J., Kohler, N. E., Jensen, C. F., Mello, J. J., Pratt Jr., H. L. and Myklevoll, S. (2002b). Population dynamics of the porbeagle in the Northwest Atlantic Ocean. *North American Journal of Fisheries Management* 22: 106-121. Campana, S. E., Joyce, W. and Marks, L. (2003). Status of the Porbeagle Shark (*Lamna nasus*) Population in the Northwest Atlantic in the Context of Species at Risk. *Canadian Stock Assessment Secretariate Research Document* 2003/007. Campana, S. E. and Joyce, W. N. (2004). Temperature and depth associations of porbealge shark (*Lamna nasus*) in the northwest Atlantic. *Fisheries Oceanography*

	13: 52-64. Campana, S. E., Joyce, W., Marks, L., Hurley, P., Natanson, L. J., Kohler, N. E., Jensen, C. F., Mello, J. J., Pratt Jr., H. L., Myklevoll, S. and Harley, S. (2008). Pp. 445-461. The rise and fall (again) of the porbeagle shark population in the Northwest Atlantic. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds M. D. Camhi, E. K. Pikitch and E. A. Babcock). Blackwell Publishing, Oxford, UK. Fowler, S., Raymakers, C. and Grimm, U. (2004). Trade in and conservation of two shark species, porbeagle (*Lamna nasus*) and Spiny Dogfish (*Squalas acanthias*). Bundesamt für Naturschutz – Skripten 118. Francis, M. P., Natanson, L. J. and Campana, S. E. (2008). Pp. 105-113. The biology and ecology of the porbeagle shark, *Lamna nasus*. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds M. D. Camhi, E. K. Pikitch and E. A. Babcock). Blackwell Publishing, Oxford, UK. Jensen, C. F., Natanson, L. J., Pratt Jr., H. L., Kohler, N. E. and Campana, S. E. (2002). The reproductive biology of the porbeagle shark (*Lamna nasus*) in the western North Atlantic Ocean. *Fisheries Bulletin* 100: 727-738. Pade, N., Sarginson, J., Antsalo, M., Graham, S., Campana, S., Francis, M., Jones, C., Sims, D. and Noble, L. (2006). Spatial ecology and population structure of the porbeagle (*Lamna nasus*) in the Atlantic: an integrated approach to shark conservation. Poster presented at 10th European Elasmobranch Association Science Conference. 11-12 November 2006. Hamburg, Germany. Pade, N. G., Queiroz, N., Humphries, N. E., Witt, M. J., Jones, C. S., Noble, L. R. and Sims, D. W. (2009). First results from satellite-linked archival tagging of porbeagle shark, *Lamna nasus*: Area fidelity, wider-scale movements and plasticity in diel depth changes. *Journal of Experimental Marine Biology and Ecology* 370: 64-74.

Management Documentation

54. *Identify **key management documentation** available for the species, e.g. recovery plans, conservation plans, threat abatement plans.*	The nominee is not aware of *Lamna nasus* being the specific focus of any recovery plans or threat abatement plans, although documents that examine the management of shark stocks in general may be relevant.
55. *Departmental use only:*	

Section 3 — Indigenous Cultural Significance

56. *Is the species known to have Indigenous cultural significance to groups within the Australian jurisdiction and, if so, to which Indigenous groups? Are you able to provide information on the nature of this significance?*	The nominator is unaware of any Indigenous cultural significance *Lamna nasus* has to groups within the Australian jurisdiction. It is recommended that further investigation is undertaken with relevant groups to examine this issue further.

Section 4 – References and Reviewers

Notes:

- The opinion of appropriate scientific experts may be cited (with their approval) in support of a nomination. If this is done the names of the experts, their qualifications and full contact details must also be provided in the reference list below.
- Please provide copies of key documentation/references used in the nomination

57. *Reference list*

Austin, D., Bowen, W. D., Mcmillan, J. and Boness, D. (2006). Stomach temperature telemetry reveals temporal patterns of foraging success in a free-ranging marine mammal. *Journal of Animal Ecology* 75: 408-420.

Babcock, E. A. (2008). Recreational fishing for pelagic sharks worldwide. Pp. 193-204. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds M. D. Camhi, E. K. Pikitch and E. A. Babcock). Blackwell Publishing, Oxford, UK.

Bascompte, J., Melian, C. H. and Sala, E. (2005) Interaction strength combinations and the overfishing of a marine food web. *Proceedings of the National Academy of Sciences* 102:5443-7.

Baum, J. K. and Myers, R. A. (2004). Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. *Ecology Letters* 7: 135-145.

Bestley, S., Patterson, T. A., Hindell, M. A. and Gunn, J. S. (2008). Feeding ecology of wild migratory tunas revealed by archival tag records of visceral warming. *Journal of Animal Ecology* 77: 1223-1233.

Bonfil, R. (1994). Overview of world elasmobranch fisheries. FAO Fisheries Technical Paper 341, Food and Agriculture Organization of the United Nations, Rome.

Bonnaterre, J. P. (1788). Tableau encyclopedique et methododique des trois regnes de la nature… Ichthyologie. Vol. 6. Paris. 215pp. 102 pls.

Bowen, B. W. and Roman, J. (2005). Gaia's handmaidens: the Orlog model for conservation. *Conservation Biology* 19:1037-43.

Bromhead, D., Ackerman, J., Graham, S., Wight, M., Wise, B. and Findlay, J. (2005). Byproduct: Catch, economics and co-occurrence in Australia's pelagic longline fisheries. Western and Central Pacific Fisheries Commission, WCPFC-SCI EB WP-9. 21pp.

Camhi, M. D. (2008). Conservation status of pelagic elasmobranchs. Pp. 397-417. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds M. D. Camhi, E. K. Pikitch and E. A. Babcock). Blackwell Publishing, Oxford, UK.

Campana, S. E., Natanson, L. J. and Myklevoll, S. (2002a). Bomb dating and age determination of large pelagic sharks. *Canadian Journal of Fisheries and Aquatic Science* 59: 450–455.

Campana, S. E., Joyce, W., Marks, L., Natanson, L. J., Kohler, N. E., Jensen, C. F., Mello, J. J., Pratt Jr., H. L. and Myklevoll, S. (2002b). Population dynamics of the porbeagle in the Northwest Atlantic Ocean. *North American Journal of Fisheries Management* 22: 106-121.

Campana, S. E., Joyce, W. and Marks, L. (2003). Status of the Porbeagle Shark (*Lamna nasus*) Population in the Northwest Atlantic in the Context of Species at Risk. *Canadian Stock Assessment Secretariate Research Document* 2003/007.

Campana, S. E. and Joyce, W. N. (2004). Temperature and depth associations of porbealge shark (*Lamna nasus*) in the northwest Atlantic. *Fisheries Oceanography* 13: 52-64.

Campana, S. E., Joyce, W., Marks, L., Hurley, P., Natanson, L. J., Kohler, N. E., Jensen, C. F., Mello, J. J., Pratt Jr., H. L., Myklevoll, S. and Harley, S. (2008). Pp. 445-461. The rise and fall (again) of the porbeagle shark population in the Northwest Atlantic. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds M. D. Camhi, E. K. Pikitch and E. A. Babcock). Blackwell Publishing, Oxford, UK.

Castro, J. I., Woodley, C. M. and Brudek, R. L. (1999). A Preliminary Evaluation of the Status of Shark Species. Series title: *FAO Fisheries Technical Paper – T380*.

Clarke, S. C., Magnussen, J. E., Abercrombie, D. L., McAllister, M. K., Shivji, M. S. (2006). Identification of shark species composition and proportion in the Hong Kong shark fin market based on molecular genetics and trade records. *Conservation Biology* 20:201-11.

Compagno, L. J. V. (2001). Sharks of the World. Volume 2. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). *FAO Species Catalogue for Fisheries Purposes*. No. 1, Vol. 2. Rome. FAO. 2001. 269p.

DFO (Department of Fisheries and Oceans. (2005). Recovery Assessment Report on NAFO Subareas 3-6 Porbeagle Shark. DFO Canadian Science Advisory Secretariat. Science Advisory Report 2005/043.

DSEWPaC. (2010). Marine Protected Areas: Map of Commonwealth marine reserves. http://www.environment.gov.au/coasts/mpa/index.html. Accessed on 03/03/2011.

Dulvy, N. K., Baum, J. K., Clarke, S., Compagno, L. J. V., Cortes, E., Domingo, A., Fordham, S., Fowler, S., Francis, M. P, Gibson, C., Martinez, J., Musick, J. A., Soldo, A., Stevens, J. D. and Valenti, S. (2008). You can swim but you can't hide: the global status and conservation of oceanic pelagic sharks and rays. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18: 459-482.

Evans, S. K. (2007). *Eastern Tuna and Billfish Fishery Data Summary 2005-2006.* Data Group, Australian Fisheries Management Authority, Canberra.

FAO (Food and Agricultural Organization). (2001). Report of the second technical consultation of the CITES criteria for listing commercially exploited aquatic species. FAO Fisheries Report 667. FAO, Rome.

FAO (Food and Agricultural Organization). (2008). FISHSTAT Capture Production. (1950-2008). Database available at http://www.fao.org.

FAO (Food and Agricultural Organization). (2009). FISHSTAT Plus (v. 2.30), Capture Production Database, 1950-2007, and Commodities Trade and Production Database 1976-2007. FAO, Rome, Italy.

FAO (Food and Agriculture Organization). (2011). *Lamna nasus* Species Fact Sheet. http://www.fao.org/fishery/species/2798/en. Accessed on 15/03/2011.

Fleming, E. H. and Papageorgiou, P. A. (1997). Shark fisheries and trade in Europe. TRAFFIC Europe. 78 pp.

Fowler, S., Raymakers, C. and Grimm, U. (2004). Trade in and conservation of two shark species, porbeagle (*Lamna nasus*) and Spiny Dogfish (*Squalas acanthias*). Bundesamt für Naturschutz – Skripten 118.

Francis, M. P. (1998). New Zealand shark fisheries: development, size and management. *Marine and Freshwater Research*. 49: 579-591.

Francis, M. P., Griggs, L. H. and Baird, S. J. (2001). Pelagic shark bycatch in the New Zealand tuna longline fishery. *Marine Freshwater Research* 52: 165-178.

Francis, M. P., Campana, S. E. and Jones, C.M. (2007). Age underestimation in New Zealand and porbeagle sharks (*Lamna nasus*): is there an upper limit to ages that can be determined from shark vertebrae? *Marine and Freshwater Research* 58: 10-23.

Francis, M. P., Natanson, L. J. and Campana, S. E. (2008). Pp. 105-113. The biology and ecology of the porbeagle shark, *Lamna nasus*. In: *Sharks of the Open Ocean: Biology, Fisheries and Conservation* (eds M. D. Camhi, E. K. Pikitch and E. A. Babcock). Blackwell Publishing, Oxford, UK.

Frid, A., Baker, G. G., and Dill, L. M. (2007). Do shark declines create fear-released systems? *Oikos* 1-13.

Griffin, E., Miller, K. L., Freitas, B. and Hirshfield, M. (2008). Predators as Prey: why healthy oceans need sharks. *Oceana*, Washington DC.

Harley, C. D. G., Hughes, A. R., Hultgren, K. M., Miner, B. G., Sorte, C. J. B., Thornber, C. S., Rodriguez, L. F., Tomanek, L. and Williams, S. L. (2006). The impacts of climate change in coastal marine systems. *Ecology Letters* 9 (2): 228-241.

Holts, D. B., Julian, A., Sosa-Nishizaki, O. and Bartoo, N. W. (1998). Pelagic shark fisheries along the west coast of the United States and Baja California, Mexico. Fisheries Research 39: 115–125.

Humane Society International. (2009). Shark conservation: Policy recommendations for the Australian Government. http://tinyurl.com/4fe3lob

Jensen, C. F., Natanson, L. J., Pratt Jr., H. L., Kohler, N. E. and Campana, S. E. (2002). The reproductive biology of the porbeagle shark (*Lamna nasus*) in the western North Atlantic Ocean. *Fisheries Bulletin* 100: 727-738.

Joyce, W. N., Campana, S. E., Natanson, L. J., Kohler, N. E., Pratt, H.L. Jr. and Jensen, C. F. (2002). Analysis of stomach contents of the porbeagle shark (*Lamna nasus*) in the northwest Atlantic. *ICES Journal of Marine Science* 59: 1263-1269.

Jung, A. (2008). A preliminary assessment of the French fishery targeted porbeagle shark (*Lamna nasus*) in the Northeast Atlantic Ocean: Biology and catch statistics. ICCAT SCRS/2008/152.

Lack, M. and Sant, G. (2011). The Future of Sharks: A Review of Action and Inaction. TRAFFIC International and the Pew Environment Group.

Last, P. R. and Stevens, J. D. (2009). Sharks and rays of Australia. Harvard University Press. 644pp.

Lynch, A. W. (2003). *Eastern Tuna and Billfish Fishery Data Summary 2002-2003.* Logbook Program, Australian Fisheries Management Authority, Canberra.

Lynch, A. W. (2004). *Eastern Tuna and Billfish Fishery Data Summary 2003-2004.* Logbook Program, Australian Fisheries Management Authority, Canberra.

Lynch, A. W. (2005). *Eastern Tuna and Billfish Fishery Data Summary 2004-2005.* Data Group, Australian Fisheries Management Authority, Canberra.

Macbeth W. G., Geraghty, P. T., Peddemors, V. M. and Gray, C. A. (2009). Observer-based study of targeted commercial fishing for large shark species in waters off northern New South Wales. Northern Rivers Catchment Authority, Industry & Investment NSW – *Fisheries Final Report Series* 114.

Matsunaga, H. and Nakano, H. (1999). Species composition and CPUE of pelagic sharks caught by Japanese longline research and training vessels in the Pacific Ocean. Fisheries Science 65: 16–22.

MFSC (Ministry of Fisheries, Science Group (Comps.)) (2008). Report from the Mid-Year Fishery Assessment Plenary, November 2008: stock assessments and yield estimates. (Unpublished report held in NIWA Greta Point Library, Wellington, New Zealand).

Musick, J. A., Burgess, G., Cailliet, G., Camhi, M. and Fordham, S. (2000). Management of sharks and their relatives (Elasmobranchii). AFS Policy Statement 25 (3).

Myers, R. A., Baum, J. K., Shepherd, T. D., Powers, S. P. and Peterson, C. H. (2007) Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science* 315:1846-50.

NAFO (Northwest Atlantic Fisheries Organization). (2008). Report of the Scientific Council Meeting, 5-19 June 2008. NAFO SCS Doc. 08/19. 248pp.

Natanson, L. J., Mello, J. J. and Campana, S. E. (2002). Validated age and growth of the porbeagle shark (*Lamna nasus*) in the western North Atlantic Ocean. *Fisheries Bulletin*: 266-278.

Pade, N., Sarginson, J., Antsalo, M., Graham, S., Campana, S., Francis, M., Jones, C., Sims, D. and Noble, L. (2006). Spatial ecology and population structure of the porbeagle (*Lamna nasus*) in the Atlantic: an integrated approach to shark conservation. Poster presented at 10th European Elasmobranch Association Science Conference. 11-12 November 2006. Hamburg, Germany.

Pade, N. G., Queiroz, N., Humphries, N. E., Witt, M. J., Jones, C. S., Noble, L. R. and Sims, D. W. (2009). First results from satellite-linked archival tagging of porbeagle shark, *Lamna nasus*: Area fidelity, wider-scale movements and plasticity in diel depth changes. *Journal of Experimental Marine Biology and Ecology* 370: 64-74.

Paine, R. T. (2002). Trophic control of production in a rocky intertidal community. *Science* 296:736-9.

Rose, D. A. (1996). An overview of world trade in sharks and other cartilaginous fishes. TRAFFIC International. 106 pp.

Sergio, F., Newton, I., Marchesi, L., and Pedrini, P. (2006). Ecological justified charisma: preservation of top predators delivers biodiversity conservation. *Journal of Applied Ecology* 43: 1049-1055.

Stevens, J. D. (1976). First results of shark tagging in Northeast Atlantic, 1972-1975. *Journal of the Marine Biological Association of the United Kingdom* 56: 929-937.

Stevens, J. D. (1990). Further results from a tagging study of pelagic sharks in the North-East Atlantic. *Journal of the Marine Biological Association of the United Kingdom* 70: 707-720.

Stevens, J. D., Bonfil, R., Dulvy, N. K. and Walker, P. A. (2000). The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science*. 57 (3): 476-494.

Stevens, J. D., Fowler, S. L., Soldo, A., McCord, M., Baum, J., Acuña, E., Domingo, A. and Francis, M. (2005). *Lamna nasus*. In: IUCN 2006. 2010.4 *IUCN Red List of Threatened Species*. http://www.iucnredlist.org/apps/redlist/details/11200/0. Accessed on 01/03/2011.

Stevens, J., Fowler, S. L., Soldo, A., McCord, M., Baum, J., Acuña, E., Domingo, A. and Francis, M. (2006). *Lamna nasus*. In: IUCN 2010. IUCN Red List of Threatened Species. Version 2010.4. www.iucnredlist.org. Accessed on 17/03/2011.

Walker, T. I. (2007). The state of research on chondrichthyan fishes. *Marine and Freshwater Research* 58: 1-3.

Wearmouth, V. J. and Sims, D. W. (2008). Sexual segregation in marine fish, reptiles, birds and mammals: Behaviour patterns, mechanisms and conservative implications. *Advances in Marine Biology* 54: 107-170.