CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

Seventeenth meeting of the Conference of the Parties
Johannesburg (South Africa), 24 September – 5 October 2016

CONSIDERATION OF PROPOSALS FOR AMENDMENT OF APPENDICES I AND II

A. Proposal

Inclusion of the Family Nautilidae (Blainville, 1825) in Appendix II in accordance with Article II paragraph 2 (a) of the Convention and satisfying Criterion B in Annex 2a of Resolution Conf. 9.24 (Rev. CoP16)[1].

B. Proponents

Fiji, India, and United States of America[2]

Figure 1 Chambered nautilus over coral (USFWS)

C. Supporting statement

1. Taxonomy

1.1 Class: Cephalopoda

1.2 Order: Nautilida

1.3 Family: Nautilidae (Blainville, 1825)

1.4 All species in the Family Nautilidae,[3] as follows:

Allonautilus spp. (Ward & Saunders, 1997)
  Allonautilus perforatus (Conrad, 1949)
  Allonautilus scrobiculatus (Lightfoot, 1786)
Nautilus spp. (Linnaeus, 1758)
  Nautilus belauensis (Saunders, 1981)
  Nautilus macromphalus (Sowerby, 1849)
  Nautilus pompilius (Linnaeus, 1758)
  Nautilus repertus (Iredale, 1944)
  Nautilus stenomphalus (Sowerby, 1849)

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1 *CITES listing criteria and definitions must be applied with flexibility and in context. This is consistent with the "Note" at the beginning of Annex 5 in Resolution Conf. 9.24 (Rev. CoP16): "Where numerical guidelines are cited in this Annex, they are presented only as examples, since it is impossible to give numerical values that are applicable to all taxa because of differences in their biology." The definition of "decline" in Annex 5 is relevant to the determination of whether a species meets either criterion in Annex 2a of the resolution. Nonetheless, it is possible for a species to meet the criteria and qualify for listing in Appendix II even if it does not meet the specific parameters provided in the definition of "decline", which is in fact more relevant for the inclusion of species in Appendix I. Where quantitative data are available, they should be used to evaluate a species' status. However, where data on population abundance are not available but there are indications that over-exploitation is or may be occurring (i.e., "it is known, or can be inferred or projected") and the regulation of trade could benefit the conservation of the species, listing should be supported.*

2 *The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CITES Secretariat (or the United Nations Environment Programme) concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.*

3 *Two species reported in U.S. trade data may be synonyms of other species: Allonautilus perforatus (native to Indonesia) may be a synonym of A. scrobiculatus (native to Papua New Guinea and Solomon Islands), and N. repertus (native to western Australia) may be a synonym of N. pompilius. In this proposal, we use the Integrated Taxonomic Information System as the standard reference for Nautilidae nomenclature, which recognizes the above seven species as valid (ITIS 2016a, 2016b).*

1.5 Scientific synonyms:

While some of these synonyms may not be taxonomically valid, for the practical purposes of CITES these are associated names under which specimens may be found in international trade.

Species	Synonyms, in alphabetical order
Allonautilus perforatus	*Nautilus perforatus* (Conrad, 1849)
Allonautilus scrobiculatus	*Nautilus perforatus* (Conrad, 1849) *Nautilus scrobiculatus* (Lightfoot, 1786) *Nautilus texturatus* (Gould, 1857) *Nautilus umbilicatus* (Linnaeus, 1758)
Nautilus pompilius	*Nautilus alumnus* (Iredale, 1944) *Nautilus ambiguus* (Sowerby, 1849) *Nautilus pompilius pompilius* (Linnaeus, 1758) *Nautilus pompilius suluensis* (Habe & Okutani, 1988) *Nautilus pompilius* var. *caudatus* (Lister, 1685) *Nautilus pompilius* var. *marginalis* (Willey, 1896) *Nautilus pompilius* var. *moretoni* (Willey, 1896) *Nautilus pompilius* var. *perforatus* (Willey, 1896) *Nautilus pompilius* var. *pompilia* (Shimansky, 1948) *Nautilus pompilius* var. *rumphii* (Shimansky, 1948) *Nautilus repertus* (Iredale, 1944)
Nautilus repertus	*Nautilus ambiguus* (Sowerby, 1849)
Nautilus stenomphalus	*Nautilus stenomphalus stenomphala* (Shimansky, 1948)

1.6 Common names: English: Chambered nautilus, Pearly chambered nautilus
French: Nautiles
Spanish: Nautilos

Above are the common names used for the genera *Nautilus* and *Allonautilus*. Common names associated with each species are in the Annex to this proposal.

Note: In this document, we refer to all animals in both genera as "chambered nautiluses," and use the scientific names to refer to particular species.

1.7 Code numbers: None

Resolution Conf. 9.24 (Rev.CoP16), Annex 3, section on Higher Taxa, states that 'If all species of a higher taxon are included in Appendix I or II, they should be included under the name of the higher taxon'. Accordingly, because all species are being proposed for listing, this proposal seeks to list the Family Nautilidae in Appendix II.

2. Overview

The distinctive coiled shells of chambered nautiluses are well-known in international trade. The shells are traded internationally as souvenirs to tourists and shell collectors, as jewelry and home décor items ranging from whole-shell decorative objects to chambered nautilus shell-inlay lacquerware, and as live specimens for use as pets, in aquaria, and by research institutions. Shell trade drives the international demand for these species and meat may be eaten locally or traded internationally as a by-product of the shell trade.

Whereas *Nautilus pompilius* is the species most reported in trade, all species of chambered nautilus are found in international trade. The consumer market for chambered nautilus products includes North and South America, Eastern and Western Europe, Eastern and Southeast Asia, Africa, the Middle East, and Oceania. While global quantitative trade data do not exist, information is available in published and unpublished market surveys, web-based advertisements, personal communications, a trade study conducted by TRAFFIC/WWF in several major exporting and importing countries, and from U.S. trade data obtained from the U.S. Fish and Wildlife Service Law Enforcement Management Information System (LEMIS).

In the United States alone, U.S. trade data recorded in LEMIS indicates that more than 900,000 chambered nautilus commodities were traded internationally with the United States between January 2005 and December 2014, coming mainly from the Philippines (85 percent) and Indonesia (12 percent). Over this ten-year period, trade included more than 104,000 individuals (e.g., whole shells, bodies, live, and biological specimens) and an excess of 805,000 parts (e.g., jewelry, shell products, and trim), representing an unquantifiable number of individuals. At least 99 percent of this trade is supplied by wild harvest.

Chambered nautiluses are native to tropical reef habitats of Indo-Pacific countries, including: American Samoa (USA), Australia, Fiji, India, Indonesia, Malaysia, New Caledonia, Palau, Papua New Guinea, the Philippines, Solomon Islands, and Vanuatu; and may be native to China, Myanmar, Thailand, Viet Nam, and Western Samoa. Species in the Family Nautilidae are each native to only one or two countries within the Indo-Pacific archipelago, except *Nautilus pompilius,* the most wide-ranging species, that is possibly native to 16 of 17 countries (the countries listed above with the exception of Palau).

All chambered nautiluses are vulnerable to overexploitation, based both on intrinsic biological traits, including their limited distribution and k-selected life history strategy, and extrinsic threats from targeted, largely unregulated harvest and mortality or habitat degradation caused by other human activities, including destructive fishing practices and overfishing in other fisheries.

These slow-growing marine invertebrates are late-maturing (10-15 years of age) and long-lived (at least 20 years), producing a small number of eggs annually that require a lengthy incubation period (about 1 year). These animals are extreme habitat specialists and cannot persist in water that is too warm or too deep. They do not swim in the open water column and they lack a mobile larval phase. Because of these significant physiological limitations, chambered nautiluses live in discrete, geographically-isolated populations that are separated by deep ocean water. Dispersal is left to chance events, such as drift via a tropical storm. Thus, re-colonization is unlikely when populations become depleted due to over-exploitation.

Populations of chambered nautiluses are patchy in distribution, and irregular and unpredictable in their area of occupancy. An unexploited population of *N. pompilius* associated with the Osprey Reef in Australia was found to only include 844 to 4467 individuals, with an abundance of 10-15 individuals per square kilometer. Three additional unexploited populations of *N. pompilius* associated with the Great Barrier Reef in Australia, the Beqa Passage in Fiji, and the Taena Bank in American Samoa had population abundances averaging less than one individual per square kilometer. Because chambered nautilus populations are naturally sparse, small, and isolated, they are extremely vulnerable to unsustainable exploitation.

Population declines have been documented in areas where fisheries exist or have existed. Harvest of these species removes mature individuals and mostly males. In the Philippines, the population in Tañon Strait has demonstrated a 97 percent decline in trap yields and the species is believed to be locally extirpated. Chambered nautilus abundance in a commercially-harvested population in the Bohol Sea, Philippines, were estimated to contain between 1 and 3 orders of magnitude fewer chambered nautiluses compared to populations of unfished populations. Research at other sites in the Philippines suggests that *N. pompilius* populations are being serially depleted and that trade may be shifting to Indonesia and elsewhere. The Philippine Management Authority in Palawan, indicates that traders report a declining number of shells available from harvesters in the last 5 years. In addition, the Scientific Authority reports decline of chambered nautiluses in India following several decades of harvest. Declines have been reported in New Caledonia, where fisheries existed in the past; in Indonesia, where harvest may be increasing; and possibly in Palau, where fisheries previously existed. Known populations are predictable in their habits and specimens are readily exploited using traps baited with fresh meat.

Chambered nautiluses are not included in any fisheries management plans and where protections or harvest regulations exist, they appear poorly implemented and enforced. Harvest is demand-driven mainly for the shell trade and follows a boom-bust cycle that is estimated to last 10-15 years until a population becomes depleted by overharvest. Where several chambered nautilus populations exist, harvest might continue for many years as each population is serially depleted. Given the biology of these species and evidence of serial depletion in the widest-ranging species, *Nautilus pompilius*, chambered nautiluses are highly susceptible to over-exploitation and local extinction, especially the narrow-ranging endemic species. Captive breeding has shown that offspring do not survive to reproductive age and therefore is not a viable option to either satisfy the trade or to restore depleted populations.

All species of the Family Nautilidae qualify for Appendix II of CITES, criterion B of CITES Resolution 9.24 Annex 2a because they are intrinsically vulnerable to overharvest and subject to extrinsic threats, including international trade in all known species, significant commercial harvest in some areas, habitat degradation and overfishing in other reef fisheries throughout most of their ranges. CITES regulation will benefit the conservation of these species through the cooperation of 182 CITES Parties to ensure only legal and sustainable harvest of chambered nautiluses to supply international demand.

3. Species characteristics

3.1 Distribution

Figure 2 Distribution of chambered nautiluses (World Association of Zoos and Aquariums)

Chambered nautiluses are native to tropical, coastal reef, deep-water habitats of the Indo-Pacific, occurring variously on fringing reefs (for example, in Fiji), barrier reefs (as in Australia), and atolls (also in Australia) (Dunstan 2011a, 2011b; Hayasaka *et al.* 1982; Jereb & Roper 2005; Saunders 1981b; Saunders & Spinosa 1978; Saunders *et al.* 1989; Ward *et al.* 1977). *Nautilus pompilius* appears to have the broadest distribution, being native or possibly native to 16 countries. All other chambered nautiluses are native to one or two countries, as shown below (HSUS & HSI 2008; Jereb & Roper 2005; W.B. Saunders, Professor *Emeritus*, Department of Geology, Bryn Mawr College, Bryn Mawr, Pennsylvania, USA, pers. comm. 2009; Saunders & Ward 1987; Saunders *et al.* 1989; Ward 1987, 1988).

Species	Known Range	Possible Range
Allonautilus perforatus	Indonesia	N/A
Allonautilus scrobiculatus	Papua New Guinea, Solomon Islands	N/A
Nautilus belauensis	Palau	N/A
Nautilus macromphalus	New Caledonia	N/A
Nautilus pompilius	American Samoa (USA), Australia, Fiji, India, Indonesia, Malaysia, New Caledonia, Papua New Guinea, Philippines, Solomon Islands, Vanuatu	China, Myanmar, Western Samoa, Thailand, Viet Nam
Nautilus repertus	Australia	N/A
Nautilus stenomphalus	Australia	N/A

Within their range, chambered nautiluses are irregular and unpredictable in their area of occupancy and, where they are known to occur, they are patchy in distribution (Saunders pers. comm. 2009). A preponderance of research indicates that these species are distributed erratically in association with coral reefs such that, where suitable habitat conditions exist, it cannot be presumed that chambered nautiluses will occur there (Dunstan *et al.* 2011a; Jereb & Roper 2005; Reyment 2008; Saunders pers. comm. 2009; Saunders & Ward 2010; Saunders *et al.* 1989). Ecological research on populations in the Philippines and Fiji led researchers to conclude “that the distribution pattern of *Nautilus* is infered [sic] not to be ubiquitous but rather restricted to some fixed small areas almost permanently” (Hayasaka *et al.* 1988, p. 18).

In addition, chambered nautiluses have physiological constraints that limit their vertical and horizontal distribution to geographically-separated areas of suitable habitat (Barord *et al.* 2014; Dunstan *et al.* 2010, 2011a, 2011b, 2011c; Hayasaka *et al.* 1982; Jereb & Roper 2005; Saunders pers. comm. 2009; Saunders 1984b; Saunders & Ward 1987, 2010; Saunders *et al.* 1989; Ward & Martin 1980; Williams *et al.* 2015).

3.2 Habitat

Chambered nautiluses are extreme habitat specialists that live in close association with steep-sloped forereefs and associated sandy, silty or muddy-bottomed substrates, ranging from shallow water (rarely) to about 500 meters (m) (Jereb & Roper 2005; Saunders & Ward 2010). As noted by Hayasaka *et al.* (1982), the sea bottom configuration and bathymetric topography may be among “the most fundamental features controlling the distribution of chambered *Nautilus…*” (p. 72). Habitats with high concentrations of carbonate may also be an important characteristic of chambered nautiluses’ habitat (Hayasaka *et al.* 1982).

Physiologically, chambered nautiluses cannot withstand temperatures above approximately 25° C (Carlson 2010; Dunstan *et al.* 2011a; Hayasaka *et al.* 1982, 1985; Jereb & Roper 2005; Saunders pers. comm. 2009; Saunders 1984b; Saunders & Ward 2010; Saunders *et al.* 1989), which, within their geographic range is typically at about 100 m (Dunstan *et al.* 2011b; Hayasaka *et al.* 1982; Saunders 1984b). In areas where water temperatures drop seasonally, chambered nautiluses will range into much shallower water nocturnally. For example, in New Caledonia, chambered nautiluses have been found in water as shallow as 5 m at night, but this only occurs in the winter when the water temperature is about 22° C (Jereb & Rober 2005; Saunders 1984b; Saunders & Ward 2010; Ward *et al.* 1984). Thus, shallow shelf areas where water temperatures exceed 25° C are not traversable and represent a geographic barrier to movement for these species (Hamada 1977; Hayasaka *et al.* 1985).

Hydrostatic pressure at depths exceeding 600 - 800 m will cause the shells of chambered nautiluses to implode and the animal subsequently dies (Jereb & Roper 2005; Saunders 1984b; Saunders pers. comm. 2009; Saunders & Ward 2010; Saunders & Wehman 1977). Research indicates that chambered nautiluses must equilibrate around 200 m “to regain neutral buoyancy” or chamber flooding will occur beginning at approximately 250 m (Dunstan *et al.* 2011b; Saunders & Wehman 1977). This may also help explain chambered nautiluses’ apparent habitat preference for reef areas with “step-like” topography (Hayasaka 1985; Hayasaka *et al.* 1982, 1985, 1988, 2010; Shinomiya *et al.* 1985). Thus, water depth greater than 800 m is a geographic barrier to movement of chambered nautiluses, except for rare shallow or mid-water vicarious drifting events. Suitable habitat for chambered nautiluses may remain unoccupied when separated by depths greater than 800 m.

Though often described as pelagic, these species might best be characterized as mobile benthic bottom-dwelling fore-reef scavengers and opportunistic scavengers (Dunstan *et al.* 2011c; Jereb & Roper 2005; Nichols 1991; Saunders 1981a; Saunders & Ward 2010). Chambered nautiluses do not swim in the open water column (where they are vulnerable to predation), but are nektobenthic (or epibenthic), living in close association with reef slopes (along the reef face or fore reef) and bottom substrate (Barord *et al.* 2014; Dunstan *et al.* 2010, 2011a, 2011b; Hayasaka *et al.* 1982, 1985; Nichols 1991; Saunders 1981a, 1984b; Saunders & Spinosa 1979; Saunders & Ward 2010; Ward & Martin 1980; Ward *et al.* 1977), and resting by attaching to the substrate with their tentacles (Dunstan *et al.* 2011b; Hayasaka *et al.* 1982; Kier 2010). Because chambered nautiluses do not swim through mid-water, open ocean acts as a geographic barrier to movement between reefs.

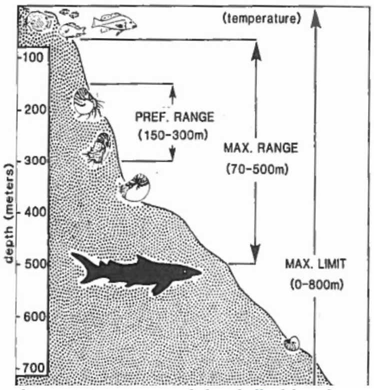

Figure 3 Summary of depth-limiting factors for chambered nautiluses based on *N. belauensis*, Palau (from Saunders (1984b). These habitat limitations seem to apply across all species of chambered nautiluses (Saunders & Ward 2010).

3.3 Biological characteristics

Chambered nautiluses are slow-growing, late-maturing (10-15 years of age), long-lived marine invertebrates (living at least 20 years) (Collins & Ward 2010; Dunstan *et al.* 2010, 2011c; Landman & Cochran 2010; Saunders 1983, 1984a). These life history traits differ from all other living cephalopods, such as octopuses, cuttlefishes, and squids, which are distributed worldwide and are short-lived (1-2 years) and are highly fecund, with planktonic larvae (Allcock 2011; Barord & Basil 2014). Cephalopod researchers Wood and O’dor (2000) note that delayed maturity increases the risk of predation prior to reproduction, due to the longer period between birth and maturity.

Little is known about chambered nautilus reproduction in the wild. Female chambered nautiluses produce one large egg at a time, which requires a lengthy incubation period (1 year) (Carlson 1985; Carlson *et al.* 1984; Collins & Ward 2010; Landman & Cochran 2010; Okubo *et al.* 1995; Uchiyama & Tanabe 1996; Ward 1983, 1987, 1988). Egg-laying has not been directly observed in the wild. Chambered nautiluses are iteroparous (having multiple reproductive cycles over the course of its lifetime), but ecological information is insufficient to determine how many eggs a single wild female might lay over an entire year or if a female “lays more than one [egg] a season” (P. Ward, Professor, Department of Biology, University of Washington, Seattle, Washington, USA, pers. comm. 2010).

Chambered nautiluses lack a larval phase that would allow for dispersal across ocean expanses (Dunstan 2011a; Saunders & Landman 2010). Juveniles hatch at about 22-26 millimeters in diameter (Davis & Mohorter 1975; Dunstan *et al.* 2011c; Hamada *et al.* 2010; Okubo *et al.* 1995; Uchiyama & Tanabe 1999; Ward & Saunders 1997). Live hatchlings have only occasionally been seen in the wild (Davis & Mohorter 1975; Dunstan 2011a; Hayasaka *et al.* 1982; Saunders & Spinosa 1978).

3.4 Morphological characteristics

All species of chambered nautiluses are distinguished by their coiled external, calcium carbonate shell which is divided into compartments, called chambers. Embryonic shell development occurs similarly across all species (Arnold 1985; Arnold *et al.* 2010; Okubo *et al.* 1995), with shells containing at least 7 chambers in a newly-hatched chambered nautilus to 28 or more chambers in mature individuals (Arnold 1985; Arnold *et al.* 2010; Crick & Mann 2010; Dunstan *et al.* 2011c; Okubo *et al.* 1995; Shapiro & Saunders 2010; Ward 1987, 1988; Ward & Saunders 1997). They differ from other living cephalopods by having up to 90 retractable appendages that lack suckers (Fukuda 2010; Jereb & Roper 2005; MarineBio 2013). Chambered nautiluses use their tentacles to scavenge by digging in the substrate to find food

(Barord 2015) and to rest by attaching to reef surfaces (Dunstan *et al.* 2011b; Hayasaka *et al.* 1982; Kier 2010).

As the animal grows, its body moves forward and a wall called a septum is produced that seals off the older chambers. The body is contained within the newest and largest chamber, into which it can completely withdraw, closing the opening with a leathery hood (Jereb & Roper 2005). Researchers believe that these animals use their renal appendages to store calcium phosphate that is used in the formation of the septa and in outer shell development (Arnold 1985; Cochran *et al.* 1981; Landman & Cochran 2010; Ward 1987).

Cephalopods are distinguished from other marine mollusks by such features as a buoyancy mechanism, which facilitates movement, and a beak, which facilitates a carnivorous diet (Boyle & Rodhouse 2005). All cephalopods, including chambered nautiluses, have well-developed brains capable of learning (Barord 2015; Crook & Basil 2008a, 2008b, 2012; Larson *et al.* 1997; Tanabe & Fukuda 2010).

Chambered nautiluses are sexually dimorphic, with mature males larger than females (Jereb & Roper 2005; as summarized by Saunders & Ward 2010; Ward & Saunders 1997). Age to maturity is between 10-15 years across the species, but some species reach maturity at a larger size than others (Collins & Ward 2010; Cochran & Landman 2010; Dunstan *et al.* 2011c; Saunders 1983, 1984a). The maximum shell size varies with species.

Shell color (white to orange) varies among species, with markings that can serve as a diagnostic character for some species and in differentiating adults from juveniles (Jereb & Roper 2005). It is the distinctive, often colorful, coiled, chambered shell that makes chambered nautiluses a sought after commodity in international trade. Their shells are rivalled by few other species.

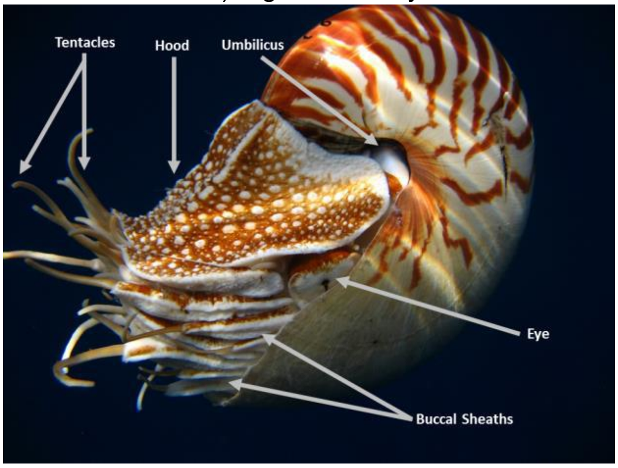

Figure 4 ***Nautilus pompilius (*****Barord 2015)**

3.5 Role of the species in its ecosystem

Chambered nautiluses have been characterized as deep-sea scavenging generalists and opportunistic predators (Dunstan *et al.* 2011c; Jereb & Roper 2005; Nichols 1991; Saunders 1981a; Saunders & Ward 2010). Deep sea scavengers are important in energy flow, nutrient cycling, and in stabilizing marine food webs (Beasley *et al.* 2012; Kaiser & Moore 1999). Recent research suggests that chambered nautiluses may be strict or obligate scavengers (Barord 2015; Barord *et al.* 2014). If this is true, chambered nautiluses would be among the largest obligate marine scavengers (Ruxton & Houston 2004).

Chambered nautiluses are the last living representatives of the multi-chambered, externally-shelled cephalopods that appeared at least 450 million years ago (Boyle & Rodhouse 2005), and are often called "living fossils" (Crook & Basil 2008a, 2008b; Saunders & Landman 2010). Of the five Cephalopod subclasses – Actinoceratoidea, Ammonoidea, Coleoidea, Endoceratoidea, and Nautiloidea – three are extinct, including the last of the externally-shelled ammonoids which went extinct 65 million years ago possibly in response to predation following the rapid evolution of shallow-water teleosts during the Cretaceous (Saunders 1984b). Today, the soft-bodied octopus, squid, and cuttlefish exist as the only modern-day relatives to chambered nautiluses (Boyle & Rodhouse 2005; Larson *et al.* 1997; Teichert & Matsumoto 2010). Chambered nautiluses play a role in human understanding of molluscan evolution and are important to present-day paleontological, paleoecological, and paleoclimatological study (Allcock 2011; Arkhipkin 2014; Barord 2015; Biodiversity Clearing-House Mechanism of China *no date*; Boyle & Rodhouse 2005; Carlson 1985; Crook & Basil 2008a, 2008b, 2012; Crook *et al.* 2009; Larson *et al.* 1997; Mapes *et al.* 2010; Neumeister & Budelmann 1997; Ritterbush *et al.* 2014; Seuss *et al.* 2015; Sinclair *et al.* 2011; Wani *et al.* 2005).

4. Status and trends

4.1 Habitat trends

Much of the chambered nautilus habitat is impacted by human activities, including destructive fisheries, pollution, sedimentation, and changes in water temperature and pH. More than half the reef areas in

China, India, Indonesia, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam are considered to be at risk from these threats, in addition to coastal development (Burke *et al.* 2002; De Angelis 2012).

The coral reef habitat of chambered nautiluses is home to a variety of other species that are harvested for human use or consumption, including shrimp, crabs, and anemones (Hayasaka 1985; Hayasaka *et al.* 1982; Saunders 1984b); stony and hard coral, starfish relatives, hermit crabs, a variety of sea snails and ornamental fish (Burke *et al.* 2002; CCIF 2001; Hayasaka *et al.* 1982; Suzuki & Shinomiya 1995; Sykes & Morris 2009). Fish include those typically associated with coral reefs, such as parrotfish (Scaridae family) and butterflyfish (Chactodontidae family), as well as teleosts such as herring relatives (Clupeidae family) and those associated more typically with silty sea bottoms, such as stargazers (Uranoscopidae family) and flounders (Pleuronectidae family) (Hayasaka *et al.* 1982; Shinomiya *et al.* 1985).

Harvest of coral and live rock for the aquarium trade contributes directly to the destruction of coral reefs and decreases the biodiversity of the reef ecosystem (Burke *et al.* 2002; Conservation & Community Investment Forum (CCIF) 2001; Lal & Cerelala 2005; Sykes & Morris 2009). The bustling trade in live reef fish to satisfy high-end Asian food markets has been on the rise since the 1970s (Petersen *et al.* 2004). Most marine products in the aquarium trade are sourced from coral reefs worldwide (Lal & Cerelala 2005). Harvest for the food aquarium trade occurs within nautilus habitat, including in Indonesia, New Caledonia, Papua New Guinea, the Philippines, Vanuatu (Aguiar 2000; Manez *et al.* 2015; Raubani 2009; Saunders pers. comm. 2014).

In some cases, unselective and destructive fishing practices are used to satisfy these industries. Unselective fishing techniques, such as the use of dynamite and poison kill unintended species, degrade or destroy habitat, and negatively impact the marine ecology of the ecosystem (Burke *et al.* 2002). Such techniques are used variously throughout the chambered nautiluses' range—to a lesser extent in Fiji, where only a few fishermen employee blast fishing and to a greater extent in the waters off China, Indonesia, the Philippines, and Viet Nam (Aguiar 2000; Barber & Pratt 1997, 1998; Uthicke & Conand 2005; Wilkinson 2008Burke *et al.* 2002; World Resources Institute (WRI) 2008).

Figure 5 Map of destructive fishing practices occurring within chambered nautilus habitat (WRI 2008)

Cyanide is used to harvest both food fish and aquarium fish in various regions of the Indo-Pacific. This is destructive to the coral reef ecosystems, because it kills non-target fish, coral, and reef invertebrates (Barber & Pratt 1997, 1998; CCIF 2001). This technique was developed in the 1960s in the Philippines and spread to Indonesia in the 1990s by Filipino divers in search of new sources of live fish for the food trade who trained local fishermen (Barber & Pratt 1997, 1998). According to the Conservation and Community Investment Forum, cyanide fishing has been used there for so long that it is commonly thought of as "traditional" (CCIF 2001). Locations where use of cyanide and destructive fishing practices are known or suspected to occur correspond to the majority of chambered nautilus' range countries (Barber & Pratt 1997; WRI 2008). Notably, the Philippines Cyanide Fishing Reform Program is attempting to address this problem by providing training in alternative fishing techniques (WRI 2008).

Pollution and sedimentation impacting large portions of coral reefs, especially the coastal reefs areas, are reported in parts of Australia, China, Fiji, New Caledonia, Solomon Islands, the Philippines, Vanuatu, Viet Nam, and Western Samoa, potentially impacting chambered nautilus habitat (Ah-Leong & Sapatu 2009; Burke *et al.* 2002; Kere 2009; Raubani 2009; Sykes & Morris 2009; Wantiez *et al.* 2009). Between 80-90 percent of the wastewater dumped into Indo-Pacific waters is untreated (Nelleman *et al.* 2008). Increased sedimentation compromises the health and composition of the coral community on the reef, destroying habitat (International Society for Reef Studies (ISRS) 2004). Habitat destruction and pollution from deep sea mining occurs within or impacts chambered nautilus habitat; for instance, in Australia and Papua New Guinea, effluent and mining tailings from coastal areas either flow into or are dumped into chambered nautilus habitat (A. Dunstan, Queensland Government Department of Environment and Heritage Protection, Raine Island Recovery Project, Australia, pers. comm. 2010).

Cephalopods are sensitive to chemical pollution and have low tolerance for salinity changes (Beeton 2010). Bioaccumulation and transfer of heavy metal pollutants up the food chain have been reported for three cephalopod relatives of chambered nautiluses: the common octopus (*Octopus vulgaris*), the common cuttlefish (*Sepia officinalis*), and the European squid (*Loligo vulgaris*) (as summarized in Pierce *et al.* 2010; Rjeibi *et al.* 2014). Despite their differences in life histories, it is possible that chambered nautiluses are similarly affected, as they share certain physiological characteristics with their coleoid counterparts. For example, chambered nautiluses have blood chemistry similarities with octopuses and giant squid (*Architeuthis* spp.) (Brix *et al.* 1994); oxygen-diffusing capacities similar to octopuses (Eno 1994); and genetic structural similarities of hemocyanins with octopuses (Bergmann *et al.* 2006).

Coral bleaching caused by increased water temperatures has impacted reefs in Australia, Palau, and Thailand, exacerbating the negative impacts on coral reefs from pollution and overharvest (Burke *et al.* 2002; Golbuu *et al.* 2005; Nelleman *et al.* 2008; NOAA Satellite & Information Service 2010). Ocean acidification and warming increases uptake of heavy metals in early life stages, as documented in cuttlefish in the context of ocean acidification and ocean warming, as well as decreased salinity on hatching (Lacoue-Labarthe *et al.* 2009; Palmegiano & d'Apote 1983). Ocean acidification changes oxygen distribution and reduces pH (e.g. Hofmann *et al.* 2010; Stramma *et al.* 2010). Rising acidity increased the corrosiveness of the water to calcium carbonate (Turley & Boot 2010; Turley & Gattuso 2012). Such fluctuations may negatively impact chambered nautiluses given their reliance on calcium uptake, storage, and processing as part of their physiological development and biological functions.

4.2 Population size

There are no global population estimates for chambered nautiluses. The first known quantitative population estimate was made in 2010 for an unexploited population (i.e., no history of commercial fishing) of *N. pompilius* at Osprey Reef, Australia, and found a small and dispersed population of between 844 and 4467 individuals (Dunstan *et al.* 2010, 2011a), with an abundance of 10-15 individuals per square kilometer (km^2). Subsequent population research at three other unfished sites yielded the following population abundances for *N. pompilius*: Great Barrier Reef, Australia: 0.34 individuals per km^2; Beqa Passage, Fiji: 0.21 individuals per km^2; and Taena Bank, American Samoa: 0.16 individuals per km^2 (Taena Bank) (Barord *et al.* 2014).

The dispersed nature and low abundances in the unfished populations may be indicative for these animals across their range (Barord *et al.* 2014), demonstrating that they are naturally rare. This is consistent with palaeontological observations based on the geologic record (Larson *et al.* 1997), "that the immediate ancestors of living *Nautilus*" were rare (Wadr 1984, as cited in Teichert & Matsumoto 2010, p. 25). The species' natural rarity is believed to make them vulnerable to over-exploitation, particularly in the absence of management. Population research on *N. pompilius* in the Panglao Region of the Bohol Sea, Philippines, where commercial harvest exists, yielded abundance estimates of between 1 and 3 orders of magnitude fewer individuals when compared to unfished populations (Barord *et al.* 2014). Barord *et al.* (2014) notes that due to these species' keen sense of smell chambered nautiluses are easily attracted to baited traps used both for scientific research and for the fishery. Saunders (pers. comm. 2009) noted that these animals may habituate to baited trapping sites—as evidenced by the large number (30 percent) of recaptured individuals in catch-and-release research on *N. belauensis* in Palau. The attraction of these animals to bait and the ease of their recapture may lead to overestimations of the apparent population size, and a false impression that the species is common.

4.3 Population structure

Recent genetics data suggests that chambered nautiluses may be comprised of numerous as yet "unrecognized but separate sibling species" that exist as genetically distinct, geographically- and reproductively-isolated populations (Barord *et al.* 2014, p. 1; Bonacum *et al.* 2011; Dunstan *et al.* 2011c; Sinclair *et al.* 2011; Williams *et al.* 2012, 2015).

All trapping data in which animals were sexed, including mark-recapture studies, are male-dominated with 75-80 percent of the nautiluses captured being males. In addition, 75 percent of all of the captured individuals (males and females combined) are mature. Young animals are rarely captured (Arnold *et al.* 2010; Dunstan *et al.* 2010, 2011c; Hayasaka *et al.* 1982; Saunders 1984; Saunders & Spinosa 1978; Saunders & Ward 2016 *in review*; Ward 1988).

There are consistently few juveniles in the populations studied (Hayasaka *et al.* 1982; Saunders & Spinosa 1978; Ward & Martin 1980). Detailed age class distribution information from the 12-year study of the unfished population in Osprey Reef, Australia, found fewer than 10 percent of the population were juveniles, indicating that chambered nautiluses exhibit low fecundity in the wild (Dunstan 2011a) and affirming previous field studies which found that juvenile chambered nautiluses represent less than 10-20 percent of the population (Carlson & Degruy 1979; Havens 1977; Saunders 1983, 1990; Saunders & Landman 2010; Tanabe *et al.* 1990; Ward 1987; Ward & Martin 1980; Ward *et al.* 1977; Zann 1984).

The male-biased sex ratio could reflect the natural equilibrium for these populations. While population theory suggests it is the females that are the critical sex for population growth, there are examples where population growth which may be male-biased density-dependent (as summarized by Caswell & Weeks 1986; Hamilton 1967; Rankin & Kokko 2007). A male-biased sex ratio and high genetic diversity within populations may be indicative of a population structure based on multiple paternity, as with loggerhead sea turtles (Lasala *et al.* 2013). Chambered nautilus experts have noted the high levels of morphological and genetic variation (Bonacum *et al.* 2011; Sinclair *et al.* 2007, 2011; Swan & Saunders 2010; Tanabe & Fukuda 2010; Tanabe *et al.* 1985, 1990; Ward & Saunders 1997; Williams *et al.* 2012, 2015), and research in the 1980s on the genetic structure of *N. pompilius* populations in Papua New Guinea found high levels of genetic variation within populations, indicating that individuals within that population were freely interbreeding (Woodruff *et al.* 2010). If males of the species are the critical sex for population growth, the trapping of mostly adult males to supply international trade is of particular concern to the sustainability of the species.

Researchers have also speculated whether the consistently larger proportion of males could be due to sampling-bias. For instance, Ward & Martin (1980) noted that these animals may exhibit size segregation, with immature individuals in deeper water and further from shore. However, the long-term data from Osprey Reef, Australia, indicated that the chambered nautiluses are not segregated within their overall habitat by either size or sex (Dunstan *et al.* 2010).

4.4 Population trends

Chambered nautiluses exhibit classic characteristics of k-strategists typically living in resource-limited "climax" environments, where population size is constant and near the carrying capacity of the environment, and where population growth (or replacement rate) is equal to one (Dunstan *et al.* 2010; Saunders 1981a; Saunders & Spinosa 1979; Saunders & Ward 2010; Saunders *et al.* 1989; Sinclair *et al.* 2007, 2011; Tanabe *et al.* 1990; Ward 2008; Ward and Saunders 1997). As such, populations are presumed to be stable where fisheries are absent (such as Fiji and the Solomon Islands), despite scant ecological data (Aguiar 2000; R. Mapes, Professor, Department of Geological Sciences, Ohio University, USA, pers. comm. 2011). The unfished, but small population of *N. pompilius* at Osprey Reef, Australia, was stable with no evidence of decline over a 12-year period (Dunstan *et al.* 2010). Anecdotal declines were reported in Palau (with the endemic *N. belauensis),* where a fishery reportedly existed in the 1990s but has not been confirmed (Aguiar 2000). Carlson & Awai (2015) recently repeated fishery-independent research conducted 30 years prior (Saunders 1983; Saunders & Spinosa 1979) which indicated that *N. belauensis* may be stable currently.

Declines have been reported where fisheries occur or have existed. The Scientific Authority of India reported decline of *N. pompilius* in Indian waters following several decades of harvest (K. Venkataraman, Director, Zoological Survey of India, West Bengal, India, pers. comm. 2011). Fishermen, traders, and species experts report declines in Indonesia, where *A. perforatus* and *N. pompilius* are native and where harvest may be increasing (Freitas & Krishnasamy 2016; Saunders pers. comm. 2009). There are also reports of past declines in New Caledonia (home to *N. macromphalus* and *N. pompilius*)*,* where commercial harvest occurred in the past (Aguiar 2000; Saunders pers. comm. 2009, 2016).

According to the Palawan Council for Sustainable Development (PCSD), the Philippine Management Authority in Palawan, traders report a decline in the number of *N. pompilius* shells provided by harvesters over the last five years (N. Devanadera, Executive Director, PCSD, Puerto Princesa City, Palawa, Philippines, pers. comm. 2016). Anecdotal declines were reported in the early 2000s by some harvesters in the Visayan Regions where several harvesting sites occur (Schroeder 2003). A survey of 26 harvesters and 7 traders reported declines at several fishing sites in Palawan province, as well as reports of "crashed" fisheries in Cagayancillo (Palawan Province), in Tawi-Tawi Province, and in Tañon Strait (which lies within three Provinces) (Dunstan *et al.* 2010).

Declining catch rates have been recorded during field work on the ecology or physiology of these species. Research in the 1970s in the Tañon Strait, Philippines, coincided with the resurgence of an intensive fishery there (Haven 1977). Scientific collections conducted during a year-long research study (August 1971-August 1972) yielded as many as 19 individuals, with an average of five animals per trap. Commercial trapping of that population commenced and continued at that site and a 1975 ecological research expedition to the same location found that catch yields had decreased by 27 percent (when compared to a comparable period in 1971) despite a tripling in the number of harvesters who were trapping at greater and greater depths (Haven 1977). In a 1979 study, yields had decreased to an average of only one animal per trap (Haven 1972, 1977; Saunders pers. comm. 2009; Saunders & Ward 2010). By 1987, the fishery had ceased in Tañon Strait and a fishery-independent research expedition yielded

0.01 chambered nautiluses per trap, indicating a population decline of about 97 percent in 16 years (Dunstan 2010). As of the late 1980s, the species is commercially extinct and possibly extirpated from Tañon Strait (Alcala & Russ 2002; Saunders pers. comm. 2009; Ward 1988).

In New Caledonia, a fishery-independent field study involved the capture and retention of large numbers, possibly thousands, of specimens in 1983-1984 (Ward pers. comm. 2011). By mid-1984, researchers had difficulty catching animals in any of the sampling locations, indicating possible declines of 100 percent in local populations subject to harvest within a 2-year period.

Given the biology of the species (slow growth, low reproduction, long gestation, lack of dispersal options, and low population numbers), species experts consider the species to be highly susceptible to local extinction, especially the endemic species and more localized populations (B. Carlson, Science Officer, Georgia Aquarium, Atlanta, Georgia, USA, pers. comm. 2009; Barord *et al.* 2014; Dunstan *et al.* 2010, 2011a, 2011c; Landman & Cochran 2010; M. Seddon, Chair, IUCN Mollusc Specialist Group, Devon, United Kingdom, pers. comm. 2003; Saunders 1984a; Saunders pers. comm. 2009).

5. Threats

Threats to the Family Nautilidae include directed harvest for commercial international trade, habitat degradation throughout most of its range, as described in Section 4.1, ecotourism, predation, and small population size.

Commercial Harvest: Chambered nautiluses are harvested for wholesale commerce and the tourist trade (Aguiar 2000; De Angelis 2012; Freitas & Krishnasamy 2016; Monks 2002). The trade is driven largely by international demand for shells and shell products (Dunstan *et al.* 2010; LEMIS 2016; NMFS 2014). The consumer market for chambered nautilus products includes North and South America, Eastern and Western Europe, Eastern and Southeast Asia, Africa, the Middle East, and Oceania (Freitas & Krishnasamy 2016; HSUS & HSI 2008; LEMIS 2016; Vina Sea Shells 2006).

All of the currently recognized species of chambered nautiluses are found in international trade. In the tourist trade and home décor markets, chambered nautilus shell is generally used without differentiation by species. There is also a selective market for collectors who will pay higher prices for live animals or shells of rarer species of chambered nautiluses (Freitas & Krishnasamy 2016; HSUS & HSI 2008; Saunders pers. comm. 2009). In the selective markets, shells are identified to the species level. The potential higher value for the rarer species could further drive the demand (Dunstan *et al.* 2010; Kailola 1995; NMFS 2014).

Commercial demand is met largely by targeted harvesting that is occurring or has occurred in India, Indonesia, New Caledonia, Papua New Guinea, and the Philippines, and possibly in China, Palau, Thailand, and Vanuatu (Aguiar 2000; Dunstan 2010; Freitas & Krishnasamy 2016; Kailola 1995; LEMIS 2016; NMFS 2014; Saunders pers. comm. 2009; Venkataraman pers. comm. 2011). Commercial harvesters use fish traps baited with a variety of locally-available meats dropped to depths between 130 and 250 m (Carlson pers. comm. 2009; del Norte-Campos 2005; Dunstan *et al.* 2010; Freitas & Krishnasamy 2016; Jereb & Roper 2005; Neumeister & Budelmann 1997; Saunders pers. comm. 2009). Chambered nautiluses are easily lured to traps “with almost any type of meat” (Carlson pers. comm. 2009) due to their keen sense of smell (Barord *et al.* 2014; Basil *et al.* 2000; Crook & Basil 2008a; Saunders pers. comm. 2009).

The Philippines and Indonesia appear to have the largest commercial fisheries for products entering international trade, with multiple nautilus harvesting sites throughout these island nations (del Norte-Campos 2000, 2005; Dunstan *et al.* 2010; Freitas & Krishnasamy 2016; LEMIS 2016; Nijman *et al.* 2015). There is scant information as to the status of these populations or the volume of harvest, although declines are reported by harvesters and traders throughout these countries. A 12-month catch survey of Panay fisherman conducted in the Philippines from October 2001 to October 2002 estimated the total annual harvest of 6.6 metric tons (including body and shell), equating to an estimated 12,200 chambered nautiluses per year (del Norte-Campos 2005). In Palawan, Philippines, about 9,091 animals were harvested in 2013 and 37,341 were harvested in 2014 (Devanadera pers. comm. 2016).

Overfishing is among the greatest threats to marine fisheries worldwide, including within the chambered nautilus’ range (Allison *et al.* 2009; FAO 2009; Hofmann *et al.* 2010; Jackson *et al.* 2001; Nelleman *et al.* 2008; Pauly 2010; UNEP 2006; Worm *et al.* 2009). Overfishing may stem from both artisanal reef fisheries, as in Fiji to satisfy domestic markets (Sykes & Morris 2009), or large-scale commercial reef fisheries, as in Vanuatu for the aquarium trade (Raubani 2009). In the 'Coral Triangle,' which encompasses the chambered nautilus range countries of Indonesia, Malaysia, Papua New Guinea, the Philippines, and Solomon Islands, scientific studies indicate that 90 percent of the natural resources there are threatened by overfishing, unsustainable fishing practices, pollution, and climate change (The Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security 2016).

Dunstan *et al.* (2010) notes similarities in the chambered nautilus fishery to other demand-driven fisheries throughout their biogeographic range, such as bêche de mer (sea cucumber) fisheries, which have led to overharvest (Uthicke & Conand 2005). Wilkinson (2008) describes the serial depletion of marine life on coral reefs as 'fishing down the food web,' where fishermen begin by harvesting high-value species and as those resources are depleted, move down the food web to other species. Such harvest, driven by international demand that can lead to destructive or unsustainable fishing practices, has resulted in declines of such species. The serial depletion of coral reef fishes is well-known throughout the Indo-Pacific region (Wilkinson 2008), including humphead wrasse (*Cheilinus undulatus*, CITES Appendix II, 2005) (Russell 2004). Ward (pers. comm. 2013) reported no large fishes were found at the site of recent chambered nautilus population research in the Philippines, where chambered nautiluses are targeted for fishing. Uthicke and Conand (2005) provide examples of bêche de mer and other reef species that have been overfished or commercially depleted in eight of the chambered nautilus range states.

Similar to other external, demand-driven fisheries in the region (i.e., live reef fish and aquarium trade) (CCIF 2001; Lal & Cerelala 2005; Petersen et al. 2004), there is little local demand for chambered nautilus species (Dunstan *et al.* 2010; Freitas & Krishnasamy 2016; Kailola 1995; NMFS 2014). In some communities where commercial nautilus harvest occurs or has occurred (e.g., Savu, Indonesia; Bohol, Philippines; Rabaul and Manus Island, Papua New Guinea), harvesters were taught by traders how to trap the chambered nautiluses, traders organized transport for them, and may have also paid other expenses associated with harvesting (Dunstan *et al.* 2010; Kailola 1995; NMFS 2014).

The chambered nautilus fishery follows a boom-bust cycle that lasts until the population is depleted and the fishery moves to a new location. Intensive chambered nautilus fisheries are short-lived, lasting a decade or two before becoming commercially nonviable (Aguiar 2000; Dunstan *et al.* 2010). Where several chambered nautilus populations exist, harvest might continue for many years as each population is serially depleted (Dunstan *et al.* 2010). The relatively high numbers of individuals harvested annually in Philippine waters compared to the low numbers estimated for the unexploited population of Osprey Reef, Australia (844 to 4467 individuals) indicate that serial depletion of numerous isolated populations may be occurring there.

Jereb & Roper (20015) characterized the chambered nautilus fishery as one supported mostly from beach-drift specimens and subsistence fisheries. However, only a small portion of the international commercial market is fed by incidental collection of drift shells in some range countries (Carlson pers. comm. 2009; del Norte-Campos 2005; Freitas & Krishnasamy 2016; Schroeder 2003). Species experts do not believe that incidental collection could satisfy the U.S. market, let alone global consumer demand for nautilus shells because of the sheer number of shells in demand (NMFS 2014). Since drift shells are often etched or broken, these damaged shells are not as valuable in the marketplace (Kailola 1995; NMFS 2014). Most dealers and collectors in the specimen shell trade prefer shells from animals that have been caught alive and then boiled, in order to preserve and maintain the pristine condition of the shells (Kailola 1995).

Predation: Natural predators of chambered nautiluses include teleost fish, octopuses, and sharks (Saunders 1984b; Saunders & Ward 2010; Saunders *et al.* 1989, 1991; Ward 1987, 1988) (See Figure 2). Predation is evident on drift shells and as "shell wounds" on living animals (Arnold 1985; Saunders *et al.* 1989, 1991; Ward 1987, 1988). Predation pressure varies across their range. For example, research in Papua New Guinea indicated that more than 50 percent of drift shells showed evidence of bore hole predation by octopus species, and that 2–8 percent of live-caught animals showed evidence of octopus drilling (Saunders *et al.* 1991), while predation rates in Fiji appeared to be lower (Ward 1987).

Predation limits chambered nautiluses' movements within their habitat (Jereb & Roper 2005; Saunders pers. comm. 2009, 2016; Saunders et al. 2010; Ward 1987). Chambered nautiluses show little defense or escape response, beyond retreating inside the chamber and closing their mantle (Daw & Barord 2007; Saunders & Landman 2010; Saunders *et al.* 2010). However, they exhibit certain behaviours that appear to be favourable to predator avoidance (Jereb & Roper 2005). Chambered nautiluses avoid swimming in the open water column, where they are more vulnerable to predation (Saunders 1984b, 1990). Chambered nautiluses migrate vertically within their habitat, with individuals moving into shallow water at night (up to about 100 m) and migrating back into deep-water at dawn (Saunders 1984b, 1990), which appears to coincide with reduced activity of teleosts in the shallows (Saunders *et al.* 2010; Saunders pers. comm. 2009, 2016; Ward 1987). While all chambered nautiluses seem to exhibit these vertical movements, the frequency and extent of such migrations differ, probably depending on habitat, food availability, and predator conditions (Dunstan *et al.* 2011b; Saunders & Ward 1987; Ward & Martin 1980).

As summarized by Wood and O'Dor (2000), species with delayed maturation are at increased risk of predation prior to reproduction versus those that mature and reproduce at an early age. Moreover, recent research suggests that populations of chambered nautiluses that are subject to commercial harvest are subject to increased risk of predation. Ward (2014) found a statistically significant higher amount of mature specimens with major shell breaks in fished areas (e.g., Bohol and New Caledonia) when compared to unfished populations (e.g., Australia and Papua New Guinea, the latter of which was based on data from the early 1980s).

Ecotourism: There are reports of ecotourism operations in Palau which trap chambered nautiluses for use in photographs with customers of dive tour operations; the chambered nautiluses are subsequently released into shallow waters. Although not as intensive as a commercial export fishery, chambered nautiluses are especially vulnerable to predation from shallow water predators in the daytime. This has been noted by researchers conducting capture-release studies, where teleost fish attack the chambered nautiluses as they are released in waters as shallow as 20 m (NMFS 2014; Saunders *et al.* 2010; Ward 1987). As seen in recent video footage, when animals are released in a consistent location, it essentially becomes a feeding station for triggerfish (Carlson & Awai 2015; https://www.youtube.com/watch?v=dM9TFKUxnYc). In addition, captured chambered nautiluses can overheat and die before they are returned to the deep (Aguiar 2000); *Allonautilus* die quickly if pulled out of the water (NMFS 2014); and chambered nautiluses may develop air bubbles upon descent which inhibits their ability to quickly return to the safety of their deep-water habitat zone (NMFS 2014). Thus, ecotourism may increase the predation threat to the animals upon their release.Given this tendency toward higher daytime predation in shallow waters, researchers have modified their techniques to release animals in deeper waters following capture-release studies (Carlson & Awai 2015; Dunstan *et al.* 2011c).

Small population size: Chambered nautiluses are patchy and dispersed in distribution and appear to be naturally rare, maintaining small population sizes that are reproductively-isolated in geographically-separated populations (Barord *et al.* 2014; Dunstan *et al.* 2011c; Saunders pers. comm. 2009; Sinclair *et al.* 2011). Species that maintain small population sizes are at increased risk of extinction. These risks are magnified if they occupy a small geographic range and occur at low density. Once a population is reduced below a certain number of individuals, it tends to rapidly decline towards extinction (Frankham 1996; Franklin 1980; Gilpin & Soulé 1986; Holsinger 2000; Purvis *et al.* 2000; Reed & Frankham 2003; Soulé 1987). Small, isolated wildlife populations, like chambered nautiluses, are also more susceptible to environmental fluctuations, demographic shifts, and genetic impacts, such as reduced reproductive success of individuals, which could have individual or population-level consequences (Charlesworth & Charlesworth 1987; Pimm *et al.* 1988; Shaffer 1981). Species with a small population size, combined with a restricted and severely fragmented range, are more vulnerable to adverse natural events and manmade activities that destroy individuals and their habitat (Holsinger 2000; Primack 1998; Young & Clarke 2000). Given the reproductive isolation between geographically-separated populations, and the likelihood that these populations could represent distinct species of chambered nautiluses, the loss of any one population could be significant enough to result in the loss of a species.

6. Utilization and trade

6.1 National utilization

Following is information on local use, market, and fishery activities in some chambered nautilus range states.

American Samoa (USA): There is no known local utilization of this species and no known history of commercial harvest of chambered nautiluses (M. Sabater, formerly Chief Fishery Biologist, Department of Marine and Wildlife Resources, Pago Pago, American Samoa, pers. comm. 2009).

Australia: There is no known local utilization of this species and no known commercial harvest of chambered nautiluses (Dunstan 2010; P. Murphy, Assistant Secretary, Wildlife Trade and Biosecurity Branch, Canberra, Australia, pers. comm. 2016). Many *Nautilus repertus* were caught as bycatch from deep-water trawling for shrimp off Port Hedland, but trawling reportedly ceased about 20 years ago (Dunstan 2010).

China: Meat and shells may be found in local seafood markets and curio shops, and are sometimes sold at airport gift shops (Freitas & Krishnasamy 2016). Harvest may occur on Hainan Island (Freitas & Krishnasamy 2016), but the extent of the fishery is unknown.

Fiji: There is no known local utilization of this species and there have been no known commercial fisheries. Drift shells have been incidentally collected for use in making jewelry and wood inlays that may be sold to tourists (Carlson pers. comm. 2009). LEMIS (2016) reports recent U.S. imports from Fiji (during 2011-2014). In the absence of commercial fisheries, exports from Fiji may be supplied by incidental collection (Carlson pers. comm. 2009; HSUS & HSI 2008).

India: According to the Scientific Authority of India, *Nautilus pompilius* has been exploited for decades in Indian waters and is also caught as bycatch by deep sea trawlers (Venkataraman pers. comm. 2011). In a 2007 survey of 13 major coastal tourist curio markets in southern India, *N. pompilius* shells were found in only 20 percent of the markets but were among the most common shells offered and among the most important shells, in terms of price and the rate of purchase (Sajan *et al.* 2012).

Indonesia: Chambered nautiluses are commercially harvested throughout the Indonesian islands despite being protected from harvest since 1990. Chambered nautilus meat, whole shells and worked products (including furniture inlaid with nautilus shell) are sold locally (Freitas & Krishnasamy 2016; Nijman & Nekaris 2014). According to a 2013 survey, a total of 171 specimens of *N. pompilius* and *A. scrobiculatus* were being offered for sale in two of the largest open-air markets in Indonesia on the island of Java (Nijman *et al.* 2015). Shells are sold whole and carved, or used in jewelry and inlays to be sold internationally (Freitas & Krishnasamy 2016). Meat is exported to Singapore; shells to the United States; and products are sold to New Caledonia and the Pacific Islands (Freitas & Krishnasamy 2016). Wholesale companies in Java sell chambered nautilus shells to customers in Malaysia and Saudi Arabia and also online (Nijman *et al.* 2015).

New Caledonia: *Nautilus macromphalus* was the first of the chambered nautiluses to be displayed in a public aquarium in New Caledonia in 1958. Ward (2014) noted that unrestricted fishing occurred in New Caledonia from 1981 to 1983. An intense, decade-long fishery reportedly sprang up in the 1990s (Aguiar 2000). In 2005, Jereb & Roper reported a small fishery in New Caledonia supporting the aquarium trade. Saunders (pers. comm. 2009) also noted the existence of a single commercial operation, though it is unclear during which years this may have occurred. Another report indicates that commercial harvest in New Caledonia apparently ceased in 2011 (Mapes pers. comm. 2011). Chambered nautilus shells are sold to tourists near the airport, according to the airport police (Wisnu 2008), and shells of *N. macromphalus*, which is endemic to New Caledonia are sold online (Freitas & Krishnasamy 2016).

Palau: Significant past collection and an intensive fishery were reported (Aguiar 2000; HSUS & HSI 2008). Chambered nautilus trade is limited today compared to other marine resources; government records indicate the 54 shells and 3 live specimens were exported in 2014 and 2015 (K. Sam, Special Assistant to the Minister/Program Manager, Protected Areas Network, Ministry of Natural Resources, Environment and Tourism, Koror, Republic of Palau, pers. comm. 2016). Most recently, harvest has been associated with commercial dive boat operations (Saunders pers. comm. 2016). Local diving outfits advertise tourist photo opportunities with the Palauan nautilus (*N. belauensis*) (Carlson & Awai 2015; HSUS & HSI 2008; Saunders pers. comm. 2010). Though minor in comparison to the shell export industry, ecotourism is among the threats to these species.

Papua New Guinea: Nautilus meat does not appear to be traditionally eaten locally (Kailola 1995). Shells might occasionally be kept as ladles, but it would be rare to find the shell being sold in the local market (Saunders *et al.* 1991). Trade from this country was believed to derive from incidental collection of drift shells because there had been no known chambered nautilus fishery or deep-water trapping prior to the 1990s (Saunders pers. comm. 2009; Saunders *et al.* 1991). Research data obtained on two populations in the early 1980s showed similar male:female ratios to unfished populations (Saunders pers. comm. 2014; Ward 2014). However, a fisheries resources publication later noted that chambered nautiluses are collected in Papua New Guinea as 'specimen shells' (for shell collectors); such shells are generally collected from live animals to obtain undamaged shells. Shells are also used as inlay and the species may be caught as bycatch in deep-slope fisheries (Kailola 1995). New fishing sites may have opened in at least two locations around 2008, but the extent and impact of harvest have not been investigated.

Philippines: According to traders, harvest and trade of chambered nautiluses has occurred here since at least the 1970s (Freitas & Krishnasamy 2016). Schroeder (2003) noted that while the fishery was targeted in some areas, bycatch occurred in others where the specimens were not marketed. Fishermen in Palawan and Bohol report that harvesting chambered nautilus is not a traditional subsistence fishing activity and that trapping techniques were learned from demand-driven shell traders (Dunstan 2010; NMFS 2014). More than 18,500 whole nautilus shells were encountered in a survey of 162 shops visited in Luzon, Visayas, Mindanao, Manila, Cebu, and Zamboanga, (Freitas & Krishnasamy 2016). Many of the shells are processed in Cebu City, Philippines, where there are many factories as well as an international airport that facilitates export (Devanadera pers. comm. 2016). The meat is less valuable but rather than discard it, fishermen will eat it or occasionally sell some of the meat in local markets (del Norte-Campos 2005; Freitas & Krishnasamy 2016). Traders indicate that international demand for chambered nautiluses is primarily for the whole shell, including shells that are incorporated whole as curios (Freitas & Krishnasamy 2016). There appear to be no cultural, historical, or social connections to harvesting chambered nautiluses in the Philippines, other than as a source of local income for the shell and meat trade (del Norte 2005; Dunstan *et al.* 2010).

Samoa (Western): CITES Authorities in Samoa are not aware of any trade in these species (R.N. Aiono, Acting Chief Executive Officer, Ministry of Foreign Affairs and Trade, Apia, Samoa, pers. comm. 2016). Research in the late 1980s failed to locate chambered nautiluses. However, the study conditions were not optimal and the researchers determined that the presence or absence of chambered nautiluses in Samoa remained inconclusive (Saunders *et al.* 1989).

Solomon Islands: There is no known commercial fishery. Drift shells are occasionally collected and used for jewelry and wood inlays that may be sold to tourists (Carlson pers. comm. 2009).

Thailand: Shells were reportedly found in gift shops in the past (HSUS & HSI 2008), including fresh-caught specimens of the rare *Allonautilus* species (Ward pers. comm. 2010). However, we are unaware of any published information as to the intensity or duration of such harvest, including whether it is ongoing.

Vanuatu: Nautilus shells are sold to tourists and to shell collectors (Amos 2007). Species experts note that a large-scale commercial fishery has existed here (NMFS 2014).

6.2 Legal trade

All of the currently recognized species in both genera have been reported in trade and the consumer market for chambered nautilus products includes North and South America, Eastern and Western Europe, Eastern and Southeast Asia, Africa, the Middle East, and Oceania (Freitas & Krishnasamy 2016; HSUS & HSI 2008; LEMIS 2016; Vina Sea Shells 2006). Large numbers are reportedly traded within Asia to satisfy the meat market, with as many as 25,000 specimens exported from Indonesia to China between 2007 and 2010 (De Angelis 2012). The meat trade is thought to be a by-product of the shell trade. Many non-range countries are involved in the international trade of chambered nautilus and chambered nautilus products (Freitas & Krishnasamy 2016; HSUS & HSI 2008; LEMIS 2016).

Information on international trade in chambered nautiluses is available in published and unpublished market surveys (del Norte-Campos 2005; Schroeder 2003), web-based advertisements, personal communications (summarized by Freitas & Krishnasamy (2016), and HSUS & HSI (2008)), a trade study conducted by TRAFFIC/WWF in several major exporting and importing countries (Freitas & Krishnasamy 2016), and from U.S. trade data for the period from January 2005 to December 2014 (LEMIS 2016).[4]

Between 2005 and 2014, U.S. trade was comprised of more than 900,000 chambered nautilus commodities, as reported by quantity (Tables 1 & 2, Annex) (LEMIS 2016). These were mostly imports, along with some re-exports. Most trade consisted of jewelry, trim, and shell products, such as buttons, along with whole shells. At least 104,476 individuals are represented by the trade in whole shells, live specimens, biological specimens, and bodies, as reported by quantity. This equates to just over 1,000 individuals annually. Approximately 99 percent of this trade was reported as wild. The remainder were reported as captive-bred (source code C), captive-born (source code F), or ranched (source code R) sources; however, there is evidence that these species have yet to be successfully produced in captivity (Carlson pers. comm. 2009; Saunders pers. comm. 2009; NMFS 2014).[5]

4 *The LEMIS data are compiled from U.S. wildlife declaration forms required for import or export of any fish and wildlife and the data cannot be equated with trade data such as that in the WCMC database. The LEMIS figures likely underestimate actual trade volumes because additional chambered nautilus imports may have been recorded in the database under a broader category, such as mollusks. In addition, LEMIS trade data rely upon the veracity of traders or consumers to declare wildlife products when passing through United States ports of entry (i.e., air and ocean ports). Some travelers may not declare these items, while others may not know the correct species name and some trade is reported at the genus level.*

5 *The LEMIS source codes should not be compared to CITES source codes.*

The LEMIS data indicate that at least thirteen range countries (or purported range countries) traded chambered nautilus commodities with the United States during the ten years of examined data (LEMIS 2016; Table 2). These include range countries where active fisheries exist or have existed (such as Indonesia and the Philippines) and where there have been no known fisheries (such as Fiji and Solomon Islands) (LEMIS 2016). The exports from Fiji and Solomon Islands are worked items, and may be derived from drift shells. The Philippines exported the most products to the United States (approximately 768,000 commodities), accounting for about 85 percent of the trade as reported by quantity and the greatest variety of products including, bodies, jewelry, live specimens, meat, shell products, trim, and whole shells (Table 1). Indonesia was the second largest exporter to the United States (approximately 102,000 commodities) accounting for about 12 percent of the trade as reported by quantityof a variety of mostly worked products including, jewelry, shell products, trim, and whole shells. Exports from China and India account for nearly 13,000 and almost 12,000 commodities, respectively.

N. pompilius is the species most often reported in U.S. trade data (LEMIS 2016). However, the data indicate trade in the endemic species (other than *Nautilus pompilius*) that began in 2009 with *Allonautilus* spp. and *N. macromphalus*; *A. perforatus* and *N. belauensis* in 2010; and *N. repertus* and *N. stenomphalus* in 2012. Notably, U.S. data indicates commercial trade is occurring in endemic species but originating from countries to which they are not native (including *N. belauensis, N. macromphalus*, and *N. repertus*). For instance, a large number of worked items made from the Palauan-endemic species *N. belauensis* (8,144 by quantity) are reported emanating from Indonesia and Thailand. *Allonautilus scrobiculatus* is the only species not specifically named in U.S. trade data (LEMIS 2016).

6.3 Commodities in trade

Globally, products derived from chambered nautiluses range from live specimens and meat to whole shells and parts of shells. Shells are used to make handicrafts, buttons, and jewelry; the meat is consumed sometimes only locally, although international trade in meat may be occurring secondary to the trade in shells; and live animals are collected for use in public and home aquariums and for research (del Norte-Campos 2005; HSUS & HSI 2008; Jereb & Roper 2005; LEMIS 2016; Reef Central 2001; Waikiki Aquarium 2016; Ward pers. comm. 2010).

Prices vary depending on the commodity, the species, and the size and condition of the shell, and prices are generally higher for non-*pompilius* species. A 2007 market survey in Southern India estimated that, of 15 mollusk species, 10 coral genera, and one seahorse species, chambered nautilus shells were the fourth highest valued shell in the markets, selling for approximately 275INR (7USD in 2007 dollars) (Sajan *et al.* 2012). Whereas *N. pompilius* may sell for 6 – 65USD per shell, the rarer, endemic species sell for 25-170USD per shell (Freitas & Krishnasamy 2016; HSUS & HSI 2008). Shell value increases exponentially along the supply chain. One wholesaler at a German mineral and fossil exposition selling *N. repertus* for 35-55 € (40-62USD) indicated that these shells were fairly plentiful (obtaining up to 2,000 shells per year); whereas *A. scrobiculatus* are more difficult to obtain and so the price would be higher (approximately 110 €, 124USD) (S. Altherr, Biologist, Pro-Wildlife, Munich, Germany, pers. comm. 2011). Another trader confirmed that the rarer species are highly sought-after among collectors (Altherr pers. comm. 2011). In 2014, a rare, brownish form of *Nautilus pompilius* was offered for 100 € (113USD), while the price for *A. scrobiculatus* has increased to 180 € (203USD).

6.4 Illegal trade

Data indicates that trade is emanating from some range countries where trade in chambered nautiluses is prohibited or where required permits are reportedly evaded (Freitas & Krishnasamy 2016; LEMIS 2016). Therefore, we assume that this trade may be illegal.

<u>China</u>: Harvest of *N. pompilius* requires a permit. However, some traders claim either not to know the origin of specimens or that specimens originated from another country in order to avoid regulations (Freitas & Krishnasamy 2016; Wisnu 2008).

Enforcement officials in Shenzhen reportedly seized two small shipments of chambered nautilus shells in 2013: three shells entered China from East Timor and two shells in a shipment from Madagascar (Freitas & Krishnasamy 2016).

<u>Indonesia</u>: Despite being protected from harvest under Indonesian law, harvest and trade in *N. pompilius* is ongoing, as well as trade in species endemic to other countries (including *N. belauensis* and *N.*

repertus) (Freitas & Krishnasamy 2016; LEMIS 2016; Nijman & Nekaris 2014). Some traders attempt to circumvent regulations protecting *N. pompilius* by not providing receipts for purchases or mislabelling items with the names of other chambered nautilus species, which are not protected under Indonesian law (Freitas & Krishnasamy 2016). Shells are openly sold in some local markets and to tourists on beaches (Marinos 2013; Nijman & Nekaris 2014; Nijman *et al.* 2015).

Data from Indonesian authorities show that more than 3,000 shells of *N. pompilius* (worth an estimated 60,000USD) were seized between 2008 and 2013, nearly all of which were destined for foreign markets (Nijman *et al.* 2015). Some seizures are sizable, including one seizure of hundreds or thousands of shells in 2007 (Freitas & Krishnasamy 2016). Authorities at the Ngurah Rai International Airport (Bali) continuously find locals and non-locals attempting to sell chambered nautilus shells (Wisnu 2008). Seizures occur mainly in Bali, but also in Jakarta and Surabaya, and include whole shells and products made from shells (Freitas & Krishnasamy 2016; Ministry of Forestry 2005).

New Caledonia: Wildlife smugglers have been known to use New Caledonia as a transit point for the smuggling of chambered nautilus shells. A 2008 confiscation of marine shells being smuggled from Bali, Indonesia into New Caledonia included at least 213 *N. pompilius* shells (Freitas & Krishnasamy 2016; Wisnu 2008).

Philippines: Bohol (where chambered nautilus fishing occurs) and Cebu (the center of shell trade) are known as transit points for legal and illegal trade, including wildlife products (Freitas & Krishnasamy 2016). Chambered nautilus shells are reportedly included in shipments moving through privately-owned seaports that are apparently exempt from inspection procedures (Freitas & Krishnasamy 2016).

6.5 Actual or potential trade impacts

Chambered nautilus populations are susceptible to overfishing and serial depletion throughout their range wherever commercial harvest occurs.

Declines have been reported in areas where intensive fisheries exist or have existed, including India, Indonesia, the Philippines, New Caledonia, and possibly in Palau (Aguiar 2000; Alcala & Russ 2002; Carlson pers. comm. 2009; Dunstan *et al.* 2010; Freitas & Krishnasamy 2016; HSUS & HSI 2008; Saunders pers. comm. 2009; Saunders 1984; Ward 1988). Given their vulnerability to overexploitation, there is a great potential for depletion or even extirpation of populations that are rare and restricted endemic species (such as *N. macromphalus, N. stenomphalus,* and *N. repertus* and, in particular, *A. scrobiculatus* and *A. perforatus*), which exist in fewer localities and are most highly sought after by shell dealers and collectors (Saunders pers. comm. 2009).

Information from the Philippines and Indonesia, where there is the largest amount of commercial trade in chambered nautiluses according to U.S. trade data (LEMIS 2016; Table 2), suggests the serial depletion of populations across the Philippines and a shifting of the trade south to Indonesia and in waters to the north. Similar to the pattern of serial depletion occurring on coral reefs for the food and live reef fisheries which began in the Philippines and has moved to Indonesia (Barber & Pratt 1997, 1998; Uthicke & Conand 2005; Wilkinson 2008), species experts have seen indications that serial depletion may be occurring in some areas and that harvest effort is expanding to new areas (NMFS 2014).

The Tañon Strait, located between Negros and Cebu Islands in the Philippines, covers a large area within three Provinces (Cebu, Negros Occidental, and Negros Oriental). In 1971, a population of chambered nautiluses was located in the southern portion of the Tañon Strait (Negros Oriental), that had previously been unknown by local fishers and intensive commercial harvest commenced (Haven 1977). Between 1971 and 1987, four scientific expeditions to one location in the Tañon Strait, Philippines, revealed a population decline of about 97 percent in 16 years (Dunstan 2010; Haven 1972, 1977; Saunders pers. comm. 2009; Saunders & Ward 2010; Ward 1988). Whereas an estimated 5,000 chambered nautiluses were captured per year in the early 1980s, as of the late 1980s the species was commercially extinct and possibly extripated from Tañon Strait as (Alcala & Russ 2002; Dunstan 2010; Saunders pers. comm. 2009; Saunders & Ward 2010; Ward 1988).

In the late 1980s, several fishing sites were established in the western Philippine Province of Palawan initiated by traders and by fishers from other locations where harvest had crashed, such as in Tawi-Tawi (to the south of Palawan, in the southern Sulu Sea), Cagayancillo (northern Sulu Sea), and Cebu Strait (to the East of Tañon Strait) (Dunstan *et al.* 2010). Research at 12 fishing locations in five municipalities around Palawan Island, demonstrated statistically significant declines of between 70-94 percent in four municipalities over a period of less than 20 years (1 generation), when present catch rates were compared to those from the 1980s (Dunstan *et al.* 2010). Notably, in the fifth municipality, where no statistical decline was detected, fishing had been underway for the least amount of time (less than eight years). The declining number of shells being offered to traders by local harvesters in the past five years in Palawan Province has been noted by the Palawan Council for Sustainable Development (Devanadera pers. comm. 2016). In the Visayan Regions to the east, some Philippine harvesters and traders indicated an increasing difficulty obtaining shells as early as 2003 (Schroeder 2003). Recent research in the Bohol Sea (located to the east of Central Visayas and where an intensive chambered nautilus fishery exists) provided abundance estimates of between 1 and 3 orders of magnitude fewer chambered nautiluses, as compared to unfished populations in American Samoa, Australia, and Fiji (Barord *et al.* 2014). In the Central Luzon Region to the north, several harvesting sites in Bulacan and Pampanga Provinces were reportedly depleted in 2003 and 2007, and a new harvesting area has opened in Zambales Province (Freitas & Krishnasamy 2016).

In 2009, Saunders (pers. comm.) noted that "reports of trapping for *Nautilus/Allonautilus* shells are also beginning to emerge from parts of Indonesia," and considered that an apparently increasing number of Indonesian-origin shells on the market may be indicative of a shift in the fishery because of depletion in the Philippines. A potential trade shift may be further supported by possible trends shown by U.S. trade data, as reported by quantity. From 2005-2009, the Philippines accounted for 87 percent of the trade and Indonesia accounted for 9 percent (De Angelis 2012). More recently, from 2010-2014, the Philippines accounted for 75 percent of the trade, while Indonesia accounted for 20 percent of the nautilus commodities reported in U.S. trade data (LEMIS 2016).

Similar patterns of harvest sites being established and reports of declines are emanating from various locations in Indonesia (Dunstan 2010; Freitas & Krishnasamy 2016). Some Indonesian harvesting sites may have opened thirty years ago (such as Ambon Bay and the Banda Islands, in Maluku Province), while Indonesian traders in other areas indicate that demand for nautilus shells and products began as recently as 2002 or 2006 (such as Bali Province) (Freitas & Krishnasamy 2016). Recent reports indicate that there are several chambered nautilus harvesting sites throughout Indonesia, including Central Java, East Java, West Nusa Tengarra, South Sulawasi, and Papua Provinces (Freitas & Krishnasamy 2016; Nijman *et al.* 2015). In Bali Province, where harvest has mostly ceased, fishermen report declines in the past ten years; until 2005, 10 to 20 nautilus could be caught in one night. Harvesters in Lombok (West Nusa Tengarra Province) report that catch has declined from 10 to 15 chambered nautiluses in one night to 1 to 3 per night (Freitas & Krishnasamy 2016). As new fishing areas have opened in Indonesia, harvest may also be shifting to waters north of the Sulu Sea (Freitas & Krishnasamy 2016). Thus, in countries with several populations, nautilus harvest may continue for many years as each population is serially depleted (Dunstan *et al.* 2010).

Recent data indicates that intensive harvest is causing dramatic shifts away from the mature, male-dominated population structure because the chambered nautilus fishery removes predominantly mature male specimens (Arnold *et al.* 2010; Dunstan *et al.* 2010; Saunders 1984; Saunders *et al.* 1987; Ward, 1988). Saunders (pers. comm. 2014) compared research data collected in the 1970s and 1980s from several unfished populations of *N. pompilius,* as well as a single population each of *A. scrobiculatus, N. macromphalus,* and *N. belauensis* and compared it to 1979 data from a fished population of *N. pompilius* (Tañon Strait, Philippines) (NMFS 2014). The results showed that in Tañon Strait, where the population had crashed, less than one-third of the catch were males and nearly two-thirds of the catch were juveniles (Saunders pers. comm. 2014; Saunders and Ward 2016 *in review*). This contrasts sharply with the population structure found in natural populations that have not been subjected to commercial fishing, where most of the population is mature and juveniles represent less than 10 percent of the population (Carlson & Degruy 1979; Havens 1977; Saunders 1983, 1990; Saunders & Landman 2010; Tanabe *et al.* 1990; Ward 1987; Ward & Martin 1980; Ward *et al.* 1977; Zann 1984). According to Saunders & Ward (2016 *in review*), this represents population disequilibrium brought on by fisheries pressure. Barord *et al.* (2014) demonstrated a similar shift in age-structure and size classes in the commercially fished location in the Bohol Sea (Philippines), concluding that the removal of mature males may exponentially compound a reduction in new recruitment.

Another indicator of a shift in population structure and depletion of local populations might be found in the curio market, where larger shells are preferred for the higher prices they bring (Sajan *et al.* 2012). According to a 2013 survey of the two largest open-air markets in Java, Indonesia, nearly 20 percent of the specimens were estimated to be just below the fully mature size (Nijman *et al.* 2015). A 2006 survey in two curio markets in southern India, indicated that *Nautilus pompilius* shells offered there were nearly half "the common wild size" (Sajan *et al.* 2012).

Chambered nautiluses exhibit classic k-selected life history traits (low fecundity, slow growth, late maturity and long life span), as evidenced by a range of studies from analysis of dead shells to long-term aquarium observations, trapping, and mark and recapture studies in nature (Aguiar 2000; Dunstan 2010; Dunstan *et al.* 2010, 2011a, 2011c; Monks 2002; NMFS 2014). These characteristics render them vulnerable to over-exploitation, as indicated according to population management theory for a variety of taxa (e.g., Adams 1980; Guynn 2011). Species experts are concerned about the potential for exploitation in places where fishing may not currently be underway, especially for the more localized chambered nautilus species which would be more susceptible to population reduction (Barord *et al.* 2014; De Angelis 2012; Dunstan *et al.* 2011a, 2011c; Monks 2002; Nichols 1991; Saunders *et al.* Sinclair *et al.* 2011). Given the barriers to dispersal (Barord *et al.* 2014; Dunstan *et al.* 2010, 2011a, 2011b, 2011c; Jereb & Roper 2005; Saunders 1984b; Saunders & Ward 2010; Ward & Martin 1980), the ability of these species to recolonize geographically isolated areas if local populations become depleted would be left to chance events (Barord *et al.* 2014; Dunstan 2011a; NMFS 2014) (See Section 3.2 Habitat).

7. Legal instruments

7.1 National

Nautilus pompilius is protected in some portions of its range (Australia, China, Philippines, and Indonesia), along with *N. stenomphalus* (endemic to Australia). *Nautilus belauensis* (endemic to Palau) and *N. macromphalus* (endemic to New Caledonia) may also be protected.

Australia: Australia recognizes two native species, *Nautilus pompilius* (syn. *N. repertus*) and *N. stenomphalus*. The Management Authority notes that, in addition to domestic protection under state and territory legislation, all native species are regulated under the Environment Protection and Biodiversity Act 1999 (Murphy pers. comm. 2016). *Nautilus pompilius* is protected as a species of concern in Australia (Aguiar 2000). There is no known commercial fishery or targeted harvest of these species.

China: *Nautilus pompilius* is included as a ‘Class I’ species under the national Law of the People’s Republic of China on the Protection of Wildlife, enacted in 1989. Harvest of *N. pompilius* is regulated under Article 16 which allows national level authorities to evaluate and grant permission to harvest the species. Allowable activities include scientific research, ranching and breeding, exhibitions or “other special conditions” (Freitas & Krishnasamy 2016).

India: In 2000, *Nautilus pompilius* was protected under Schedule I of the Indian Wildlife (Protection) Act of 1972 (Sajan *et al.* 2012). According to CITES Authorities, domestic law prohibits all trade in chambered nautiluses.

Indonesia: All domestic or international trade in *Nautilus pompilius* is prohibited (Nijman & Nekaris 2014; Wisnu 2008). Although *Allonautilus perforatus* is not protected, *N. pompilius* was added to the protected species list in Indonesia in 1987, along with several other marine mollusks that are harvested and traded in large numbers (Aguiar 2000; Nijman *et al.* 2015). This law was later consolidated into Act No. 5/1990, the Law on conservation of living resources and their ecosystems, enacted in 1990, which made it illegal to harvest, transport, kill, or trade in this species – whether live or dead (Indonesia Ministry of Forestry 1990; Nijman & Nekaris 2014; USAID 2014). But the implementing legislation was not published until 1999 under Government Regulation 7/1999 on the Preservation of Plants and Animals and Government Regulation No. 8/1999 on Utilization of Wild Plant and Animal Species (Freitas & Krishnasamy 2016; Indonesia Government 1999; USAID 2015).

The Fisheries Law Act No. 31/2004 (amended by R.I. Law No. 45/2009) also has provisions pertaining to protected fish, which are defined as “all kinds of organisms, all or part of which life cycle is in the watery areas,” including regulating commercial aspects of fisheries such as quotas. Violations for hunting, trade, and shipping of protected species includes jail terms (6-8 years) and fines (up to 500 million Rupiah, an excess of 113,000 USD) (USAID 2015).

Exploitation of chambered nautiluses is also banned by some Provincial governments (e.g., South Sulawesi) (Freitas & Krishnasamy 2016).

Given the ongoing trade in chambered nautiluses from Indonesia, it appears that there is a lack of enforcement of the existing prohibitions.

New Caledonia: *Nautilus macromphalus* is reportedly protected (Freitas & Krishnasamy 2016). There is no information on whether *Nautilus pompilius* is protected.

Palau: The only species of chambered nautiluses in Palua, *Nautilus belauensis*, is reportedly protected (Saunders & Hastie 1992). Declaration forms are required for export (Sam pers. comm. 2016).

Philippines: *Nautilus pompilius* is reportedly protected under the Fisheries Administrative Order no. 168, enacted in 1990, which prohibits the gathering, culture and exploration of shelled mollusks without a permit (Floren 2003; Philippines Department of Agriculture 1990). It is not clear how this is administered with regard to particular species.

In Palawan Province, *Nautilus pompilius* is classified as Vulnerable under Palawan Council for Sustainable Development (PCSD) Resolution No. 15-521 and permits are required for all uses, including collection from the wild (Devanadera pers. comm. 2016). There are reports of local ordinances to conserve and protect chambered nautiluses in some municipalities in Cebu and Western Visayas Provinces (Freitas & Krishnasamy 2016).

Fishery restrictions are generally poorly enforced (Aguiar 2000) and nautilus harvest is essentially unregulated (Freitas & Krishnasamy 2016).

7.2 International

There are no known international protections for these species.

8. _Species management_

8.1 Management measures

Chambered nautilus species are not part of any known management programs. Permits are required in some areas and management may be occurring at local levels. However, we are not aware of studies conducted by fisheries or natural resource authorities to determine the status or impact of harvest on these species. There do not appear to be any harvest seasons or quotas in countries where commercial harvest occurs (del Norte-Campos 2005; del Norte-Campos *et al.* 2005; Dunstan *et al.* 2010; Freitas & Krishnasamy 2016; Nijman *et al.* 2015). Thus, existing measures would not appear to be effective in managing these fisheries. Because of chambered nautiluses' unique life history traits that differ from other cephalopods, species experts emphasize that they cannot be managed like fisheries for related species, such as octopus (NMFS 2014).

8.2 Population monitoring

There is no known population monitoring of these species.

8.3 Control measures

8.3.1 International

None.

8.3.2 Domestic

Domestic measures appear to be inadequate to control the harvest pressure caused by international trade. The harvest of chambered nautilus populations may be variously controlled at the range State, provincial, or community level across its range. For example, in the Province of Bohol, Philippines, where chambered nautilus harvest occurs, marine resources within the 15-kilometer maritime zone are owned by local communities, and some have developed coastal management plans, some have banned all commercial fishing, and others manage these areas under the auspices of the community Elders (CCIF 2001). In Palawan Province, marine management is under the purview of the Palawan Council for Sustainable Development (PCSD); whereas, the rest of the country's marine management is controlled by the Bureau of Fisheries and Aquatic Resources (BFAR) (CCIF 2001).

The economics are unlikely to control this fishery due to the low investment required to purchase traps and ropes. Boats or fleets of boats used to harvest chambered nautiluses are already used for other fishing activities and the primary product in international trade, the shell, is nonperishable (Carlson pers. comm. 2009; del Norte-Campos 2005). However, fisheries cease where chambered nautilus yields diminish to the extent that the harvest yield no longer covers the cost of bait and fuel (Dunstan *et al.* 2010).

Live trade requires more care from harvest to delivery, with more sophisticated transport networks to ensure reliable, live delivery of the organism at its destination. Higher production costs and greater risks (of an animal's death) when trading in live chambered nautilus could serve to control trade. However, live trade often brings higher prices (del Norte-Campos 2005; Carlson pers. comm. 2009), and experts have noted that in areas where gear is too expensive, some fishermen say that the buyers or middlemen may fund the fishery (NMFS 2014).

8.4 Captive breeding

Repeated attempts at captive breeding of several *Nautilus* species since 1990, have yielded eggs that hatch but none have been raised to maturity; shell abnormalities, eye disease and buoyancy problems are typical of captive-held animals (Carlson 2010; Daw & Barord 2007; Moini *et al.* 2014; Okubo *et al.* 1995; Saunders pers. comm. 2009; Ward & Chamberlain 1983). There are no known instances of captive hatchlings surviving to adulthood (Barord & Basil 2014; Carlson pers. comm. 2009; NMFS 2014; Saunders pers. comm. 2009).

In a captive setting, reports vary from females laying 0-3 eggs per month (Carlson pers. comm. 2009; Okubo *et al.* 1995). The eggs develop for 10-14 months (Carlson *et al.* 1984; Collins & Ward 2010; Dunstan *et al.* 2011b, 2011c; Landman & Cochran 2010; Saunders pers. comm. 2009; Uchiyama & Tanabe 1999; Ward 1987, 1988). Egg failure is high and survival is low. For example, of 43 *N. belauensis* eggs, three hatched and the hatchlings lived from 1-2.5 months (Okubo *et al.* 1995). Captive eggs are often abnormal in appearance, non-viable, or yolk-less (Carlson 2010). There is also evidence that eggs are subject to predation by other nautiluses in captivity (NMFS 2014; Saunders & Landman 2010). The average life expectancy of captive chambered nautiluses is 1.5-2 years (Carlson 2010).

Chambered nautilus mariculture is not currently a viable option to satisfy the demand and nature of the trade. In captivity, chambered nautiluses have low survival rates and their "shells are not as attractive as those found in the wild, so it is unlikely that captive bred specimens would be a viable market alternative to wild caught specimens" (NMFS 2014, p. 9).

Figure 6 Captive hatchling, *N. belauensis*, 1990 (Carlson/Waikiki Aquarium)

8.5 Habitat conservation

There has been no systematic review to determine what portion of chambered nautilus habitat or known localities might fall within protected areas, where some forms of habitat protections may exist.

8.6 Safeguards

The existence of *de facto* refugia in isolated locations has been postulated but not scientifically investigated throughout chambered nautiluses' range, nor quantified. It is unknown which species and what proportion might occupy habitat within protected areas, and whether their presence within those areas mitigates the impacts of fishing pressures elsewhere. The existence of unfished populations is important, but with high genetic distinctiveness across populations, it is important to preserve genetic diversity across all of the populations. There may be populations that have never been targeted for harvest that currently act as refugia; but without protection, management, and enforcement they are only refugia until they are targeted for exploitation.

9. Information on similar species

Not applicable.

10. Consultations

Consultation letters were sent by the United States to all range countries, including American Samoa. Responses were received from Australis, China, Fiji, Palau, the Philippines (Palawan), Samoa, and Viet Nam. Information was incorporated into the proposal.

11. Additional remarks

Identification: Fishermen, traders, and species experts are generally able to distinguish the species and experts, at least, can identify the sexes based on the shell, although laypeople may have difficulty (Freitas & Krishnasamy 2016; Nijman *et al.* 2015; NMFS 2014). In addition to descriptive and diagnostic information for each species outlined in several publications (Jereb & Roper 2005; Saunders 2010; Ward & Saunders 1997), species experts provided the following information that could be adapted as CITES Identification Material:

“A characteristic of chambered nautilus shells is that they are distinctively large, flat, and thin, which lends itself to being used as inlay,”..with “an external matte white layer and an inner nacreous, or pearly, layer” (NMFS 2014, pp. 10-11). The thickness of the shell might be a distinguishing characteristic in nautilus shell used as inlay; though it would currently be impossible to identify inlay to the species level based on morphological characteristics (NMFS 2014). Chambered nautilus shells are also characterized by growth lines that would be visible even if the shell is polished and on buttons; “no other mollusk has these lines” (NMFS 2014, pp. 10-11).

Substitutes: There are no substitutes for the whole shell and it would be difficult to find a substitute for the larger pieces of shell that are used as inlay (NMFS 2014).

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Chambered nautilus common names

Range Country	Species	Common local names	Notes
American Samoa / U.S.	*Nautilus pompilius*	Unknown	
Australia	*Nautilus pompilius*	Unknown	
	Nautilus repertus	Unknown	
	Nautilus stenomphalus	Unknown	
China *Possible range country*	*Nautilus pompilius*	Unknown	
Fiji	*Nautilus pompilius*	Unknown	
India	*Nautilus pompilius*	Unknown	
Indonesia	*Nautilus pompilius* *Allonautilus perforatus*	*Nautilus berongga* *lobo (in South Sulawesi)* *bia gengge (in Ambon)* *sokle (in Java)* *cukli (in Lombok)* *kalabinga (in East Nusa Tenggara)*	Not clear if species-specific or general names (Freitas & Krishnasamy 2016)
Malaysia	*Nautilus pompilius*	Unknown	
Myanmar *Possible range country*	*Nautilus pompilius*	Kha-yu-tha-pi (Burmese)	(Mason & Theobald 1882)
New Caledonia	*Nautilus macromphalus*	Unknown	Local names differentiate the species (Saunders pers.comm. 2009)
	Nautilus pompilius	Unknown	
Palau	*Nautilus belauensis*	Kedarm (Palauan)	(Palomares & Pauly 2016)
Papua New Guinea	*Allonautilus scrobiculatus*	kin I got holl namil	(Saunders pers.comm. 2009)
	Nautilus pompilius	shell i savy long trip	
Philippines	*Nautilus pompilius*	Lagang or lagan (*Filipino*)	(Freitas & Krishnasamy 2016)
Samoa (Western) *Possible range country*	*Nautilus pompilius*	no local name	(Saunders *et al.* 1989)
Solomon Islands	*Allonautilus scrobiculatus* *Nautilus pompilius*	Unknown	
Thailand *Possible range country*	*Nautilus pompilius*	Unknown	
Vanuatu	*Nautilus pompilius*	Unknown	
Viet Nam *Possible range country*	*Nautilus pompilius*	Unknown	

Common names in other countries

Country	Species	Common Names
Japan	*Nautilus pompilius*	oumugai; Symbol: おう
Germany	*Allonautilus scrobiculatus*	Königsnautilus
	Nautilus macromphalus	Neukaledonisches Perlboot
	Nautilus pompilius	Gemeines Perlboot
France	*Nautilus pompilius*	Nautile flame, Nautile chambré
	Nautilus macromphalus	Nautile bouton
English	*Allonautilus scrobiculatus*	King nautilus, Crusty nautilus
	Allonautilus perforatus	Indonesian nautilus
	Nautilus belauensis	Palau nautilus
	Nautilus macromphalus	Bellybutton nautilus
	Nautilus pompilius	Emperor nautilus, Chambered nautilus, Pearly nautilus
	Nautilus repertus	Unknown
	Nautilus stenomphalus	White-patch nautilus
Spanish	*Nautilus macromphalus*	Nautilo ombligo
	Nautilus pompilius	Nautilo común

Additional Sources: HSUS & HSI 2008; Jereb & Roper 2005; Sealifebase.org

Table 1
Main nautilus commodities traded with the United States between January 2005 and December 2014 (LEMIS 2016). All but 126 shipments were imported to the United States.

Wildlife Desc	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Overall Total (NO)	Overall Total (KG)
xxx	NO	3	--	--	--	--	--	--	--	--	--	**3**	**--**
CAR	NO	--	--	1	--	--	--	--	--	--	--	**1**	**--**
BOD	NO	--	--	--	--	--	--	--	18	27	5	**50**	**--**
GAR	NO	--	--	--	--	--	--	10	--	--	--	**10**	**--**
JWL	*KG*	*30*	*300*	--	--	*41*	--	*125*	*87*	--	*1*	**--**	***584***
JWL	NO	54,393	59,581	40,089	15,338	18,178	11,309	12,351	15,968	6,890	14,800	**248,897**	**--**
LIV	NO	82	12	6	18	44	26	16	12	53	35	**304**	**--**
LPL	NO	--	--	--	--	--	--	--	2	--	--	**2**	**--**
LPS	NO	--	--	--	--	--	40	--	2	--	2	**44**	**--**
MEA	NO	--	--	--	--	114	--	--	--	--	--	**114**	**--**
SHE	*KG*	*1,033*	--	*2,776*	*35*	*724*	--	--	*5*	--	--	**--**	***4,573***
SHE	NO	4,503	14,993	55,271	13,208	6,981	1,973	1,745	1,828	2,001	1,529	**104,032**	**--**
SPE	NO	2	--	10	13	7	6	26	4	22	--	**90**	**--**
SPR	*KG*	*332*	*620*	*1*	*133*	*16*	*27*	*228*	*22*	*8*	--	**--**	***1,387***
SPR	NO	97,294	74,040	88,643	47,188	15,390	21,327	7,982	9,157	8,222	6,436	**375,679**	**--**
TRI	NO	6,525	8,712	6,293	3,845	135,621	18,043	613	100	--	218	**179,970**	**--**
TRO	NO	--	300	--	--	1	--	--	--	--	--	**301**	**--**
UNS	NO	220	--	--	--	--	155	452	--	--	--	**827**	**--**
Annual Ttl	**NO**	**163,022**	**157,638**	**190,313**	**79,610**	**176,336**	**52,879**	**23,195**	**27,091**	**17,215**	**23,025**	**910,324**	**--**
Annual Ttl	***KG***	***1,395***	***920***	***2,777***	***168***	***781***	***27***	***353***	***114***	***8***	***1***	***--***	***6,544***

Wildlife Description: ***: unknown, CAR: carving (other than bone, horn or ivory); BOD: Dead animal (whole animal); GAR: Garments (not including shoe or trim); JWL: Jewelry; LIV: live speciments (live animals or plants); LPL: Leather products (large manufactured); LPS: Leather products (small manufactured); MEA: meat; SHE: shells (raw or unworked shells); SPR: shell products made from mollusc or turtle shell; TRI: trim (show trim, garment trim, or decorative trim); TRO: trophies (all trophy parts of one animal) (likely a data error); UNS: unspecified. Unit: GM: gram; KG: kilogram; NO: number (does not necessarily imply a whole animal).

Table 2

Range country exports and re-exports from known and putative range countries of all nautilus commodities between January 2005 and December 2014 (LEMIS 2016). This table excludes trade data from non-range countries. Note that the trade entry involving Viet Nam in 2012, which was described as shell product and reported in square meters, may be a data entry error.

											Overall Total	
Country	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**(NO)**	**(KG)**
American Samoa (U.S.)	0	0	0	0	0	0	0	0	0	0	**0**	--
Australia	756	0	2,361	0	2	0	2	0	4	0	**3,125**	--
China - *possible range state*	15	7,496	3,442	1,270	34	1	54	281	184	1	**12,778**	--
Fiji	0	12	1	0	0	0	587	1,087	803	1,156	**3,646**	--
India (NO)	0	0	192	10,000	2	0	3	0	1,630	38	**11,865**	--
(KG)	*0*	*0*	*0*	*0*	*724*	*0*	*0*	*0*	*0*	*0*	--	***724***
Indonesia (NO)	12,399	32,366	17,290	9,485	1,664	4,704	3,411	9,444	1,650	9,530	**101,943**	--
(KG)	*0*	*0*	*2,776*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	--	***2,776***
Malaysia	0	0	2	0	0	0	0	0	0	0	**2**	--
Myanmar - *possible range state*	0	0	0	0	0	0	0	0	0	0	**0**	--
New Caledonia	0	0	0	0	0	0	0	0	0	0	**0**	--
Palau	0	0	2	0	0	4	5	0	6	3	**20**	--
Papua New Guinea	0	0	0	0	0	0	0	0	0	0	**0**	--
Philippines (NO)	149,739	115,876	164,117	58,163	174,263	48,075	18,467	14,754	12,255	11,862	**767,571**	--
(KG)	*1,395*	*920*	*1*	*168*	*57*	*27*	*353*	*114*	*8*	*1*	--	***3,044***
Solomon Islands	1	0	0	0	4	0	0	0	0	0	**5**	--
Thailand - *possible range state*	31	111	2,072	74	177	11	44	28	81	45	**2,674**	--
Vanuatu	0	0	4	0	0	0	0	0	2	0	**6**	--
Viet Nam (M2) - *possible range state*	0	0	0	0	0	0	0	[0.38]	0	0	**0**	--
Western Samoa - *possible range state*	0	0	0	0	0	0	0	0	0	0	**0**	--
Total Annual Exports (NO)	**162,941**	**155,861**	**189,483**	**78,992**	**176,146**	**52,795**	**22,573**	**25,594**	**16,615**	**22,635**	**903,635**	--
Total Annual Exports (KG)	***1,395***	***920***	***2,777***	***168***	***781***	***27***	***353***	***114***	***8***	***1***	--	***6,544***

Key to abbreviations: KG: kilogram; NO: number.