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SPECIAL FEATURE: REVIEW

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Risk of extinction and categories of endangerment: perspectives from long-lived reptiles

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Abstract The IUCN Red List of Threatened Animals is an important conservation tool, but the accuracy of predictions about risks of global extinction within 10 years or three generations is difficult to test objectively. In this study, we compare IUCN predictions with the results of attempts to derive realistic scenarios that could lead to the global extinction of six species of long-lived reptiles. For three species, the IUCN predictions matched real events reasonably well but still overestimated risks of global extinction. For the other species, the predictions did not match real events. Reasons why disparities occur are discussed.

Key words IUCN criteria · Conservation · Status · Prediction · Accuracy · Threat

Introduction

The most credible and best known global overview of the status of endangered species is the IUCN Red List of Threatened Animals (Groombridge 1982; Baille and Groombridge 1996). Species are assessed using the best available information on status and known threats (Baille and Groombridge 1996), and the results are presented as a category of threat, which equates to a predicted risk of global extinction within a given time frame. Species that have no measurable risk of global extinction, but which may have other conservation problems, including local extinctions in parts of their range, should theoretically not be listed as being globally threatened in the IUCN Red List, but this occurs from time to time and creates confusion and controversy (Mrosovsky 1983, 1997; Lapointe 1997). The incorrect listing of species could reflect errors in the IUCN criteria, a failure to distinguish between national and global status, or the failure of assessors to use the criteria properly or objectively. Such listings raise the issue of how the accuracy of IUCN predictions about extinction should be tested and monitored, without having to wait until extinction occurs.

The approach we took to investigating this problem, with long-lived reptiles, was based on two assumptions: if the IUCN identified a species as having a significant threat of global extinction, then the wild population should be declining, or, if it were stable or increasing, scenarios likely to cause that extinction should be obvious. We assembled information on the past and present status of six species whose status and conservation problems were well known (two sea turtles, one freshwater turtle, and three crocodilians), and then tried to determine realistic scenarios that could result in global extinction within the short term (10 years) and long term (50–100 years). The results are compared with the levels of risk implied by the IUCN determinations.

Methods

The six species selected included two endemics that inhabit totally freshwater habitats [western swamp tortoise (*Psuedemydura umbrina*) and Chinese alligator (*Alligator sinensis*)], two widely distributed species that occupy a range of freshwater and marine habitats and occasionally move at sea between nations [saltwater crocodile (*Crocodylus porosus*) and American crocodile (*Crocodylus acutus*)], and two globally distributed marine species that regularly move long distances at sea [olive ridley sea turtle (*Lepidochelys olivacea*) and hawksbill turtle (*Eretmochelys imbricata*)]. All six had been assessed by the IUCN in accordance with the IUCN criteria (Baille and Groombridge 1996).

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Information on the biology, distribution, abundance, and status of each species (see Appendix) was gleaned from the general literature (Baille and Groombridge 1996; Cogger et al. 1993; Groombridge 1982; IUCN 1995; Kuchling 1998; Márquez 1990; Márquez et al. 1996; Meylan 1997; Ross 1998) and was modified after checking with a range of experts. We then assembled a list of potential threatening factors (loss of habitat, no protected areas, unregulated harvesting, no conservation programs, no value to local people, disease, small population size, restricted range, incidental catch, declining current status, and recovery potential) and systematically checked each species against each threatening factor, and on occasion combinations of threatening factors, in an attempt to find pathways to global extinction that could not be readily rejected. We chose a short-term (10 years) and long-term (50–100 years) time frame, to highlight needs for urgent conservation action and to conform with the IUCN's criterion of three generations.

Unpredictable events such as new diseases, serious genetic or inbreeding problems, or unknown depensation effects were not considered, because there is no evidence indicating they have caused extinction in other long-lived reptiles. Similarly, new and catastrophic threats derived potentially from complex interactions between a variety of factors were not considered seriously, because they could be invoked for any species, not just threatened ones. In terms of future legislative controls, we accepted that the demands on all resources would increase in the future (McNeely et al. 1995; North 1995), but equally accepted that national and international conservation laws and treaties would be retained, and be at least as effective as they are today. We were searching for obvious causal factors, not remote possibilities.

Results

Our assessments for the Western swamp turtle, Chinese alligator, and saltwater crocodile (Table 1) were broadly consistent with the IUCN assessments, but our assessments for the American crocodile, olive ridley, and hawksbill were not. However, in all six cases it proved difficult to find obvious pathways through which global extinction could reasonably be expected to occur in 10 or 50–100 years for any species.

Olive ridleys

The IUCN accepted that a 50% decline in the historical population size over three generations (50–100 years) (Criteria EN A1abd) indicated this species was facing a very high risk of extinction in the near future ("Endangered").

In reality, a 50% decline may have occurred over the past 50–100 years (three generations) (see Appendix) and

Table 1. Results of attempt to derive realistic scenarios that could reasonably be expected to lead to global extinction within the next 10 and 50–100 years compared with assessments made by the IUCN (Baille and Groombridge 1996)

Species	Scenarios derived for global extinction in:		IUCN assessment
	10 years	50–100 years	
Olive ridley	None	None	ENDANGERED: very high risk of extinction in the near future (EN A1abd)
Saltwater crocodile	None	None	LOWER RISK (LEAST CONCERN): does not meet criteria for being an endangered species
Western swamp turtle	Possible	Possible	CRITICALLY ENDANGERED: extremely high risk of extinction in the immediate future (CR A1c, B1 + 2c, C2b, C1, D)
Chinese alligator	Possible	Possible	CRITICALLY ENDANGERED: extremely high risk of extinction in the immediate future (CR A1c, D)
Hawksbill turtle	None	None	CRITICALLY ENDANGERED: extremely high risk of extinction in the immediate future (CR 1abd, 2bcd)
American crocodile	None	None	VULNERABLE: high risk of extinction in the medium-term future (VU 1ac)

"Possible" indicates that although no single definitive threat or scenario leading to extinction could be identified, because conservation programs are in place, very low population sizes and greatly restricted ranges makes it difficult to reject extinction through risk and uncertainty

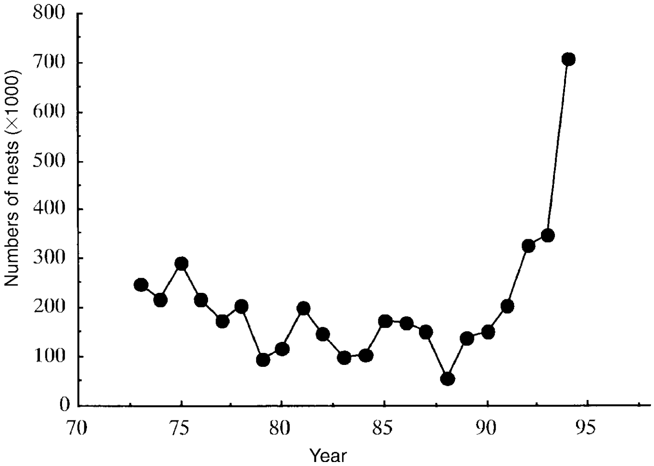


Fig. 1. Recovery of olive ridley turtles (*Lepidochelys olivacea*) on the Pacific coast of Mexico. The introduction of new management procedures in 1990 reduced turtle harvesting and resulted in population recoveries of green turtles (*Chelonia mydas*), hawksbill turtles (*Eretmochelys imbricata*), Kemp's ridley turtles (*Lepidochelys kempii*), and olive ridleys on both the Pacific and Caribbean coasts, although none of these populations are closed (Márquez et al. 1996)

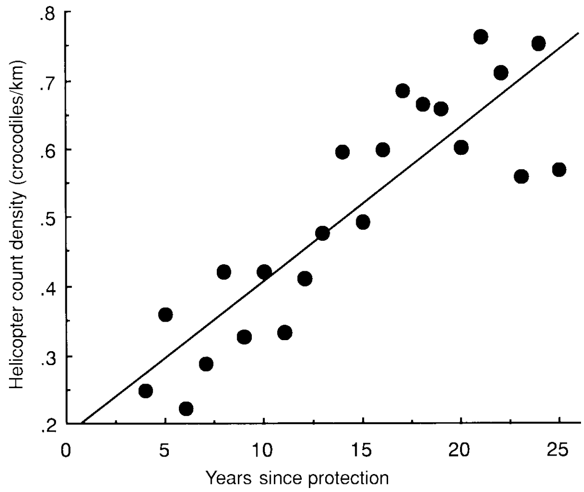


Fig. 2. Recovery of saltwater crocodiles (*Crocodylus porosus*) in the Northern Territory of Australia after protection in 1971, as indicated by the mean density recorded from counts in 70 tidal rivers around the coastline. Twenty-six years of intense, unregulated harvesting (1945–1971) reduced wild populations to fewer than 5000 nonhatchlings. The current population is estimated at 75 000 nonhatchlings. Since 1983, some 172 000 eggs have been collected from the wild in annual commercial harvests while the recovery has been taking place (After Webb 1997)

so the correct criteria were probably chosen. However, the wild population today is increasing, not decreasing, and it involves millions of individuals (e.g., Márquez et al. 1996). Olive ridleys are secure, protected, and expanding exponentially in some key countries (Fig. 1), despite incidental catch and other problems, such as a failure to nest in some locations in some years (Anonymous 1998). With a global distribution, and no populations being closed, we could find no scenario that could reasonably be expected to lead to global extinction in the short- or long term. Criteria EN A1 is not a reasonable or accurate index of the risk of global extinction with this species, given its known current status.

Saltwater crocodiles

Saltwater crocodiles were previously listed by the IUCN as "Endangered" [survival unlikely if the causal factors continue operating (Groombridge 1982)] but were later assessed as "Lower Risk: Least Concern" (Baille and Groombridge 1996). We could find no short- or long-term scenarios that could possibly lead to global extinction, and thus the determination seems accurate. Saltwater crocodiles have demonstrated a remarkable capacity to recover if habitats are intact (Fig. 2). Large populations are secure in vast tracts of habitat in Australia, Papua New Guinea, and Irian Jaya where they are harvested sustainably for trade (Ross 1998).

However, their status in many countries within their broad range (see Appendix) is poor because of habitat loss, high levels of past commercial exploitation, urbanization along rivers, and eradication as pests (Ross 1998). An 80% to 90% decline has probably occurred in most countries: they are extinct in some. They technically meet the IUCN criteria for "Critically Endangered" (CR A1a), which would imply an extremely high risk of global extinction in the wild in the immediate future, which is neither true nor realistic. The IUCN assessment in this case compromises process to increase accuracy.

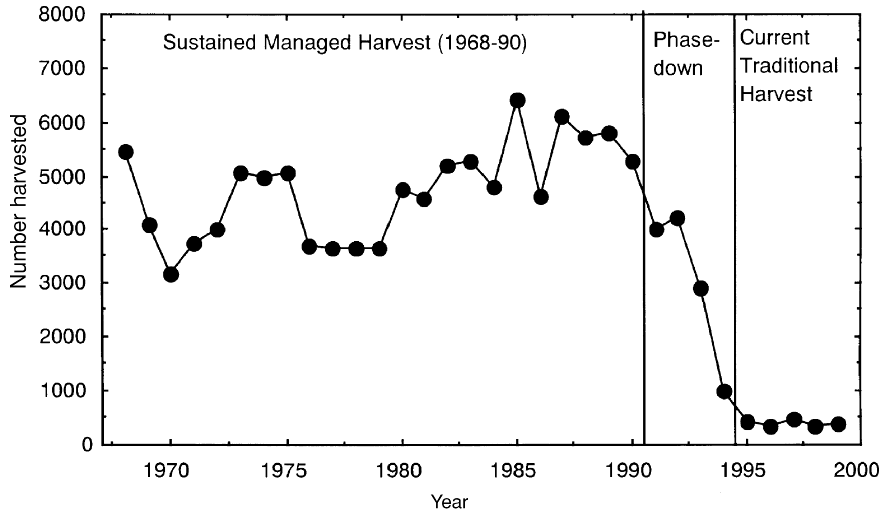
Western swamp turtles

Western swamp turtles were listed as "Critically Endangered" by the IUCN on the basis of a decline of more than 80% in the area of occupancy in three generations (50–100 years) (CR A1c); extent of occurrence less than 100 km^2 or area of occupancy less than 10 km^2 (CR B1 + 2c); the wild population consisting of less than 250 adults, in a single subpopulation (CR C2b) that is declining (CR C1); and the likelihood that fewer than 50 adults remain in the wild (CR D). The available information (see Appendix) suggests that most of these criteria are met, although the population may not still be declining, given limited restocking from captive breeding (Kuchling 1998). This species is afforded a very high level of protection and conservation action, greatly reducing the real possibility of global extinction, but this is not accounted for in the criteria that overestimate risks. We could find no realistic scenario leading to extinction, but accepted as reasonable that even small management failures could inadvertently result in extinction.

Chinese alligators

Chinese alligators were listed as "Critically Endangered" by the IUCN because of a decline of more than 80% (CR A1c) in their area of occupancy, extent of occurrence, and quality of habitat, and the existence of fewer than 50 adults in the wild (CR D). These two criteria are met (see Appendix). This species was once widely distributed in China but is now

Fig. 3. Harvest data for *Eretmochelys imbricata* in Cuba indicating unequivocally that a significant wild population lives in Cuban waters. In 1990–1994, Cuba faced severe economic restrictions and diverted fishing effort to export fisheries generating foreign exchange. The turtle fishery was phased down from 1990 onward despite stocks being abundant. In 1994, as a contribution to regional conservation, Cuba retained a small traditional harvest in less than 1% of available habitat and protected *E. imbricata* in all other Cuban waters (Data from Carrillo et al. 1998)



represented by 13 remnant populations in one location, within an area supporting some 1 million people pursuing intensive agriculture (Webb and Vernon 1992). The number of animals in the wild may still be declining, but the species is being afforded local conservation action. Extinction in the immediate future (critically endangered) is unlikely because of the production of 1000+ animals per year through captive breeding and ongoing conservation actions. The small remnant habitats could be lost, or become polluted, or the adults could decline further because they are agricultural pests: all these events could realistically lead to extinction in the wild in the future.

Hawksbill turtles

Hawksbill turtles were listed as "Critically Endangered" by the IUCN because the wild population was claimed to have been reduced by more than 80% in the last 100 years (three generations), as deduced by direct observation (CR 1a), appropriate indices of abundance (CR 1b), and levels of exploitation (CR 1d). In addition, a further reduction greater than 80% was anticipated in the next 100 years on the basis of indices of abundance (CR 2b), decline in occupancy of habitat quality (CR 2c), and actual or potential levels of exploitation (CR 2d). We could find no scenario leading to the global extinction of this species that could not be easily rejected. Risk of extinction implied by the IUCN assessment seems greatly exaggerated because of the limitations of some criteria in terms of their link to future extinction (CR 1abd), and errors in assigning other criteria to hawksbills (CR 2bcd).

Hawksbills in many countries may have been depleted relative to historical times (Meylan 1997), perhaps by more than 80% (CR 1abd). However, the global population is not distributed evenly (most range states contain small amounts of habitat), and so this could be deceptive. Regardless, they are widely distributed today [100+ nations (ROC 1998)] and are abundant and secure in major areas of habitat (see Appendix). For example, in four countries alone (Australia, Mexico, Cuba, and Puerto Rico), nest numbers indicate a wild adult population of more than 50000 individuals and perhaps 10 times that number of immature animals (AACC 1998). In the extensive coral reef habitats of Australia, the population appears stable and may be at carrying capacity (Limpus 1992; Limpus and Miller 1998). In countries such as Cuba (Fig. 3), the wild population is not small; it sustained an annual harvest of some 5000 animals per year before a voluntary phasedown (1990), which was not caused by declining abundance (ROC 1998).

The global population of hawksbills does not meet any of the CR 2bcd criteria. Monitoring results from widely distributed locations around the world indicate many subpopulations are stable or increasing, sometimes exponentially (Fig. 4) (Meylan 1997) (cf. CR 2b), which also established a significant potential for this species to recover from depleted states. The species still occupies its complete historical range (cf. CR 2c), and since 1993 harvesting for international trade has essentially ceased (cf. CR 2d) (AACC 1998).

American crocodiles

American crocodiles were listed as "Vulnerable" by the IUCN because of an assumed decline in the population of at least 20% over 50–100 years (three generations) as deduced by direct observation (VU 1a) and an ongoing decline in the area of occupancy, extent of occurrence, and habitat quality (VU 1c). The global wild population has probably declined by more than 80% in the past 50–100 years because it has been greatly reduced in countries that historically were probably major strongholds for the species (e.g., Venezuela, Colombia, Mexico) as well as in small nations with limited habitat (Ross 1998). It thus probably meets the criteria for critically endangered (CR 1A), although the risk of global extinction implied by such a listing would obviously not be realistic. American crocodiles are abundant and secure in Cuba, and are receiving serious conservation attention in the United States and other countries (Ross 1998). Global extinction is not a realistic possibility in either the short or long term, although the status of wild populations in some

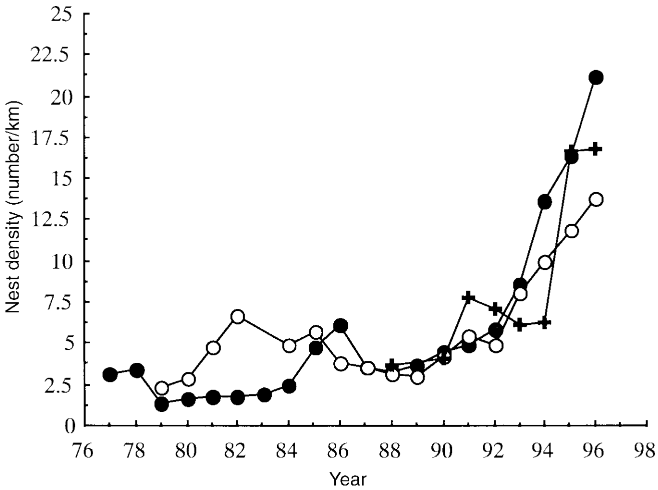


Fig. 4. Recovery of hawksbill turtles (*Eretmochelys imbricata*) in Mexico, following the introduction of new management procedures that reduced local harvesting. Marine turtle populations on both the Pacific and Caribbean coasts recovered in a similar way, and no significant cause- and-effect link with the phasedown of Cuba's harvest has been demonstrated. Nest counts are from three locations in the Yucatan Peninsula: Campeche (●), 1977–1996; Yucatan (○), 1979–1996; Holbox Island (+), 1988–1996 (Data from Meylan 1997)

countries may continue to decline (see Appendix). That captive breeding for this species is well established (Ross 1998) provides an additional safeguard. The IUCN assessment compromises process by not selecting the CR criteria, but increases the accuracy of the final prediction, even though this probably still overestimates real risks.

Discussion

The transition from greatly depleted (>80%) to extinct in the wild for reptiles is often a large step, especially when it involves species that are known to be able to exist at low densities for long periods of time yet retain the ability to recover when given the opportunity (Figs. 1, 2, 4), or species that have extensive habitat and are widely distributed. The reasons for population declines in a global population are usually obvious, but not so the reasons likely to result in global extinction. The social, cultural, economic and biological factors, acting directly and indirectly, in isolation and synergistically, can all be involved, and these are difficult if not impossible to quantify and model in advance.

Despite these problems, the IUCN Red List of Threatened Animals attempts to do this. Its efforts are encouraging conservation action on the ground (Rabb 1996), and they are leading to a greater understanding of extinction risks. The new criteria were formulated (Baille and Groombridge 1996) to improve accuracy, and for many species of plants and animals this may well have been achieved. But in the case of long-lived reptiles, it is not clear whether the current criteria are a significant advance over the more subjective, qualitative approach used previously (Groombridge 1982). Quantifying and reporting "status" remains unnecessarily confused (Webb 1986) especially with widely distributed species and species that have long generation times (Mrosovsky 1983, 1997; Messel 1998). Some problems are identified in the following list.

1. The time scales used for both reporting extinction risks and generating conservation actions are anthropocentric (e.g., in the immediate future for "Critically Endangered"), yet the time scales used for reaching those conclusions are biocentric (e.g., predicted changes over three generations that can reach 100+ years). For the six species examined here, three generations is far too long for assessing status reliably or for planning corrective actions efficiently (see Messel 1998).
2. The concept of being scientifically precautionary, and not overinterpreting data, clashes with the concept of being precautionary from a conservation point of view where exaggerating risks may lead to enhanced conservation action.
3. The criteria do not provide for ongoing conservation programs with threatened species that are reducing their risks of extinction. The criteria thus overestimate real risks and fail to acknowledge the significance of the work being done (Chinese alligator and western swamp turtle).
4. The criteria do not provide a clear pathway through which the existence of "safe" populations, which effectively prevents global extinction, is accounted for (saltwater crocodiles, olive ridleys, hawksbills, American crocodiles).
5. The distinction between national and global populations remains confused. The criteria do not provide clear advice about whether the status of a global population should be considered on the basis of a single global population, or the average national population, yet the contribution national populations make to global populations is rarely the same (olive ridleys, saltwater crocodiles, hawksbills, American crocodiles).
6. The extent of the historical decline over three generations may have nothing to do with the risk of global extinction in the future for long-lived reptiles (all six species).
7. There are no formal verification procedures, feedback checks, or onus on expert assessors to provide information on the accuracy of final determinations, yet clearly experts are in the best position to provide such information (all six species).
8. Assessors use the criteria differently with long-lived reptiles. Some determinations are based strictly on the criteria, with the result that risks of extinction are exaggerated relative to real risks (Chinese alligator, western swamp turtle), sometimes greatly and obviously (olive ridley, hawksbills). These results represent problems with some criteria (especially the A criteria), and also the deliberate selection of the wrong criteria, in some cases to reduce predicted risks and apparently improve accuracy (saltwater crocodiles, American crocodiles) but in others to exaggerate risks (CR 2bcd with hawksbill turtles).

Given the high level of public and political confidence in the IUCN assessments, despite the inherent inaccuracies, the case for maintaining public confidence is a strong one (Mrosovsky 1983, 1997). To achieve this requires increased attention to the accuracy of final predictions rather than to the processes involved in making assessments objective. Categories such as critically endangered should be reserved for species that are facing severe and obvious threats. They should not be assigned to species that are abundant and widespread, with no known scenarios that could lead to global extinction, no matter how compelling the case for public sympathy may be.

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Appendix. Factors related to risk of extinction for six species of aquatic, long-lived, slow-maturing reptiles. Data are general "ball-court" estimates gleaned from many sources and sometimes reflect informed guesses. Status refers to changes in the population size or distribution between two points in time

Parameter	Olive ridley turtle	Saltwater crocodile	Western swamp turtle	Chinese alligator	Hawksbill turtle	American crocodile
1. Main habitat	Marine	Marine, estuarine, freshwater	Freshwater	Freshwater	Marine	Freshwater, marine, estuarine
2. Age to maturity	10–20 years	10–20+ years	10–20+ years	10–20+ years	12–30 years	10–20+ years
3. Nest every	2–3 years	1–2 years	1–2 years	1–2 years	2–5 years	1–2 years
4. Eggs per female per season	200–300	50	5	10–30	400–600	45
5. Nesting	20+ countries	19 countries	Endemic (Australia)	Endemic (China)	60+ countries	17 countries
Extent of global nesting	1+ million nests/yr	<5000 nests/yr	<10 nests/yr	<10 nests/yr	From low densities to 1000–15 000 nests/yr	<500 nests/yr
6. Are nesting sites secure in some countries?	Yes	Yes	Yes	Possibly	Yes	Yes
7. Mortality, <1 year	Probably 90+%	Moderate (<50%)	Unknown	Unknown	Probably 90+%	Moderate
8. Mortality, 1 year to maturity	Unknown	90+%	Unknown	Unknown	Unknown	Unknown
9. Global distribution:						
Countries	30–40	19	1 (endemic)	1 (endemic)	100+	17
Square kilometers	100+ million	1–5 million	<2	500	100+ million	<0.5 million
10. Move between countries	Yes	Limited	No	No	Yes	Limited
11. Global wild population:						
Nonhatchlings	10–20 million	<250 000	<100	<250	>1 million	<15 000
Adults	1–2 million	<20 000	<50	<50	100 000+	<2000
12. Extinction, past 100 years:						
Countries	None	2	Unlikely	None	None	Perhaps
% of range	None	<5%	Unknown	>95%	None	<5%
13. Depleted populations	Most countries	Most countries	Yes	Yes	Most countries	Most countries
14. Recovery capacity demonstrated	Yes	Yes	Yes (restocking)	Unclear	Yes	Unknown
15. Global status in numbers:						
Last 100 years	Down (possibly >70%)	Down (>90%)	Down (unknown %)	Down (>95%)	Down (possibly 80%–90%)	Down (<80%)
Last 10 years	Up (possibly 20%)	Stable or up (0–20%)	Up (50%)	Down (10%–50%)	Up (possibly 5%–10%)	Down (<20%)
16. Harvests:						
Legal	Yes	Yes	No	No	Yes	Yes
Illegal	Yes	Yes	No	Possibly	Yes	Yes
17. International trade in wild-caught	Minimal	Extensive	None	None	Minimal	Minimal
18. Active ongoing conservation programs in some countries	Yes	Yes	Yes	Yes	Yes	Yes
19. Conservation actions expected to be sustained	Yes	Yes	Yes	Probably	Yes	Yes
IUCN Category of Threat: Reason	Endangered: 50% decline over three generations	Lower Risk (Least Concern): <50 adults; single subpopulation; small area and degraded	Critically Endangered: 80% decline over three generations; <50 adults	Critically Endangered: 80% decline over three generations; projected further 80% decline in three generations	Critically Endangered: 80% decline over three generations	Vulnerable: 50% decline over three generations

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