SEA AROUND US PROJECT

On the Exploitation of Elasmobranchs, with Emphasis on Cowtail Stingray *Pastinachus sephen* (Family Dasyatidae)

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On the Exploitation of Elasmobranchs, with Emphasis on Cowtail Stingray *Pastinachus sephen* (Family Dasyatidae)

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Executive Summary

Characterized by over-exploitation of many of the commercial stocks, the fisheries of the world are in a crisis. In particular, pressure is extremely strong on predators at the top of marine food webs. Typically, the fisheries for these predators, once initiated, last about 10-15 years, i.e., from the time the fisheries start developing and catches are minimal to the time catches have peaked, and then collapsed. This is particularly true for elasmobranchs (mainly sharks, rays and skates), which are characterized by high longevity and low fecundity. Among the elasmobranchs, large rays are particularly susceptible to trawl fishing, although in most countries, they are not targeted, but form part of the by-catch. In fact, one of the first documented extirpations (i.e., local extinctions) of marine fish was of a ray in the Irish Sea. As a large long-lived elasmobranch, the Cowtail stingray (*Pastinachus sephen*) is extremely susceptible to overfishing, and is widely caught as by-catch of the shrimp trawl fisheries throughout its Indo-Pacific range. The development of targeted fisheries for this stingray, driven by the luxury leather market demand for its skin for processing into pens, wallets, boots, etc., will accelerate the depletion to which this and allied species are already subjected. None of the countries in which the Cowtail stingray is abundant have fisheries management systems in place for this or any other species of rays. It can be expected that the directed fisheries will expand geographically from their center in Southeast Asia, as the original stocks are depleted (as has been the case for fisheries elsewhere), leaving devastated stocks behind. The fisheries science community has no way of ensuring that this exploitation can be made sustainable. It is questionable, therefore, that a demand for luxury products should be allowed to expand that may devastate this and related species, and the ecosystems of which they are a part.

Introduction

Many fisheries throughout the world are experiencing a crisis. Notably, a large number of stocks of large predatory fish have been depleted, resulting in an increasing dependency of fisheries on small fishes and invertebrates lower in the food web. This depletion of large predators, near the top of marine food webs, is occurring both as a result of targeted fisheries, and of fisheries that generate by-catch, i.e., in which other species are caught along with targeted species. This by-catch is either kept and landed, or discarded.

Many rays (including skates), which, along with sharks, represent the main groups of elasmobranchs, reach large sizes and have high longevity, and they usually represent a sizeable fraction of by-catch of trawl fisheries, especially in the tropics where demersal trawl fisheries have a shorter history (and thus ine some cases, have not yet depleted their resources). Due to their longevity and vulnerability to trawl gear, rays have been among the first fish to be locally extirpated, notably as documented for the Common or Blue skate *Raja baits* in the Irish Sea (Brander, 1981). In other cases, populations once extremely abundant have been reduced so much that the species now hovers near local extinction, e.g., the Barndoor skate (Casey and Myers, 1998).

An important feature of modern fisheries is that they usually do not last long: from the time a new stock is targeted for exploitation, it usually takes approximately 10 years for it to decline to 20 % of its original abundance, and 15 years to reach 10 % (Myers and Worm, 2003). Thus, the deliberate targeting of stingrays as a source of material for luxury products, and their conversion from incidental by-catch species to species deliberately targeted by fisheries, can be expected to lead to a faster rate of depletion, and to local extinction (i.e., extirpation) of stocks, with species extinction as the ultimate outcome. This is particularly true for the Cowtail stingray (*Pastinachus sephen*; Figure 1), which is extremely vulnerable, due to its life-history characteristics, yet is targeted for its skin which is used for production of fine leathers involved in the manufacture of luxury goods, notably pens, wallets and boots, available in developed countries.

We will first describe the biology of this species, within the context of its genus and family, which include some species that are relatively well-studied. This will serve to provide a basis for evaluating the resilience of the Cowtail stingray in spite of the dearth of data specific to this species. Then, we will analyze the chronology and status of stingray fisheries, based on available catch time series. This will be followed by an analysis of rays as elements in ecosystem models, and a review of the status of threat to rays in general, and Cowtail stingray in particular. We conclude with an examination of the growing market for leather derived from the skin of rays, and a discussion of the threat this market represents for rays.

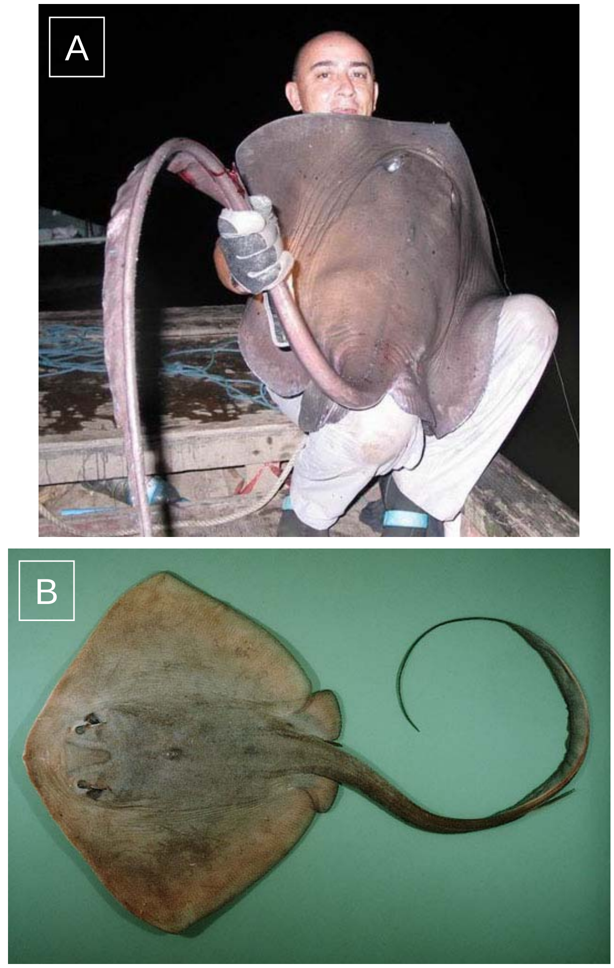

Figure 1. The Cowtail stingray *Pastinachus sephen,* Family Dasyatidae. A: Photo by Jean-Francois Helias (Fishing Adventures Thailand), 2004, showing a *Pastinachus sephens*, weight: 18 kg; length: 199 cm (measured from its nose to the end of its tail); girth: 132 cm. B: Photo by J.E. Randall (Bishop Museum, Hawaii), shot in Kuwait, 1985, 242 cm disk length, caught as trawl by-catch.

Fishery biology of Stingrays, with emphasis on *Pastinachus sephen*

Stingrays belong to the Family Dasyatidae, which has approximately 70 species in the Atlantic, Indian and Pacific Oceans, mainly in tropical waters. They are predominantly marine, but some species occur also in brackish and freshwater. They respire by drawing water through a small hole behind the eye and expelling it through gill slits on the underside of their body. The tail is long and whip-like, and most species possess at least one long venomous spine on their tail, which can cause excruciating pain to humans. The largest species reach 4 m in length. All species are live-bearing (ovoviviparous), with fully developed young. Stingrays are bottom feeders, with their food usually consisting of bivalves and other invertebrates.

The Cowtail stingray (*P. sephen*) occurs in the Indo-Pacific (Figure 2). Its maximum size is recorded from the Persian Gulf and Oman Sea as 183 cm disc width and over 300 cm total length (Sommer et al., 1996; Assadi and Dehghani, 1997). It is a typical, albeit very large dasyatid, and its exceptional size allows a number of inferences to be drawn on its biology and resilience to fishing, despite the absence of formal stock assessments on this species. Notably, we can infer a set of biological growth parameters for this species, given the parameters L∞, the asymptotic length, i.e., the mean size fish attain at a very old age, and K, a curve-shape parameter, of the von Bertalanffy Growth Function (VBGF) in other, related species. The VBGF has the general form:

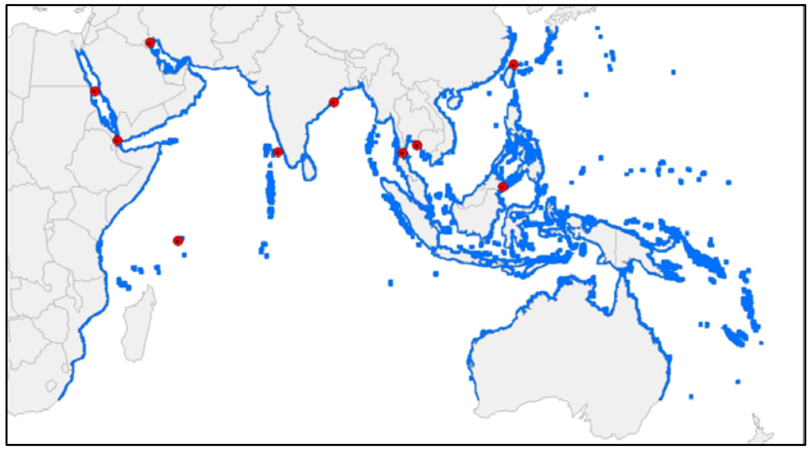

Figure 2. Distribution area of the Cowtail stingray, *Pastinachus sephen*. Ecological distribution area of the Cowtail stingray *Pastinachus sephen* (blue), as inferred from country records and depths of occurrence. Red dots are reported occurrence record corresponding to museum specimens, as documented in FishBase (www.fishbase.org).

$$L_t = L_\infty (1 - e^{-K(t-t_o)})$$

where L_t is the length at age t, and t_o the age at the origin of the growth curve (t_o is usually close to zero, and is not of importance for the current report).

In fishes, L_∞ and K have predictable distributions, with pairs of these parameters representing different stocks of the same species, or different species of the same genus or family. L_∞ and K pairs form, in double-logarithmic plots, tight ellipses with characteristic slope (see Figure 3b for the Dasyatidae, superimposed on growth parameters representing all major groups of fishes). As can be seen, K declines when L_∞ increases, and vice versa, i.e., fast growth (high K) is associated with small length (low L_∞).

This phenomenon, which is documented for all fishes for which growth parameters exist, can be used to infer K even if only L_∞ is known (Pauly, 1998). Thus, as the maximum length reported for a species (L_{max}) can be used as a proxy for L_∞, K can be inferred by calculating the mean value of the parameter Φ' in a given group, according to $\Phi' = \log K + 2*\log L_\infty$. Then, we can utilize the mean value of Φ' in the equation $\log K = \Phi' - 2*\log L_\infty$ to obtain a first estimate of K (Venema *et al.*, 1988; Pauly, 1998, 2002). Using this procedure yields, for the reported L_{max} of 300 cm (Assadi and Dehghani, 1997), an estimate of $K = 0.03$ year^{-1} in *P. sephen* (see Figure 3b). This is a very low value, although not surprisingly so for such a large fish.

This set of growth parameters, which given a mean environmental temperature of 25°C (range of 20-30°C) also implies that natural mortality (M) for this species must be very low, in the order of $M = 0.07$ year^{-1} (Pauly, 1980), also suggests that *P. sephen* should be very sensitive to fishing

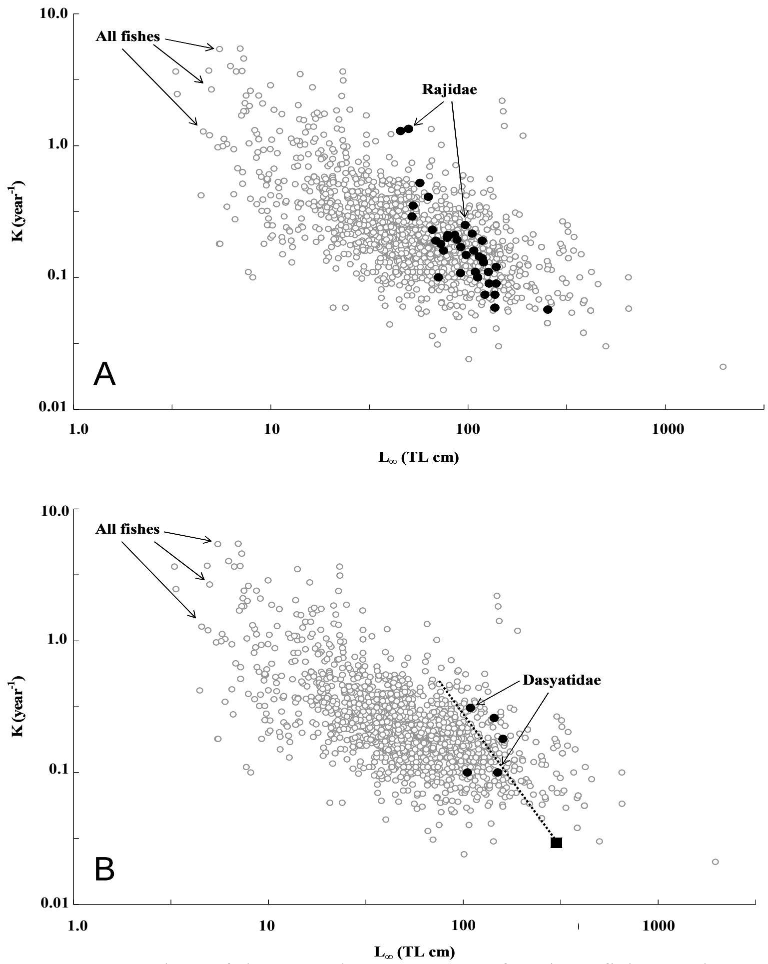

Figure 3. Plots of the growth parameters of various fishes and rays. Plots of growth parameters K of various fishes against the corresponding value of their asymptotic length. A) All fishes (white dots) with rays/skates of the family Rajidae superimposed (black dots); B) All fishes (white dots) with stingrays of the family Dasyatidae superimposed (black dots). The black square corresponds to L_∞ = 300 cm and K = 0.03 year^{-1} (from a mean Φ' value of 3.422; dotted line) as approximate growth parameter for the Cowtail stingray *Pistanachus sephen*.

pressure, and likely cannot withstand fisheries removal of more than 5 % of its stock per year. However, such low fishing rates do not occur in the multi-species shrimp fisheries that have stingray as by-catch, and are even less likely to occur in fisheries targeting rays.

'Stock assessments' using time series data of catches

In the absence of detailed catch, abundance and fishing effort data from distinct fisheries, allowing formal stock assessments using classical methods (Hilborn and Walters 1992), time series of catches in the databases of the Food and Agriculture Organization of the United Nations (FAO 2003) and the *Sea Around Us* Project (Watson *et al.* 2004) were analyzed retrospectively, using a method inspired by Grainger and Garcia (1996), as modified by Froese and Pauly (2003). In this method, different 'stages' of a fishery are distinguished, based on annual catch levels, relative to the maximum catch in the time series. Figure 4 illustrates this concept, and the stages that are identified, once a fishery has run its course. The stages are: **developing** (green, catches have reached between 10 % and 50 % of the maximum); **fully exploited** (yellow, catches are within 50 % of maximum); **overexploited** (red, catches have declined to 50-10 % of maximum); and **collapsed** (black, catches have declined to less than 10 % of maximum).

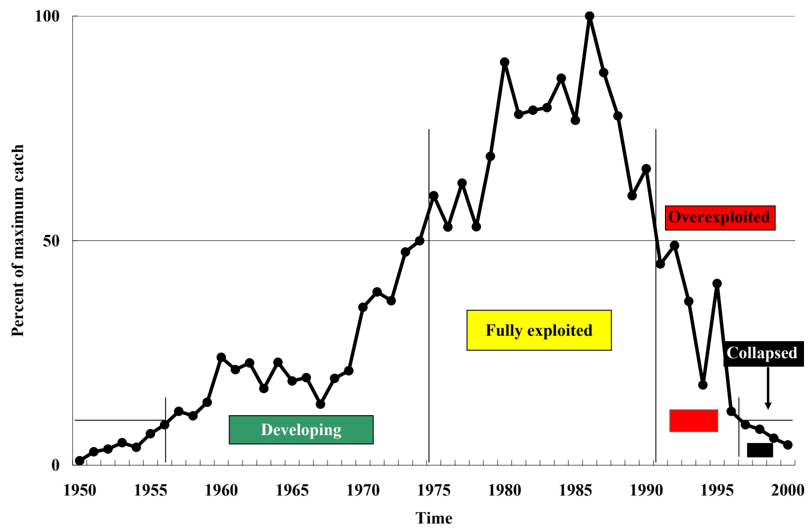

Figure 4. Stages in the development of fisheries, used to assess their status. Stages in the development of fisheries, with definitions adapted from Grainger and Garcia (1985) and Froese and Pauly (2003).

The times series we used in this analysis were given by 18 FAO statistical areas, and summarized by ocean, and by 64 Large Marine Ecosystems (LMEs), enabling us to display the results on a map. Details on these two analyses are provided below, along with the results.

Analyses of catch time series of rays by FAO area

Catches for ray species were extracted from the 2003 FAO dataset for the years 1950-2003 (FAO, 2003). Each catch record consisted, besides a catch in tonnes (= metric tons) for a given year, of the FAO area where this catch was made (1 of 18), and the taxon, i.e., a species, genus, family, or higher grouping of rays (we used taxonomic groupings up to order). It should be noted that for each FAO area, each time series was assumed to represent a 'stock'. Only those 'stocks' that had a cumulative catch greater than 1000 tonnes over all years fished were used. This resulted in 34 'stocks' of the following taxa being available: Rajiformes (Skates and rays); Dasyatidae (Stingrays); Myliobatidae (Eagle and manta rays); Rajidae (Skates); Rhinobatidae (Guitarfishes); *Bathyraja* spp. (Skates); *Dasyatis* spp. (Stingrays); *Raja* spp. (Skates); *Torpedo* spp. (Torpedos); *Amblyraja georgiana* (Antarctic starry skate); *A. hyperborea* (Arctic skate); *Bathyraja eatonii* (Eatons skate); *B. irrasa* (Kerguelen sandpaper skate); *B. meridionalis* (Dark-belly skate); *B. murrayi* (Murrays skate); *Dasyatis akajei* (Red stingray); *D. pastinacea* (Common stingray); *Dipturus batis* (Blue skate); *D. linteus* (Sailray); *D. oxyrinchus* (Longnosed skate); *Gymnura altavela* (Spiny butterfly ray); *Leucoraja circularis* (Sandy ray); *L. fullonica* (Shagreen ray); *L. naevus* (Cuckoo ray); *Myliobatis aquila* (Common eagle ray); *Raja asterias* (Starry ray); *R. brachyura* (Blonde ray); *R. clavata* (Thornback ray); *R. microocellata* (Small-eyed ray); *R. montagui* (Spotted ray); *Rhinobatos percellens* (Chola guitarfish); *R. planiceps* (Pacific guitarfish); and *R. djiddensis* (Giant guitarfish). Each 'stock' thus identified was assigned a 'status' (e.g., developing, fully exploited, overexploited or collapsed), given the level of its catch in 2003 and the criteria in Figure 4.

The results, i.e., the number of 'stocks' by status in 2003 were then grouped by ocean (there are 3-8 FAO areas per ocean). These data suggest that none of the 'stocks' could be considered in the developing fishery stage, while in each ocean, at least half of all 'stocks' evaluated were considered overexploited or collapsed (Figure 5).

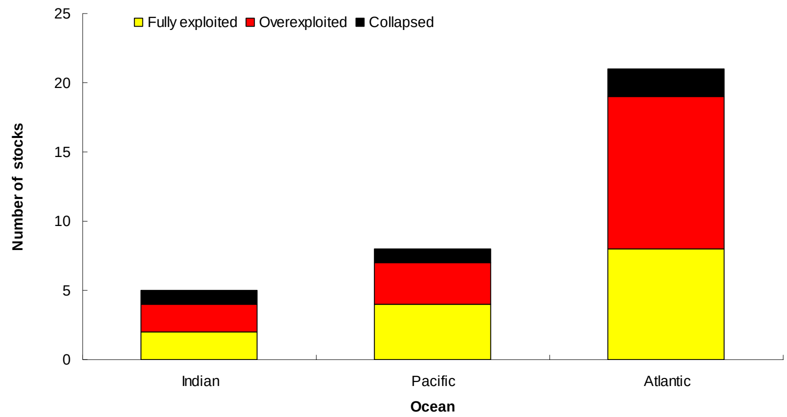

Figure 5. Number of 'stocks' of various groups of rays, by status and oceans Number of 'stocks' of various species and higher taxonomic groups of rays, by exploitation status and ocean. Based on data by FAO's 18 statistical areas (from FAO, 2003) and status definitions in Figure 4.

Analyses of catch time series of rays by LME

Given its low spatial and taxonomic resolution, the analysis noted above may be seen as too coarse, as illustrated by the fact that only 2 % of the catch of rays is identified to species in the FAO statistics, compared to 71 % for other fishes. Thus, the analysis was redone, based on the spatially (½ degree latitude by ½ degree longitude cells) and taxonomically disaggregated catch time series generated by the *Sea Around Us* Project from FAO, EUROSTAT, NAFO and other data sets, subjected to a disaggregation process described in Watson *et al.* (2004).

This process consists of identifying, for each taxon (i.e., species, genus, etc.) occurring in the catch statistics, the ecological distribution area and the area fished by a given country reporting that taxon in its catch. These fished areas are being defined, among other things, by the bilateral access agreements that each country has with other countries. Subsequently, over-aggregated taxa are disaggregated where possible, by assigning the catch, e.g., of 'rays' in a given ½ degree latitude by ½ degree longitude cell to the species of rays known to occur in that cell (details in Watson *et al.*, 2004).

The process involves the generation of catch estimates for each taxon for the years 1950 to 2003 for each of 180,000 half degree cells. These data are grouped by larger areas, for example the 64 Large Marine Ecosystems (LME) used here, as defined in Sherman and Duda (1999). These areas collectively account for approximately 83 % of the world's marine catch. As for the analysis of the raw FAO data noted above, each taxon reported within an LME with a cumulative catch of at least 1000 t was taken as a surrogate for a 'stock', and its status was identified according to the definitions in Figure 4.

The results are presented in the form of a map (Figure 6), where the number of 'stocks' that have collapsed in each LME is expressed as percentage of the number of 'stocks' occurring in that LME (based on our definition of 'stock'). Some areas in Figure 6, particularly the polar and other high-latitude LMEs, reported very few 'stocks' of rays with total cumulative catches exceeding the cut-off value of 1000 t set earlier. Other areas, particularly around the southern half of Australia, did not report rays in sufficient quantities for assessment, though rays are certainly taken if not retained, at least as by-catch in other fisheries. Nevertheless, many areas of the world seem to have suffered great reductions in the reported catch of rays. Exceptions appear to be along the west coast of Canada, the U.S. and Central America, southeastern Africa, the Bay of Bengal, northwestern Australia, New Zealand, the Sea of Japan and the East China Sea. In these areas, the lack of evidence of 'stock' declines arise, in many cases, from taxonomically over-aggregated catch data, which our disaggregation method failed to resolve.

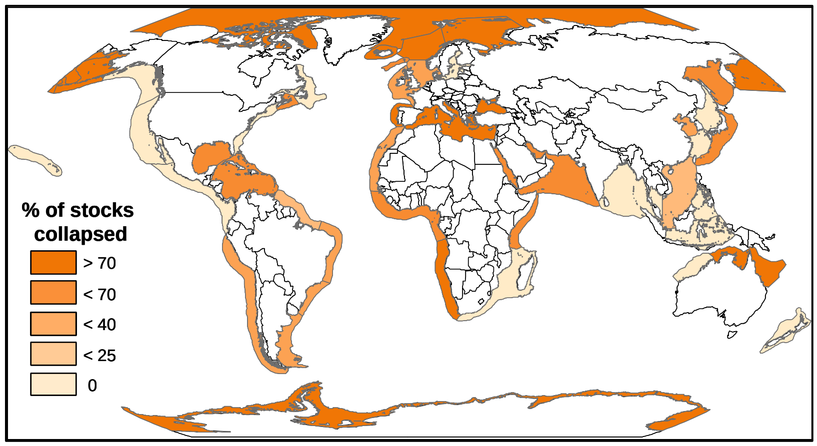

Figure 6. Percentage of 'stocks' of rays collapsed, by Large Marine Ecosystems Percentage of collapsed 'stocks' of rays, by Large Marine Ecosystems. Coastal areas without data (e.g., around Australia) did not report sufficient catches to allow analysis (see text).

Furthermore, by determining in which year a 'stock' collapsed based on the 50+ year time line of available catch data, we were able to calculate a measure of number of ray 'stocks' that collapsed in each decade. We did this by keeping track in the data of which year the catch of each 'stock' declined for the first time to 10 % or less of the maximum catch reported, and then summed these by decade. We adjusted for the start and end of the time period by assuming that no collapses can occur in the first two years of data (thus the decade of 1950 consisted of 8 years only), while for the 2000s, we only used two years as indicators. This analysis suggested that after 1980, the rate of ray 'stock' collapse might have increased rapidly (Figure 7). To what extend the available catch data for the first few decades under-represent information of declines in ray catches due to poorer data quality on rays specifically, and by-catch in general, remains unclear.

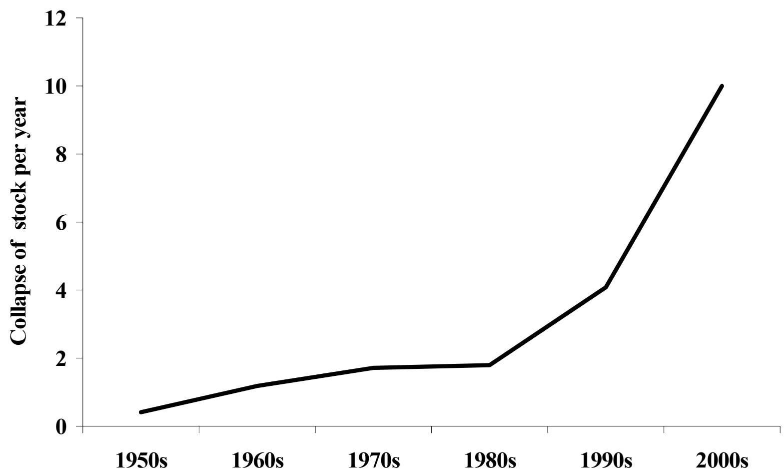

Figure 7. Collapse of ray 'stocks' per year Number of ray 'stocks' collapsing within LMEs each year, averaged for each decade. Note that for the 1950s, only eight years were considered, to permit build up of catches to maximum as per Figure 4. For the 2000s decade, only two years of data were applicable.

Summary of results from FAO areas and LME

We suggest that unless there was already evidence of impending or realized 'stock' collapse, it is unlikely that any management quotas would have been applied to the catches of rays that would limit their catch to less than 10 % of the historical maximum. Therefore, whether mandated by management or, more likely, imposed by biomass reductions, a drop to less than 10 % of the historical maximum signals a problem. The global management of ray fisheries is a tremendous challenge, given the extreme paucity of quality data. Nevertheless, despite such data limitations, the available evidence as presented here, suggests that many stocks and populations of rays are in trouble all over the world. Furthermore, many stocks may already have collapsed, or be in the process of doing so, given the accelerating pace of exploitation caused by selective targeting of rays. Thus, without significant intervention, we will lose many populations of rays.

Rays in ecosystem models: experience from the Gulf of Thailand

Ecosystem models are increasingly used for ecosystem-based management of fisheries (Christensen and Walters, 2005). We have worked extensively with Ecopath with Ecosim (EwE), an approach and software tool used for ecosystem modeling and policy evaluation (e.g., Pauly *et al*., 2000; Christensen and Walters, 2004; Walters *et al*., 2005). In the process, we have been able to observe the behavior of rays in such models, which is highly predictable, in spite of frequent problems with taxonomic resolution.

Rays tend to be pooled into one model group (without details as to species), or pooled with other groups of predators also feeding on the sea bottom. Thus, only about 20 of the 150 models in www.ecopath.org, which provides details on published EwE models, include rays explicitly. Nevertheless, based on simulations for each of these models, the general impression is that rays are among the more vulnerable groups with regards to increased fishing. This can perhaps best be illustrated by examining the Gulf of Thailand model (FAO/FISHCODE, 2001) describing the time period from 1973 to 1994. This represents the period when the demersal resources of the Gulf went from being lightly exploited to severely over-exploited (see Pauly, 1979; Boonyubol and Promokchutima, 1984; Christensen, 1998).

We fitted this Gulf of Thailand model to available time series data on group biomass (Figure 8), and found that the trophic group of rays was one of the groups in the model most severely impacted by the initial increase in fishing pressure (see also Figure 9). The Gulf of Thailand is rather unique as it is one of the few tropical ecosystems where we have good information about the history of fishing and the impact fishing (Pauly and Chuenpagdee, 2003). The development in the Gulf of Thailand was, however, rather typical for tropical shelves, where the rapid introduction of trawling led to a decrease in demersal fish biomass, with shrimps gradually becoming the most important fisheries resource in economic terms (Christensen and Walters, 2004). Thus, we conclude that available ecosystem-scale modeling confirm that rays, in general are highly susceptible to fishing.

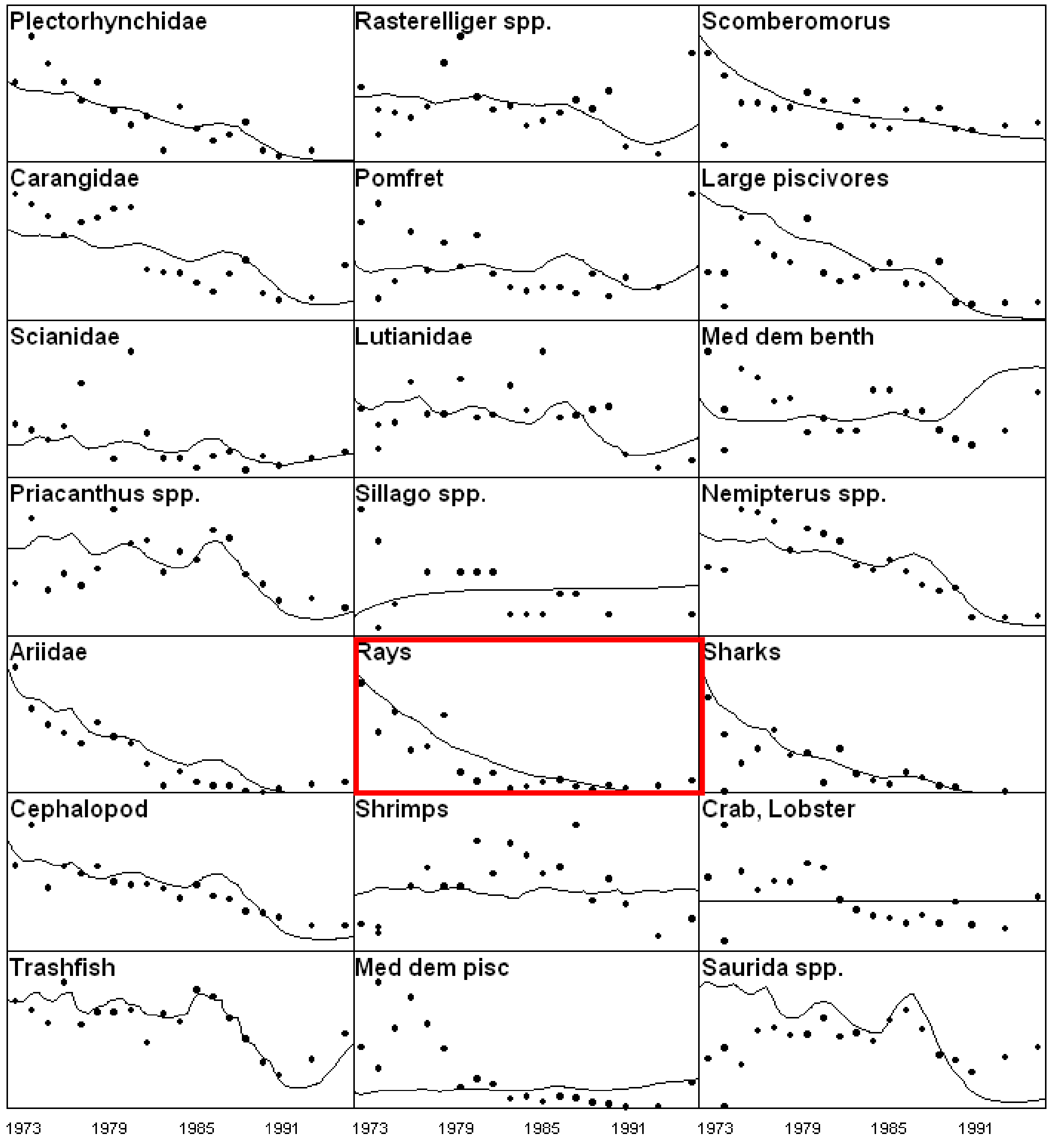

Figure 8. Modeled and observed abundance of major groups in the Gulf of Thailand Modeled and observed abundance of major taxonomic groups in the Gulf of Thailand, 1974-1994. Lines indicate results from ecosystem modeling (see text), while the dots are measured time series abundance information from standardized trawl surveys (Pauly 1979). A close examination of the first 10 years of the time series will indicate that of all groups in the ecosystem, rays (red box) experienced the most drastic reduction in abundance.

More on the intrinsic vulnerability of rays, and particularly *P. sephen*

The intrinsic vulnerability of a fish species is defined as its capacity to respond to fishing. In fishes, intrinsic vulnerability is correlated with life history traits such as body length, age at sexual maturation, longevity, fecundity etc. (Reynolds *et al.*, 2001; Dulvy *et* *al.*, 2003; Frisk *et al.*, 2004; Cheung *et al.*, 2005). Here, intrinsic vulnerability is expressed as an index of vulnerability calculated from the method described in Cheung *et al.* (2005) and based on one or more of the following input parameters: maximum body length, age at sexual maturation, longevity, the von Bertalanffy growth parameter K, natural mortality rate, fecundity, geographic range and a ranking on the type and strength of aggregation behavior. The index scales between 1 and 90, with 90 being the most vulnerable. Life history data were obtained from FishBase (www.fishbase.org; see also Appendix 1).

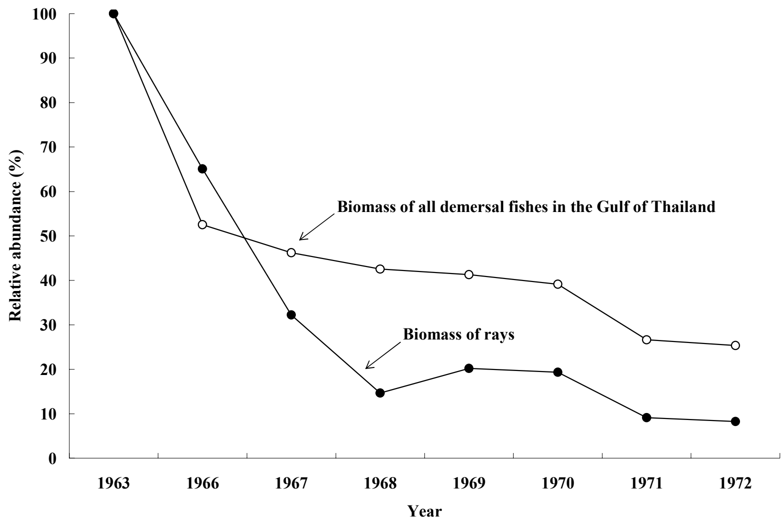

Figure 9. Observed abundance of demersal fishes and rays in the Gulf of Thailand Observed abundance of demersal fishes and rays in the Gulf of Thailand, illustrating that rays decline faster than other species. Data from systematic trawl surveys (Pauly 1979).

The Cowtail stingray has a highly vulnerable life history. It has a large body size (maximum size of 300 cm total length, disk width of 183 cm; see Appendix 1). When body size is the only input parameter, the method of Cheung *et al.* (2005) yields an index of vulnerability that is very high (90). When this input parameter is supplemented by an estimate of the von Bertalanffy growth parameter K obtained by inference from other species of the same family (Figure 3b), and the maximum fecundity in the family Dasyatidae, the index of vulnerability remains the same (90), but the confidence in the estimate increases (from 0.5 to 0.875, out of 1). This indicates that a suite of life history traits (large body size, slow growth, low fecundity) reduces the ability of the Cowtail stingray to withstand fishing pressures.

This is a feature shared with other rays, which have vulnerabilities strongly skewed to the high vulnerability side (Figure 10a). The median vulnerability of rays (i.e., of the Order Rajiformes) is 61, while the Dasyatidae are the most vulnerable family of the Order, with a median vulnerability of 67 (Table 1, Figure 10a). This is in contrast to the vulnerability trends for all marine fishes and, in particular, for reef fishes (Figure 10b). Indeed, the Dasyatidae have vulnerabilities similar to the marine fishes listed under the IUCN Red List of Endangered Species (Table 1; Baillie *et al*., 2004).

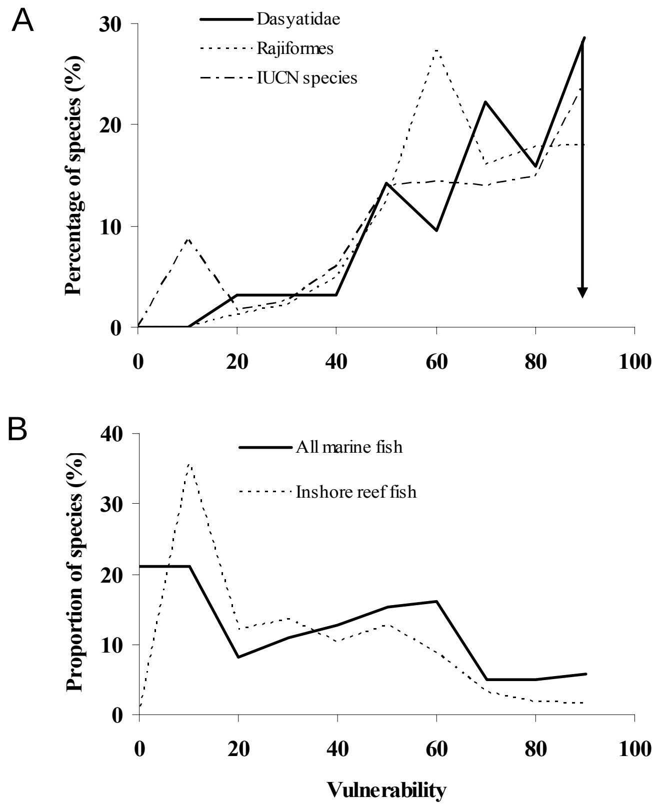

Figure 10. Frequency distribution of intrinsic vulnerability index among fish groups; A: marine rajiforms, dasyatids and fish listed under the IUCN Red List. The black arrow on the right indicates the intrinsic vulnerability of Cowtail stingray. B: all marine fish and reef fish (<100 m depth).

The wide geographic range of some species of Dasyatidae, notaby of *P. sephen* (Figure 2), does not invalidate this trend. Comparative analysis on skates (Rajidae), taxonomically close to the Dasyatidae, showed that large geographic ranges do not protect a species from the risk of extirpation and potential extinction (Dulvy and Reynolds, 2002).

Table 1. Intrinsic vulnerabilities of various groups of fishes, estimated using the method of Cheung *et al*. (2005) and data in FishBase (www.fishbase.org).

Species grouping	Species number	Median vulnerability
All marine fish	14,226	38
Marine rajiforms	416	61
Marine dasyatids	59	67
Marine fishes on IUCN Red List	203	62
Marine rajiforms on Red List	23	67

Use, trade and marketing of rays

Commercial uses

The flesh of *Pastinachus sephen* is use as food and has been tested for use in the manufacture of ‘kamaboko’, i.e., fish jelly (Irianto *et al.*, 1995). The skin is used for polishing wood (Talwar and Jhingran, 1991) and for the manufacturing of fine leather, used in luxury goods (see below). The species was also exploited for its liver oil, a good source of vitamin A (James, 1973).

History and manufacturing information

Leather made from the skin of rays is commonly known as stingray leather, shagreen or galuchat. Historically used in Asia for a variety of purposes, it is currently in demand mostly for fashion and luxury goods all over the world. The processed leather has characteristics which makes it useful for a variety of purposes. The term galuchat originated in the 18th century at the court of Louis XV in France when Jean-Claude Galuchat first started to use ray leather as a decorative finish. Later, at the turn of the 20th century, it was used for decorative craft pieces during the art deco period (Mason, 2005).

When dried, the skin of rays is abrasive, and was traditionally used as a form of sandpaper in many countries. Ray leather was first used in Asia for sword and body armor manufacturing (Mason, 2005) as the skin is very durable, flame resistant and also provides a good grip because it does not become slippery even when covered in blood during battle.

Most recently, it is being used in a variety of luxury goods, although more standard goods such as watch straps, wallets and bags seem to be also common. A retailer in France, Alain Silberstein, was attributed to being the first to use galuchat for watch straps in 1993 (Silberstein, 2005).

Ray leather is made from the dorsal part of the rays (Figure 11), and depending upon the sex of the ray a different proportion of the hide is used, with the finished leathers having different end-uses. Male skins, which are preferred by collectors because of their larger scales are used on furniture, are generally larger and approximately 70 % of the skin can be used. The skins from females are smaller with as little as 15 % of the skin being used, and they tend to be used for small items like boxes and lighter holders (Go, 2003). The size of the grain gets smaller from the center to the sides and younger fish have a smaller grain (Camilleri, 2005).

Trade

Leather made from rays is difficult to trace as an individual commodity for most countries. Since rays, in the absence of detailed catch data, are not currently considered to be a conservation concern by agencies monitoring international trade, trade statistics for ray leather are grouped into other categories such as ‘ general leather goods.’ A search on the internet identified countries in Asia as being the main suppliers, although small amounts of shagreen may also be made in Australia (The Wildlife Company, 2005), the Caribbean, the USA (Ocean Leather, 2005), and possibly France.

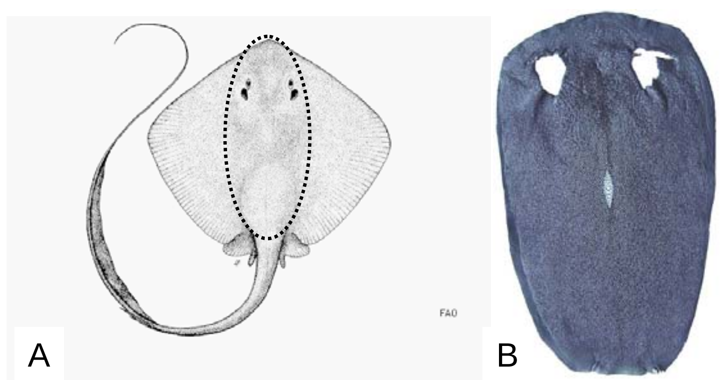

Figure 11. Body part of *Pastinachus sephen* used for leather production. A: Picture of *P. sephen* (source: Carpenter *et al.*, 1997; extracted from FishBase) with the dotted black line indicating the portion of the ray used to make leather. B: the processed leather used to manufacture goods (source: www.exoticleather.biz).

The global demand for ray products, driven primarily by the growing luxury consumption of leather products, appears to have increased considerably, as exemplified by the growing number and diversity of luxury products now decorated with stingray leather. This trend is also evident in data on the import of ray leather products into the USA. For example, US imports of products (number of items) using stingray leather has approximately doubled over the five year period spanning the late 1990s/early 2000s (Dr. Amanda Vincent, Fisheries Centre, UBC, unpublished data). Furthermore, the number of countries from which these products were imported (not necessarily the countries of origin of the stingray catch) also appears to have doubled, and is dominated by Thailand (~78 % of US imports by number of items) and Indonesia (~12 %), followed by the Philippines (~7 %), Singapore (~2 %) and Malaysia (~1 %) (Dr. A. Vincent, unpublished data).

Figure 12. Example of processed product using stingray leather. Stingray Leather Travel Kit as shown on www.millioniare.com. The original caption for this item read: "Created by leather craftsman Jacques Robin, the Cuirs d'Ocean collection of luxurious shaving and travel accessories uses shagreen, the skin for giant stingrays found in Indo-Pacific waters. This stunning leather, one of the strongest in the world, gives these items a unique nubby texture. Retail price: US$7,460."

Figure 13. Examples of processed products using stingray leather. A: Stingray covered smoking pipe available at: www.aab-taxfreepipes.com. Original caption reads: "Dunhill Stingray Covered, Group 5. This is the first time that such pipes have been produced, only 50 numbers and therefore are extremely rare and will be sought after by collectors. Retail Price: US$2,266.67". B: Cowboy boots made from stingray leather, available at: http://www.upscaleleathers.com. Original caption reads: "Stingray Diamond genuine leather. Retail Price: $699.00". C: Leather wallet available at: www.tropicalleather.com. Original caption reads: "Unique and a class in itself, this stingray leather wallet makes a striking first impression. Retail Price: US$54.00".

Indonesia, which has the largest elasmobranch fishery, increased catches between 1992 and 1993 by 8.7 % (~7000 t), the largest increase reported for that category since 1980. A large target fishery exists in the Java Sea during the dry season, with each boat landing approximately 8 t of rays per trip. The company PT Dian Mandala uses both the Cowtail (*Patinachus sephen*) and the Blue-spotted stingray (*Dasyatis kuhlii*) to produce wallets and purses under the brand name *Parri*. These items are made in Yogyakarta, tanning occurs in Jakarta and drying and salting occurs in Muara Angke (Bentley, 1996).

Marketing

The marketing of ray leather is directed to an upscale market. Recent publications, such as "Millionaire" (www.millionaire.com; Figure 12), the "Robb Report" (which identifies itself as a luxury portal; www.robbreport.com) and the '*Wall Street Journal*' have had products and articles describing ray leather as the new luxury and fashion trend. Goods may be partially covered in ray leather (Figure 13a) or may be entirely made from the product (Figure 13b, c). An internet survey of 28 companies who supply or sell ray leather found that 5 of these (18 %) have a conservation statement and 2 (7 %) state that rays remain abundant in the oceans (Table 2), while all other sites provide no information.

Table 2. Company websites statements regarding conservation or abundance of ray resources.

Internet site[1]	Statements[2]
asiaroadexports.siam-biz.com/about.html	- "Population has been estimated roughly in 1995 approximately over half billion." - "Stingrays are edible and consumed by all fishing cultures in the world especially it is the main protein ingredient for the people in underdeveloped countries thru out the world." - "Stingray […] is NON CITES species and can be exported and imported freely without any restriction."
www.rojeleather.com/index.asp	- "Stingrays remain abundant, free living populations." - "Stingrays are only caught for food, a significant source of protein for the local people." - "The skins are merely a by-product and would normally be wasted."
www.stingray.com.sg/default.asp	- "Both species (*Dasyatis bleekeri/Aetobatus narinari*) are neither endangered nor threatened. According to CITES […], there are documents to show that Stingray is not included in these appendices and therefore legal for commercial and trading through the world."
www.stingrayleatheritems.com/site/713242	-"With the concerns about animal rights, stingrays are not on the endangered species list, and are very abundant."
www.mplthailand.com/leather/stingray/	- "Population has been estimated roughly in 1995 approximately over half billion." - "Stingrays are edible and consumed by all fishing cultures in the world especially it is the main protein ingredient for the people in underdeveloped countries thru out the world."
www.walkerzabriskie.com/iShag.html	- "The stingray is not endangered and is not restricted in any manner by the CITES treaties."
wmi.com.au/thewildlifeco/twc-stingray.pdf	- "Luxury wildlife products with conservation in mind."

[1]All websites were accessed on August 29, 2005. [2]No documentation of these claims was provided.

Conclusion: prospects for sustainable stingray fisheries

Several of the retail-websites surveyed during our web-search stated that ray leather is a "sustainable" product. Sustainability implies that the natural production of the species can meet, in the long-term, the demand from human consumption, or alternatively that the catch does not exceed natural replacement. Are the fisheries of rays (both by-catch based and targeted) sustainable? Can we decide if current exploitation patterns are sustainable, given the lack of traditional stock assessments based on species-specific hard data?

Based on our assessment and evaluation of available data and information, neither perspective of sustainability seems to hold up to scrutiny. General knowledge of rays, and specifically Cowtail stingray (*Pastinachus sephen*) biology and life history characteristics clearly indicate that rays, as well as most other elasmobranchs, have population and life histories (particularly, high longevity and very low fecundity) that imply very low production rates. This, in turn, suggests that only very low exploitation levels can be sustained without threatening stocks with severe overexploitation or collapse. Given available global catch data, exploitation of the majority of 'stocks' appears to have surpassed their production potential, and the rate of 'stock' collapse is increasing, thus indicating that current exploitation levels exceed sustainability in most areas. Furthermore, it is highly likely that only the lowest levels of fishing mortality can be sustained, not exceeding removal of more than 5 % of a stock annually. Given the existing high fishing pressures in much of Southeast Asia (Paulyand Chua, 1988), these levels are likely to be exceeded in many countries by the incidental by-catch of rays in existing trawl fisheries.

In many countries in which stingrays are currently caught, they contribute to local seafood consumption. Yet, the increasing demand, and growing targeted fisheries appears almost exclusively driven by the growing demand for luxury leather goods in the developed world. This is clearly illustrated by the doubling of imports of stingray leather goods into the USA over the span of five years in the late 1990s to early 2000 alone.

Thus, based on the present analysis it may be concluded that the suite of life history traits have rendered the Cowtail stingray, as well as other rays, highly vulnerable to exploitation. The Cowtail stingray in particular appears to be among the most vulnerable members of its family, yet is currently targeted by fisheries for its skin, as well as being caught incidentally as by-catch in trawl gears. Furthermore, like other rays, the Cowtail stingray is 'live bearing' (i.e., ovoviviparous) and produces only 4-10 young per year, thus further increasing its vulnerability to exploitation. Given this high vulnerability, the general disregard of its biology, and the lack of management of its fisheries, populations of the Cowtail stingray, as well as other stingrays, may indeed be under serious threat.

What are potential solutions to reducing the thread of overexploitation to rays? The high vulnerability indices for rays as determined in the present assessment align these species directly with the marine fish, and especially marine elasmobranchs, listed on the IUCN Red List. Given that much of the increasing use and trade of rays seem to be based on the luxury leather trade, with resultant international trade aspects (i.e., country of origin of rays rarely is the same as country of final destination of product) several mechanisms come to mind. Through listing of Cowatil stingray on the IUCN Red List, and eventually on CITES, one would increase the chances of more control of the international trade, and likely a reduction in exploitation via tighter trade control and reporting mechanisms. The question remains of how one achieves listing for species with little formal stock assessments or species-specific time-series data as for fisheries in industrialized countries. A second mechanism may focus on the need to develop alternative products that imitate the characteristics of stingray leather, preferably sourced from already domesticated, terrestrial animals such as cows. This last aspect requires consumer awareness and choices to be influenced via marketing and educational avenues.

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APPENDIX: Synopsis of data on *Pastinachus sephen* (Forsskål, 1775)

Nomenclature

Pastinachus sephen (Forsskål, 1775; see synonyms in Table 3 and common names in Table 4) belongs to the Family Dasyatidae (Stingrays) of the Order Rajiformes (Skates and rays), Class Elasmobranchii (Sharks and rays). Note that some authors classify this family under the Order Myliobatiformes (see Rosenberger, 2001). The Family Dasyatidae includes five genera, i.e., *Dasyatis, Himantura, Pastinachus, Pteroplatytrygon* and *Urogymnus*, and over 62 species (Compagno, 1999). Species of the genus *Pastinachus* and *Pteroplatytrygon* are sometimes classified as *Dasyatis* (Rosenberger, 2001). Thus, because of its resemblance to some species in the genus *Dasyatis, Pastinachus sephen* is sometimes referred to as *Dasyatis sephen* (Nishida, 1990). It is, however, placed in the monotypic genus *Pastinachus* based on the extreme depth of the tail's ventral fin fold, also known as 'keel' (Compagno, 1999).

Table 3. Synonyms of *Pastinachus sephen*

Scientific name	Author	Status	References
Raja sephen	Forsskål, 1775	original combination	Nishida and Nakaya (1990)
Trygon sephen	(Forsskål, 1775)	new combination	Nishida and Nakaya (1990)
Pastinachus sephen	(Forsskål, 1775)	new combination	Last and Compagno (1999)
Hypolophus sephen	(Forsskål, 1775)	new combination	Last and Stevens (1994)
Dasybatus sephen	(Forsskål, 1775)	new combination	Suvatti (1981)
Dasyatis sephen	(Forsskål, 1775)	new combination	Compagno (1999)
Raia sancur	Hamilton, 1822	junior synonym	Eschmeyer (1999)
Raja sancur	Hamilton, 1822	junior synonym	Talwar and Jhingran (1991)
Trigon forskalii	Rüppell, 1829	junior synonym	Nishida and Nakaya (1990)
Taeniura atra	Macleay, 1883	junior synonym	Eschmeyer (1999)
Pastinachus sephen ater	(Macleay, 1883)	junior synonym	Last and Stevens (1994)
Dasyatis gruveli	Chabanaud, 1923	junior synonym	Last and Compagno (1999)
Dasyatis bennetti	(non Müller & Henle)	misidentification	Nishida and Nakaya (1990)

Distribution

Pastinachus sephen is an inshore, reef-associated, amphidromous species (Riede, 2004; Semeniuk and Dill, 2004), found to depths of 60 m in marine and brackish-water lagoons, reef flats, and reef faces (Michael, 1993), as well as in freshwater bodies, e.g., rivers, far from the sea (Compagno *et al.*, 1989). It occurs in tropical waters (32°N to 32°S) of the Indo-West Pacific (see Figure 2), from the Red Sea, Persian Gulf and South Africa to Micronesia; in the South China Sea, north to Japan, south to Melanesia and the Arafura Sea (Russel and Houston, 1989; Last and Stevens, 1994; Nguyen Huu Phung and Tran Hoai Lan, 1994; Compagno, 2000; Bonfil, 2002; Kapoor *et al.*, 2002). Table 5 lists some of the countries where this species has been reported to occur.

Table 4. Common names of *Pastinachus sephen*

Country	Common name	References
Australia	*English*: Banana-tail ray, Cowtail stingray, Fantail ray, Feathertail stingray; *Guugu Yimidhirr*: Gundurru	Last and Stevens (1994)
Bangladesh	Suncush	Quddus (1998)
China (Main.)	*Chinese*: 褶尾魟, 褶尾蘿卜魟	Wu *et al.* (1999)
Czech Rep	*Czech*: Trnucha laloková	Hanel and Novák (2001)
France	*French*: Pastenague plumetée	Sommer *et al.* (1996)
India	*English*: Cowtail ray; Drab stingray, Feathertail stingray, Frill tailed stingray, Sting ray; *Bengali*: Shankar-machh; *Kannada*: Kottar-thorake; *Mahl*: Madi; *Malayalam*: Athuthirukkai, Kottivalen-therandi, Olapadayan thirandi, Olavalan-thirandi, Padaiyan-therandee, Puzhian-thirukkai; *Marathhi*: Goval-pakat; *Tamil*: Adal-thirikkai, Adathirukkai, Adavalan-tiriki, Elathirukkai, Olaival thirukkai; *Telugu*: Velugiri-tenkee, Wolga-tenkee	Talwar and Jhingran (1991); Sen (1987); Talwar and Kacker (1984); Kumaran and Jones (1980); Anon (1968); Devanesen and Chidambaram (1953); [Review of Indian names by Brajgeet Bhathal, Fisheries Centre, UBC]
Indonesia	*Malay*: Pari ayam, Pari bunga, Kao, Aorimipi	Muller (2005); Schuster and Djajadiredja (1952)
Japan	*Japanese*: Tsuka ei	Ahmad *et al.* (2004); Nakaya (1984)
Malaysia	*English*: Banana-tail ray, Cowtail stingray, Fantail ray, Feathertail stingray; *Malay*: Pari bendera, Pari dau, Pari daum, Pari daun, Pari nyonya, Pari tanjung	Ahmad *et al.* (2004); Abu Khair Mohammad Mohsin *et al.* (1993)
Micronesia	*English*: Fantail stingray	Myers (1999)
Myanmar	*Burmese*: Leik-kyauk tin-kun	Khin (1948)
Netherlands	*Dutch*: Veerpijlstaartrog	Bor (2002)
Oman	*Arabic*: Lukhmah, Shurus	Fouda and Hermosa (1993)
PNG	*English*: Cowtail ray, Fantail-ray	Kailola (1987); Munro (1967)
Philippines	*Kuyunon*: Page; *Surigaonon*: Pague	Ganaden and Lavapie-Gonzales (1999)
Saudi Arabia	*Arabic*: Ruget	Fouda and Hermosa (1993)
Somalia	*Somali*: Shafane cordaal	Sommer *et al.* (1996)
South Africa	*Afrikaans*: Veerstert-pylstert; *English*: Feathertail stingray	Compagno (1986)
Sri Lanka	*Sinhalese*: Pol kolle maduva; *Tamil*: Ada-thirukai, Adavalan-tirike	De Bruin *et al.* (1995)
Tanzania	*Swahili*: Taa usinga	Bianchi (1985)
Thailand	*Thai*: Krabane thong, Pla Kabeng Chai Tong	Ahmad *et al.* (2004)
UK	*English*: Cowtail stingray	Sommer *et al.* (1996)

Table 5. Some countries with reports of *Pastinachus sephen*

Country	References and notes
Australia	Myers (1999); Last and Stevens (1994); Talwar and Jhingran (1991); Masuda *et al.* (1984). Most common in northern Australia (Semeniuk and Dill 2004), from Shark Bay to the Clarence River (Paxton *et al.*, 1989), and Gulf of Carpentaria (Blaber *et al.* 1994).
Bangladesh	Reported from freshwater systems (Quddus, 1998).
Brunei Darussalam	Yano *et al*. (2005).
Chagos Islands	Winterbottom and Anderson (1997); Hardy (2003).
Djibouti	Künzel *et al.* (1996).
India	Ishihara *et al.* (1998); Rao (1995). A common species (Talwar and Jhingran, 1991). Found in Palk Bay and Gulf of Mannar with disc width of 75 cm (James, 1973); captured with bottom-set gillnets on the Cuddalore Coast (Devadoss, 1978a); also in coastal waters and Chilka Lake (Kapoor *et al*., 2002). Erroneously reported from the Ganges river (Talwar and Jhingran, 1991). Used extensively by poor people. Tail often used as a whip (Sen, 1987). Female Cowtail stingrays are dominant in the demersal fisheries off Mumbai (Raje, 2003).
Indonesia	Last and Compagno (1999); Kottelat et al. (1993). Found from southwest Sumatra to Bali Strait (Gloerfelt-Tarp and Kailola, 1984). Recorded from Pulau Seribu, Java Sea (Allen and Adrim, 2003) and in the Indragiri River in Sumatra (Taniuchi, 1979). A species of minor commercial importance, frequently by-catch of Indonesian guitarfish (shark net) fishery (Dr. W. White, pers. comm. to FishBase).
Iran	Anon (2000); Assadi and Dehghani (1997). Reported from the Persian Gulf and Gulf of Oman.
Japan	Masuda *et al.* (1984). Reported from Iriomote Island (part of the Ryukyu Islands) as a “scarce” species.
Kenya	Described as a “common” species along the Kenyan coast between January 1980 and December 1981 (Ochumba, 1988).
Kuwait	Randall (1997). Based on photo of a trawl-caught specimen from Kuwait Bay.
Malaysia	Last and Compagno (1999). Reported from the Perak River (Taniuchi, 1979). Recorded in a 1994-2004 study by Ahmad *et al.* (2004). A species of commercial importance (Ahmad *et al.* 2004) usually found in the market (Yano *et al*., 2005). Large adults, recognizable by their characteristic tail fold, are often encountered by divers in coral lagoons. Usually caught by trawlers and deep gillnets (Yano *et al*., 2005).
Maldives	Randall and Anderson (1993). Regularly attracted to resort island beaches for feeding by tourists (Anderson *et al.*, 1998).
Micronesia	Last and Compagno (1999); Myers (1999). Occurs in Pohnpei (Myers, 1999).
New Caledonia	Occurs in the southwest lagoon (Thollot, 1996) and St. Vincent Bay (Wantiez, 1993).
Oman	Randall (1995).
Pakistan	Hssain (2005).
Palau	Kuronuma and Abe (1986); Myers (1999).
Papua New Guinea	Kailola (1987); Werner and Allen (1998).
Philippines	Last and Stevens (1994); Kuronuma and Abe (1986); Masuda *et al.* (1984). Lake Naujan, Mindoro Island (Taniuchi, 1979), Sulu-Celebes Sea (Herre, 1953).
Seychelles	Smith and Smith (1963).
Somalia	Sommer *et al.* (1996).
South Africa	Kottelat *et al.* (1993); Compagno (1986). Occurs off Kwa Zulu. Likely caught by anglers, “scarce” species (Compagno *et al.*, 1989).
Thailand	Taniuchi (1998); Wongrat (1998); Suvatti (1981). Known from Menam Chao Phaya; Menam Chantaburi; Tale Sap and Koh Chang (Suvatti, 1981). Sampled in the inner part of Songkhla Lake (Sirimontaporn, 1999). Recently collected from the Bangpakong River, Bang Khla, Chachoengsao Province. Common in estuarine areas of the upper part of the Gulf of Thailand. Caught with set nets and push seines and large individuals are cut into pieces and sold in markets. Small individuals are sold to aquarium fish dealers (Wongrat, 1998).
Viet Nam	Nguyen Huu Phung and Tran Hoai Lan (1994). Known from the coast of Central Vietnam. A scarce species.

Description

Pastinachus sephen is a large, plain, dark stingray with an angular snout and pectoral disc. It has no dorsal spines. The tail is long and broad-based, less than twice its body length. It does not have an upper caudal fin fold, but has a high lower caudal fin fold that is 2 to 3 times the depth of its tail but not reaching the tail tip. It has no large thorns but has 1 or 2 long stings on the tail situated further behind the tail base than in most stingrays. The tail tip is filamentous. It has unique hexagonal, high-crowned teeth (Compagno *et al.*, 1989).

The dorsal half of its body sports a dark brown or black color, without conspicuous markings. It has a white belly (Compagno *et al.*, 1989) and a black tail (Compagno, 1986). Though monochromatic, this stingray's eyes are sensitive to ultraviolet light. Their light transmission spectrum has a maximum of 402 nm (Siebeck and Marshall, 2001).

Maximum size is recorded at 183 cm disc width and over 300 cm total length from the Persian Gulf and Oman Sea (Sommer *et al.*, 1996; Assadi and Dehghani, 1997; Anon., 2000).

Biology and behavior

Pastinachus sephen is a 'hunting' species preying on benthic animals, i.e., bony fishes, crustaceans (shrimps and crabs; Michael, 1993), mollusks (Devadoss, 1978b) and on polychaete worms (Homma *et al.*, 1994). Feeding seems to be a solitary activity interspersed with about 4 hour resting periods spent in groups in shallow intertidal areas where they avoid, presumably, predation by various shark species, bottlenose dolphins (Semeniuk and Dill, 2005) and sawfish (James, 1973). It can be assumed that they are extremely vulnerable to shallow-water fishing.

The sexes are always separate in *Pastinachus sephen*, which is thus dioecious, and females are usually larger than males (Raje, 2003). Fertilization is internal. Pairing is distinct, i.e., mating pairs are locked in a characteristic embrace (Breder and Rosen, 1966), and breeding occurs for a prolonged period (Raje, 2003). Females are 'live bearers', i.e., ovoviviparous, with eggs retained within the female body in a brood chamber where the embryos develop, but without the strong umbilical attachment to a placenta as in mammals. The embryos feed initially on yolk and later receive additional nourishment from the female by indirect absorption of uterine fluid enriched with mucus, fat or protein through specialized structures (Dulvy and Reynolds, 1997). Yano *et al.* (2005) observed a female caught by a trawler in the coastal waters of Sarawak in 2003 to contain two embryos. The female embryo measured 160 mm disc width, 150 mm disc length and the male embryo measured 170 mm disc width and 155 mm disc length. Size at birth is about 180 mm disc width (Last and Stevens, 1994) or 500 mm total length (Yano *et al.*, 2005). They swim in rajiform mode, i.e., an undulatory-based pectoral locomotion style characteristic of most species in the Family Dasyatidae (Rosenberger, 2001; Lindsey, 1978).

Table 6. Some parasites of *Pastinachus sephen*.

Parasite species	Organ infested	Reference
Acanthobothrium chisholmae	Spiral intestine	Campbell and Beveridge (2002)
Acanthobothrium gasseri	Spiral intestine	Campbell and Beveridge (2002)
Acanthobothrium laurenbrownae	Spiral intestine	Campbell and Beveridge (2002)
Acanthobothrium walkeri	Spiral intestine	Campbell and Beveridge (2002)
Monocotyle corali	Gills	Chisholm and Whittington (1998), Chisholm (1998)
Decacotyle tetrakordyle	Gills	Chisholm and Whittington (1998)
Dendromonocotyle ardea	Dorsal body surface	Chisholm and Whittington (1995)
Halysiorhynchus macrocephalus		Beveridge and Campbell (1992)
Tylocepphalum bombayensis		Jadhav (1983)
Tylocepphalum madhukarii	Spiral intestine	Chincholikar and Shinde (1980)
Flapocephalus trygoni.		Deshmukh (1979)
Flapocephalus saurashtri		Shinde and Deshmukh (1979)
Lecanicephalum maharashtrae	Spiral valve	Chincholikar and Shinde (1978)
Trebius sepheni		Hameed and Pillai (1973)
Aliascaris indica		Kalyankar (1971)

Adults are sometimes accompanied by remoras or members of the trevally family (Last and Stevens, 1994). This species is host to various parasites (Appendix Table 4).

This stingray, when threatened, lashes its tail, and can inflict severe wounds with its venomous sting, which can cause wound necrosis (Barss, 1984). Often, the spine breaks off from the tail and is left embedded in the flesh of the victim (James, 1973).

A length-weight relationship of $\log_{10}$ weight = -8.09534 + (2.62806 * $\log_{10}$ length) is available for the population occurring in Mumbai, Maharashtra, India (Raje, 2000). An earlier study by Ochumba (1988) suggests allometric growth.

Nothing is known on the growth, maturity and mortality of *Pastinachus sephen*, but values for these parameters can be inferred by comparison with related species, and this is presented in the main text of this report. Stingrays (Family Dasyatidae) have fecundities ranging from 4-10 young per year. Even assuming a mean of 10 young per year, a minimum population doubling time of more than 14 years is predicted, which indicates very low resilience to environmental and exogenous impacts (www.fishbase.org).

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