Decision 19.189: Technical workshop on Aquatic species listed in the CITES Appendices

Variability of life history parameters and productivity in elasmobranchs and other commercially exploited aquatic species

Enric Cortés

CITES Secretariat - Consultant

Outline of presentation

- Brief background on life history of cartilaginous and bony fishes
- Variability in life history traits of elasmobranch and other fishes
- Comparison of life history traits of elasmobranchs and other fishes
- Identifying vulnerable aquatic species and decline thresholds
- Other measures of productivity and vulnerability, and associated management reference points, used in fisheries
- Conclusions and challenges

General life history of elasmobranchs vs. other commercially exploited fishes

“K-selected”

- Slow growth
- Late age at maturity and first reproduction
- Low fecundity, long gestation periods, low frequency of births, production of well-developed offspring
- Low natural mortality
- Long lifespan

“r-selected”

- Fast growth
- Early age at maturity and first reproduction
- High fecundity, production of eggs
- High natural mortality
- High recruitment
- Short lifespan

Data sources

Taxon	Life history traits	n
Sharks	Cortes (2000) augmented	603
	Thorson et al. (2023)	
Batoids	Barrowclift et al. (2003)	150
Teleosts	Thorson et al. (2023)	2041
Taxon	**Productivity**	**n**
Sharks	Cortes (2016) augmented	101
	Gravel et al. (2024)	67
	Finucci et al. (2024)	61
Batoids	Barrowclift et al. (2003)	85
	Gravel et al. (2024)	26
	Finucci et al. (2024)	24
Teleosts	Gravel et al. (2024)	129
Marine mammals	Finucci et al. (2024)	21

Some definitions

Life history trait	Abbreviation	Unit	Meaning
Growth completion rate	k	/ year	A constant that describes how quickly the maximum length is reached. Also referred to as the growth coefficient from the von Bertalanffy growth function
Age at maturity	t_{mat}	years	The age at which (50% of) individuals become mature
Maximum age	t_{max}	years	The maximum age of individuals in a population
Annual fecundity	fecundity	pups / year	The number of pups produced by a female in a year
Natural mortality rate	M	/ year	The rate at which animals die in a year
Theoretical maximum length	L_{inf}	cm total length	The theoretical maximum mean length of a population
Length at maturity	L_{mat}	cm total length	The length at which (50% of) individuals become mature
Intrinsic rate of increase	**r_{max}**	**/ year**	**The rate at which a population increases in a year. A direct measure of productivity**

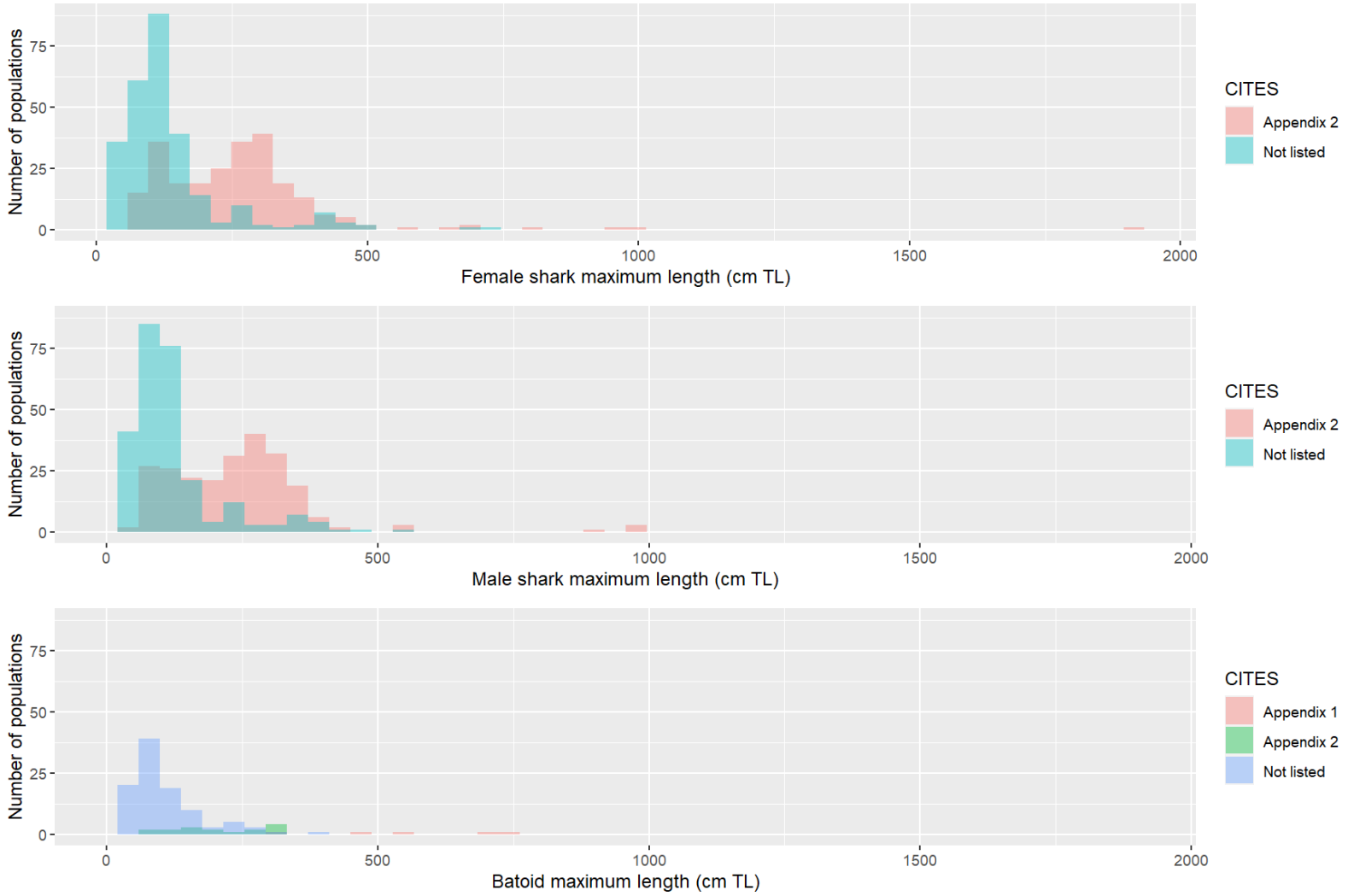
Variability in life history traits of sharks and batoids

Life history trait	Minimum	Species	Maximum	Species
Sharks				
Total length	22 cm	Pigmy shark	1900 cm	Whale shark
Litter size	1 pup	Gulper shark	300 pups	Whale shark
Gestation period	4-5 months	Bonnethead	3.5 years	Frilled shark
Breeding frequency	1 year	Many	3 years	Several
k (growth coefficient)	0.01 / yr	Blackbelly lanternshark	1.34 / yr	Australian sharpnose shark
Age at maturity	1 year	Australian sharpnose shark	36 years	Spiny dogfish
Maximum age	4 years	Australian sharpnose shark	81 years	Spiny dogfish

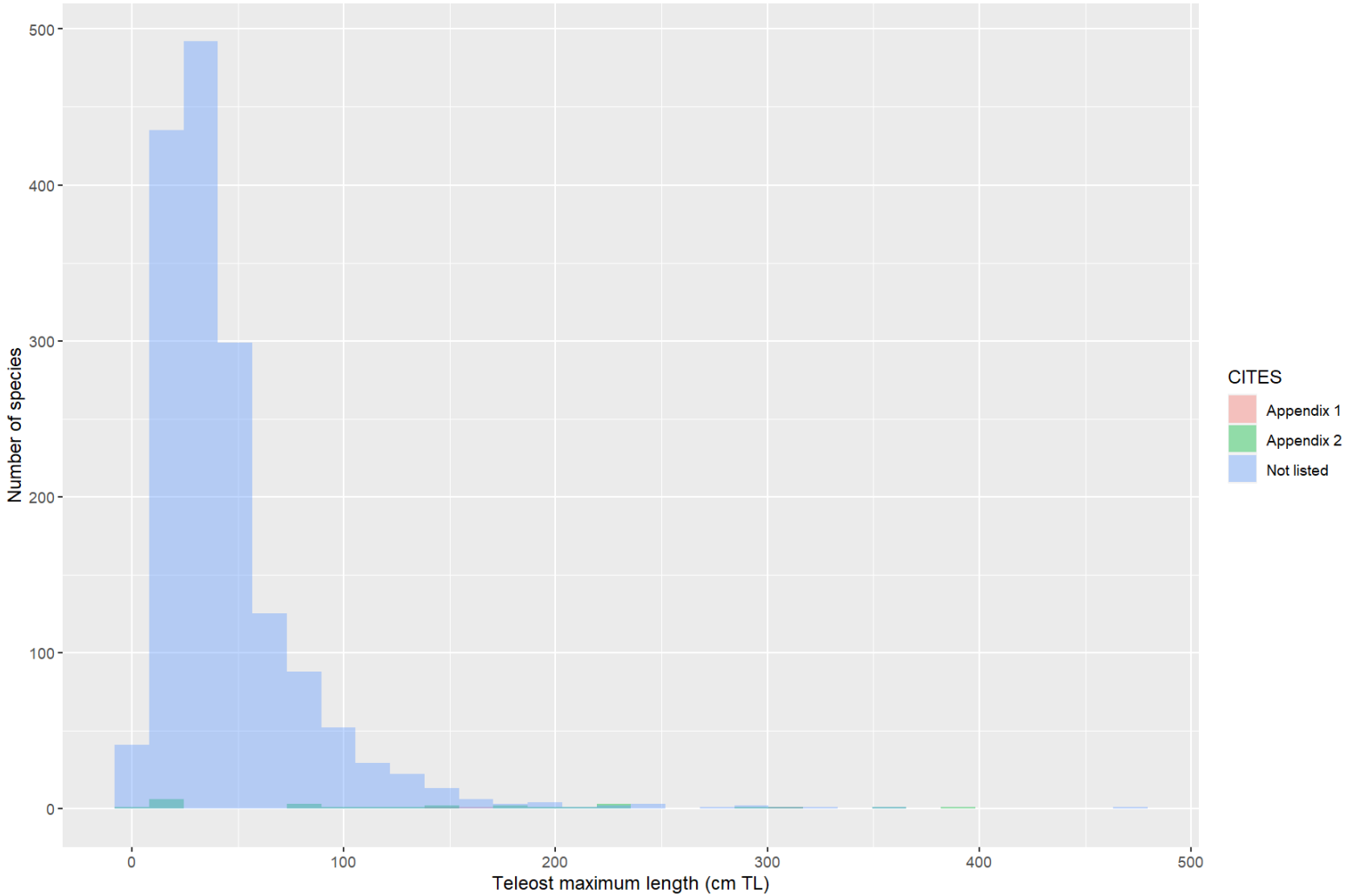
Life history trait	Minimum	Species	Maximum	Species
Batoids				
Total length	26 cm	Chilean round ray	730 cm	Longcomb sawfish
Disk width	26 cm	Dwarf stingray	700 cm	Giant oceanic manta ray
Litter size	1 pup	Brazilian large-eyed stingray	167 eggs	Thornback ray
Gestation period	3 months	Freshwater whipray	15 months	Bottlenose skate
Breeding frequency	0.074 years	Big skate	4.5 years	Reef manta ray
k (growth coefficient)	0.02 / yr	Graytail skate	0.54 / yr	Roughskin skate
Age at maturity	1 year	Roger's round ray	25 years	Roughtail skate
Maximum age	3.5 years	Bleeker's whipray	50 years	Common skate

Life history trait	Minimum	Species	Maximum	Species
Teleosts				
Total length	3.1 cm	Emerald clingfish	474 cm	Indo-Pacific blue marlin
Length at maturity	1.6 cm	Sinaripan	219 cm	Indo-Pacific blue marlin
k (growth coefficient)	0.03 / yr	Beluga	5.3 / yr	Silver-stripe round herring
Age at maturity	0.2 years	Cyprinid	24.8 years	Beluga
Maximum age	0.6 years	Silver-stripe round herring	92.5 years	Rougheye rockfish

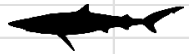
Length-frequency distributions of sharks and batoids



Length-frequency distributions of ray-finned fishes



Some examples of life history variability in sharks and teleosts

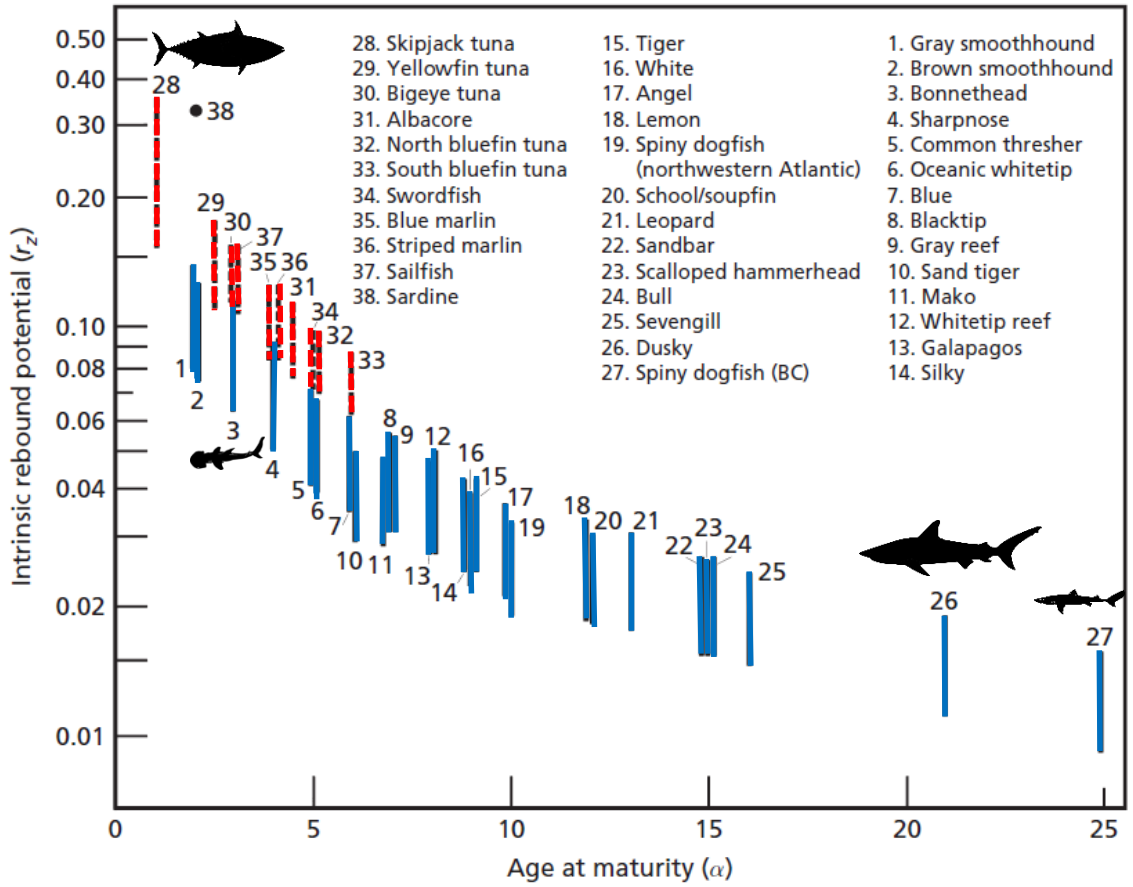
Fecundity	Offspring size	Body size	Growth	Lifespan	Example	
high	small	mid to large	mid to slow	substantial	Blue shark	
low	large	large	slow	high	Dusky shark	
low	small*	small to mid	fast	low to mid	Atlantic sharpnose shark	
low	small	small	slow	high	Spiny dogfish	
very high	very small	small	slow	high	Rougheye rockfish	
very high	very small	large	mid to slow	substantial	Atlantic bluefin tuna	
very high	very small	very small	very fast	very low	White sardinella	

* but born at high % of adult maximum size and reach maturity quickly

From Cortes (2000) and data from Thorson et al. (2023)

Comparison of life history traits of elasmobranchs and other fishes:

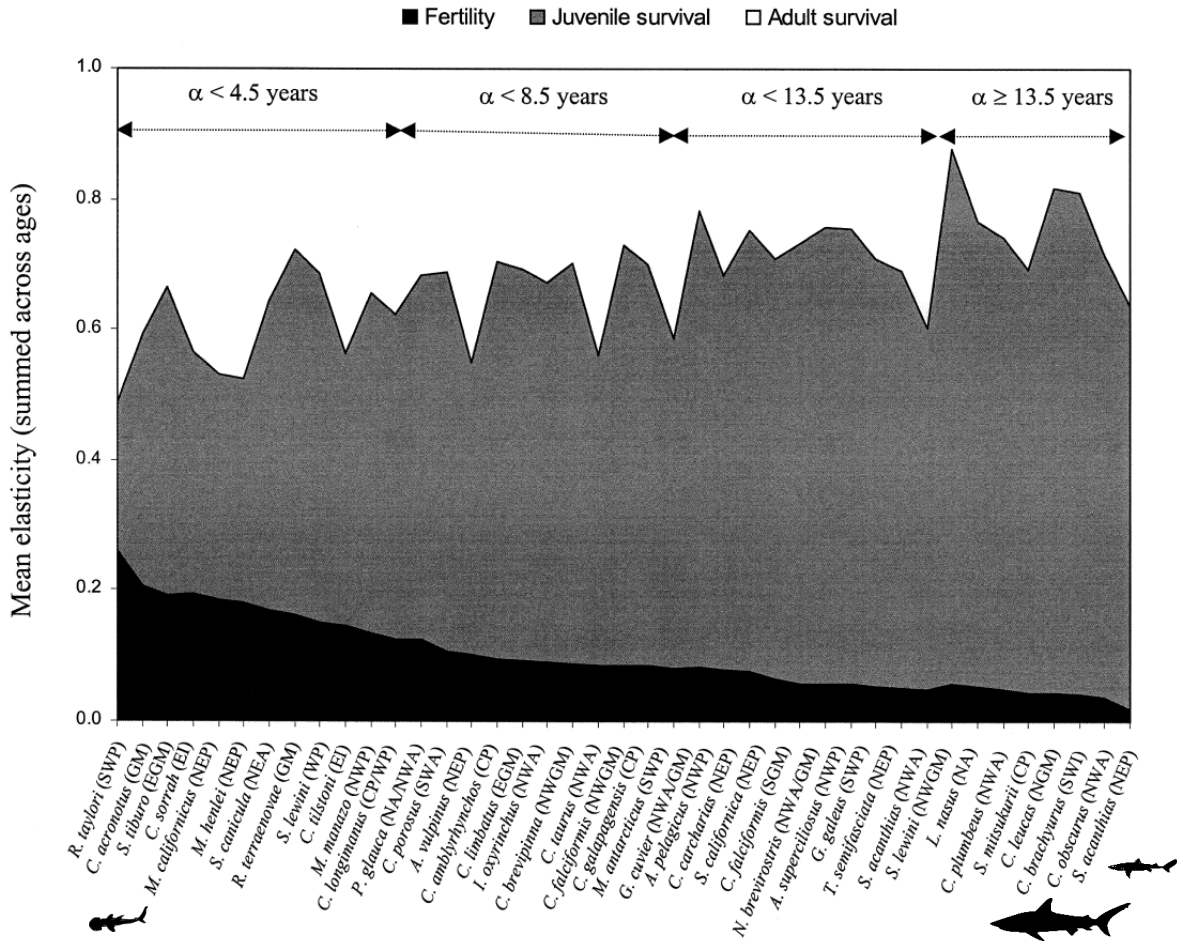
previous studies showing continuum of productivity values for sharks and teleosts



Modified from Au et al. (2008): shark species in blue; teleosts in red

Comparison of life history traits of elasmobranchs and other fishes:

previous studies showing continuum of productivity values for sharks



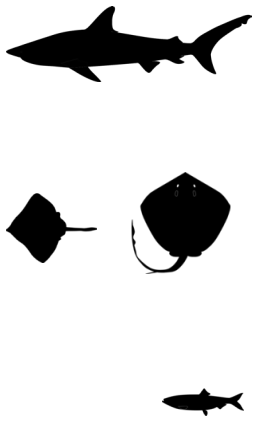
Identifying vulnerable aquatic species

Using Musick's (1999) classification as an example

	Productivity			
	High	Medium	Low	Very low
k (yr^{-1})	>0.30	0.16-0.30	0.05-0.15	<0.05
t_{mat} (yr)	<1 yr	2-4 yr	5-10 yr	>10 yr
t_{max} (yr)	1-3 yr	4-10 yr	11-30 yr	>30 yr
fecundity (yr^{-1})	>10000	100-1000	10-99	<10
r_{max} (yr^{-1})	>0.50	0.16-0.50	0.05-0.15	<0.05
Decline threshold	99%	95%	85%	70%

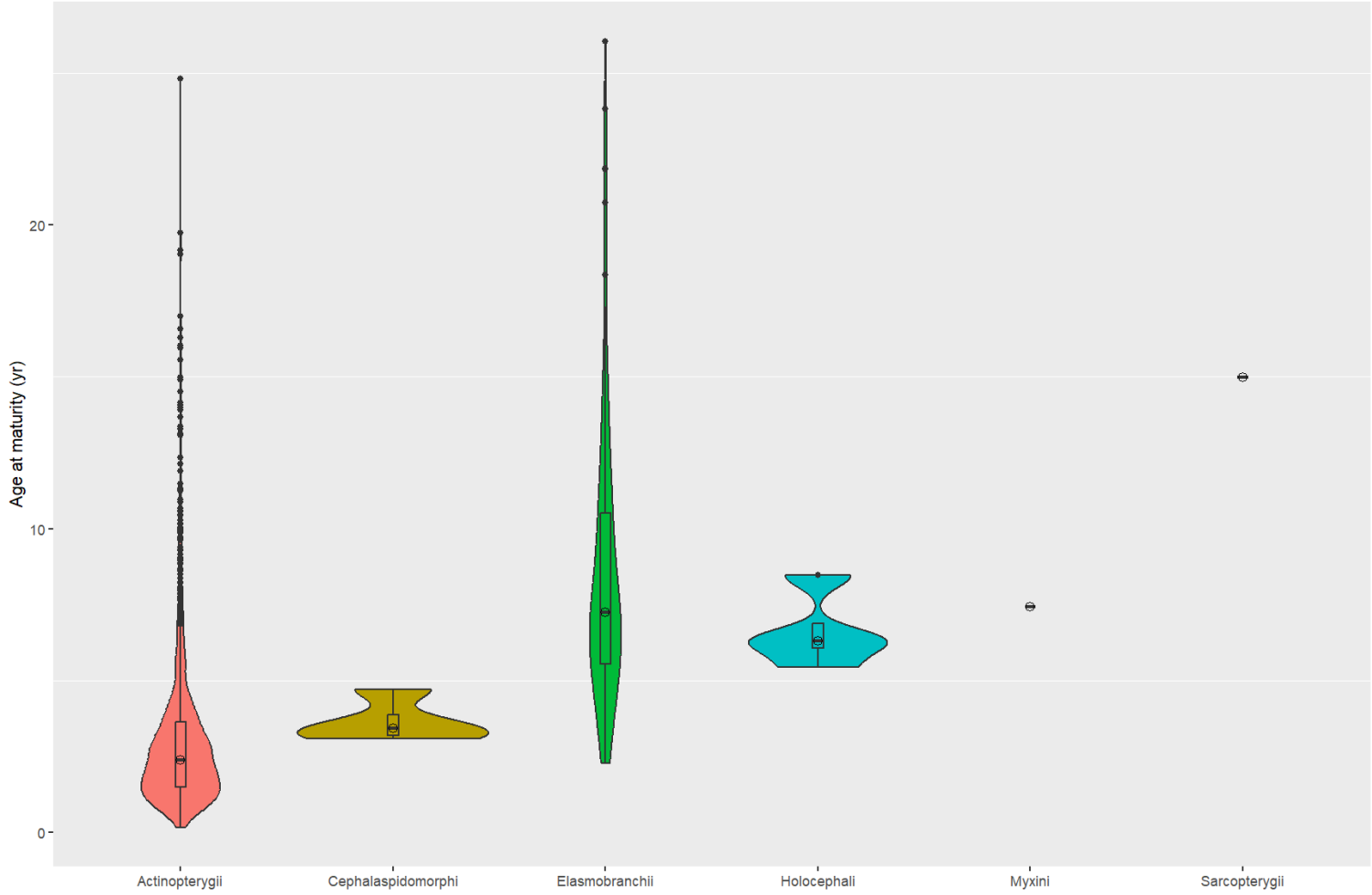
Identifying vulnerable aquatic species based on life history traits (all studies combined)

k t_{mat} t_{max} fecundity



Taxon	Productivity			
	High	Medium	Low	Very low
Sharks	0.03	0.20	0.45	0.32
Batoids	0.07	0.30	0.46	0.17
Teleosts	0.22	0.52	0.23	0.02
Decline threshold	99%	95%	85%	70%

Example distributions of life history traits (age at maturity) for classes of fishes

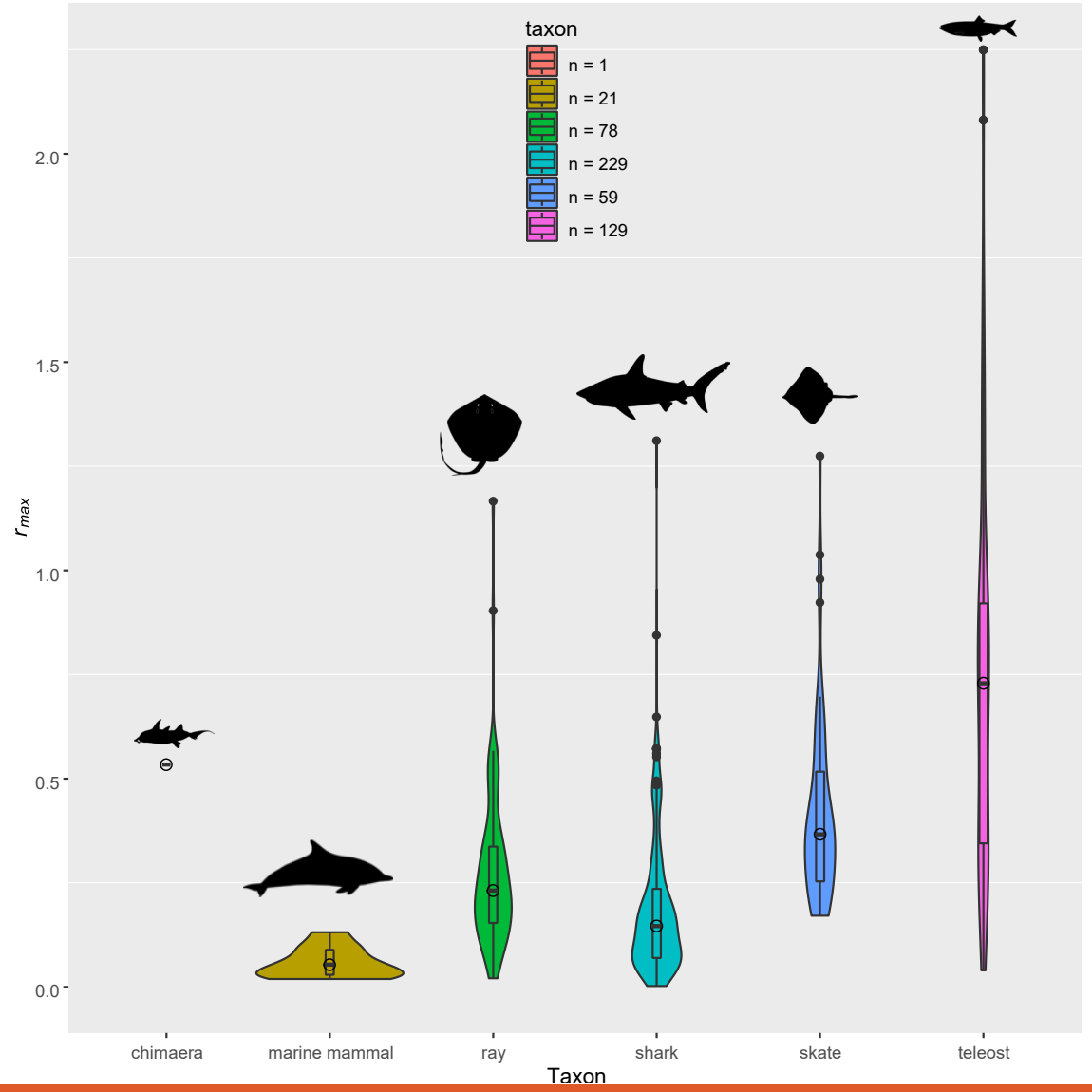


(data from Thorson et al. (2023) extracted from FishBase)

Identifying vulnerable aquatic species based on r_{max} (all studies combined)

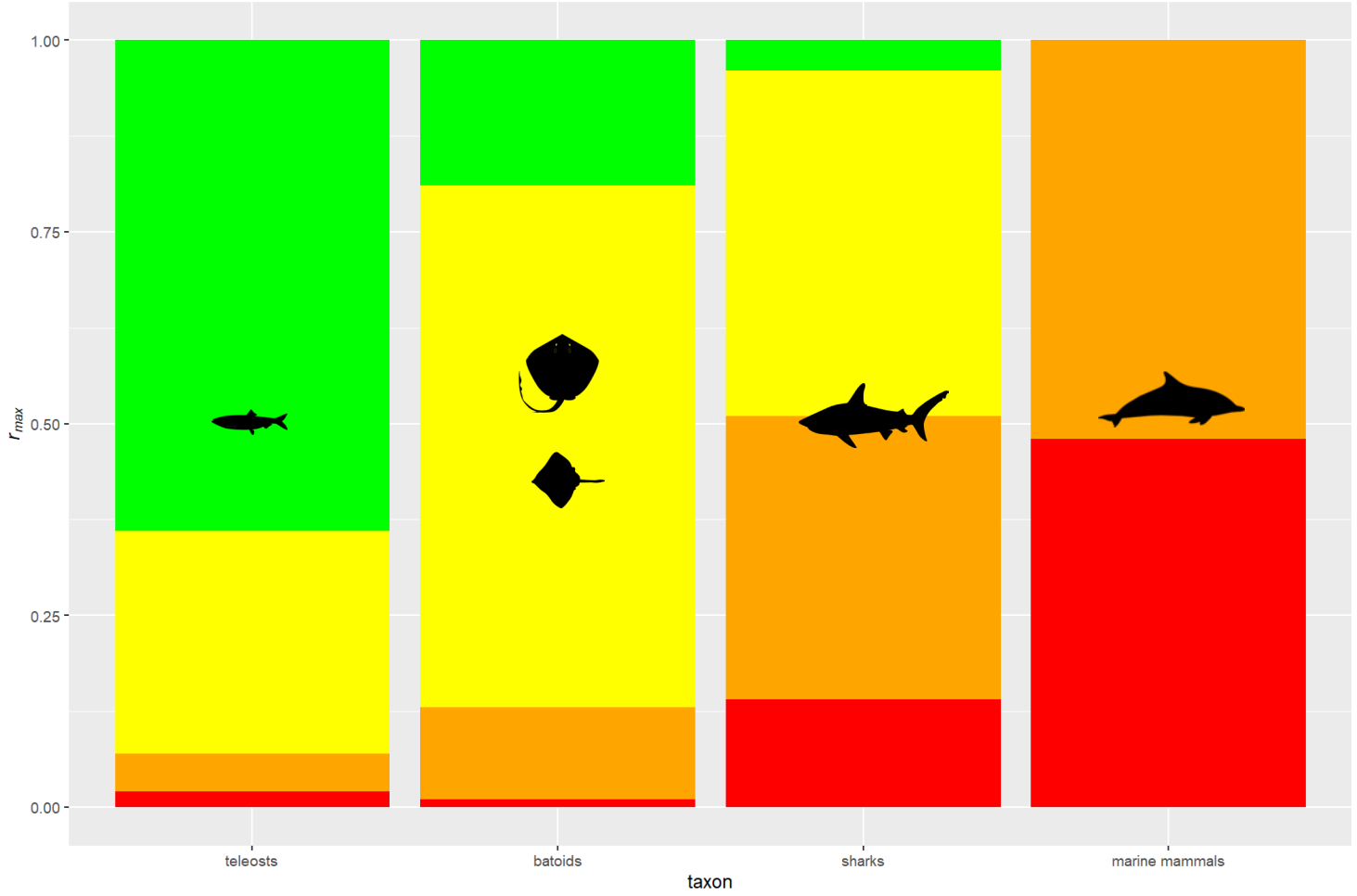
Taxon	Productivity			
	High	Medium	Low	Very low
Sharks	0.04	0.45	0.37	0.14
Batoids	0.19	0.68	0.12	0.01
Teleosts	0.64	0.29	0.05	0.02
Marine mammals	0.00	0.00	0.52	0.48
Decline threshold	99%	95%	85%	70%

Distributions of productivity (r_{max}) for sharks, skates, rays, chimaeras, teleosts, and marine mammals



(data from Cortes (2016) augmented, Barrowclift et al. (2023), Gravel et al. (2024), and Finucci et al. (2024))

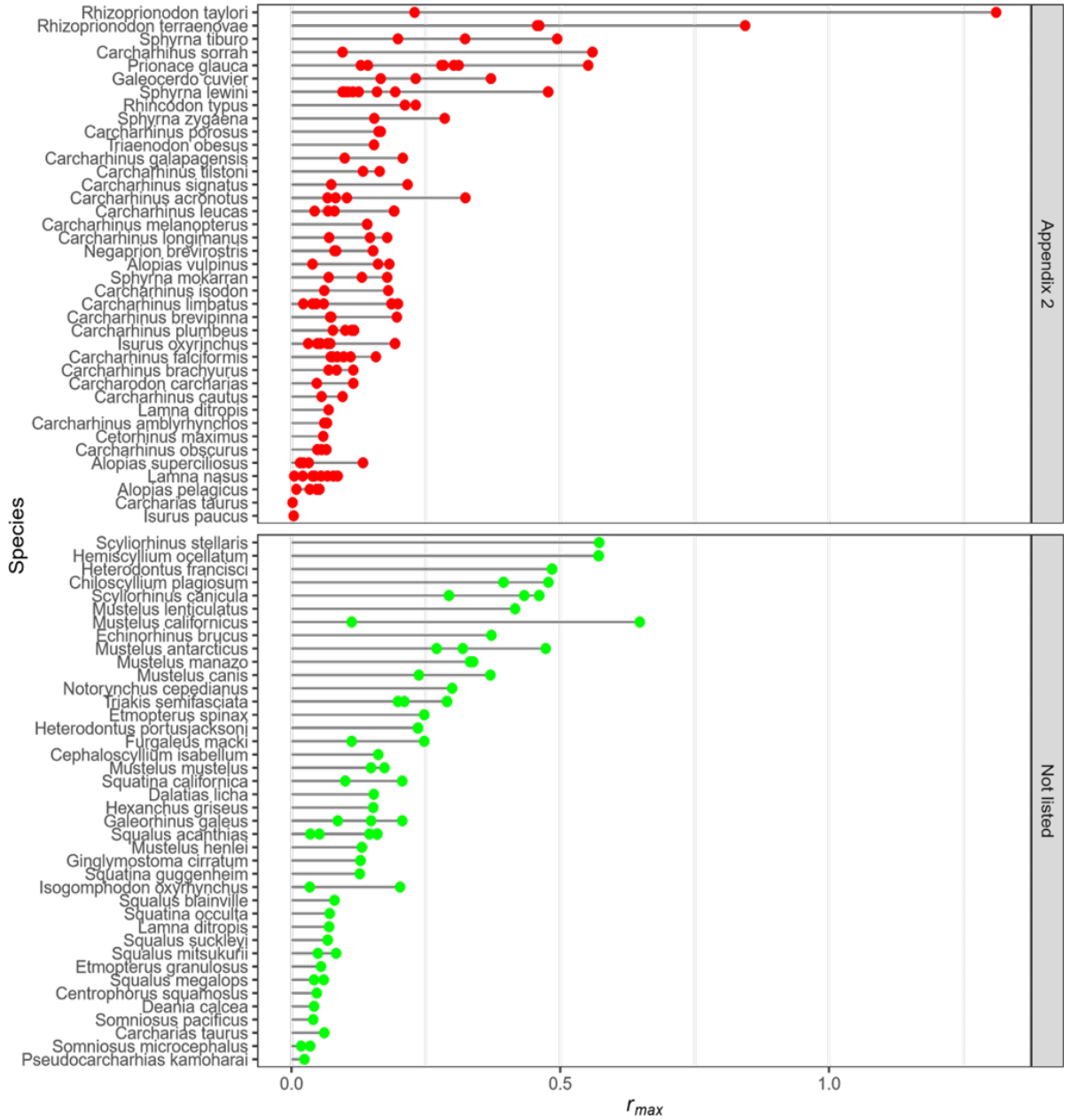
Classification of productivity into four categories (high, medium, low, and very low) according to the criteria for r_{max} from Musick (1999) for several taxa and the corresponding potential decline thresholds



Productivity	Decline threshold
High	99%
Medium	95%
Low	85%
Very low	70%

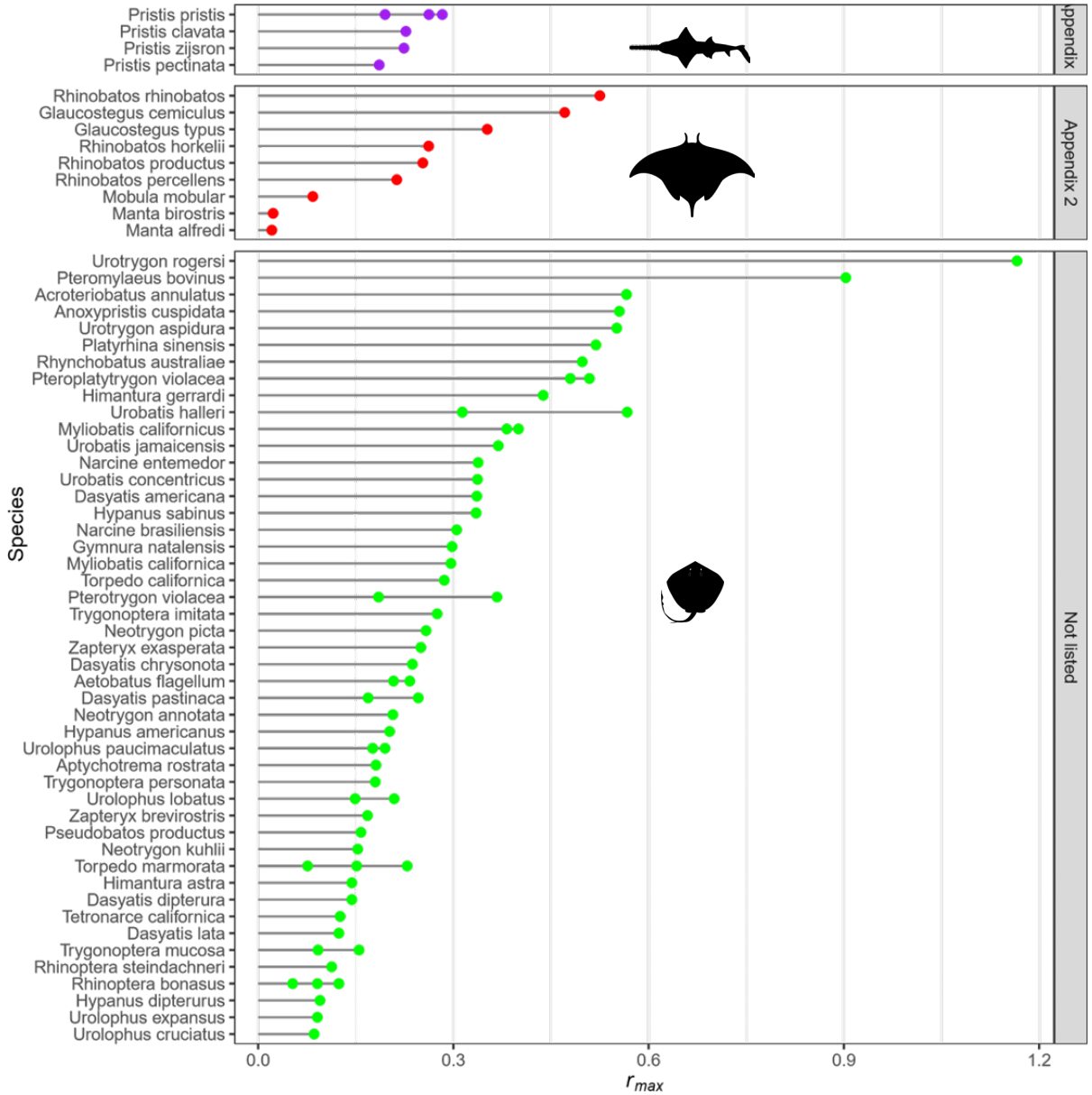
Productivity (r_{max}) for sharks (data from multiple studies) according to CITES listing

n = 227



Productivity (r_{max}) for batoids (data from multiple studies) according to CITES listing

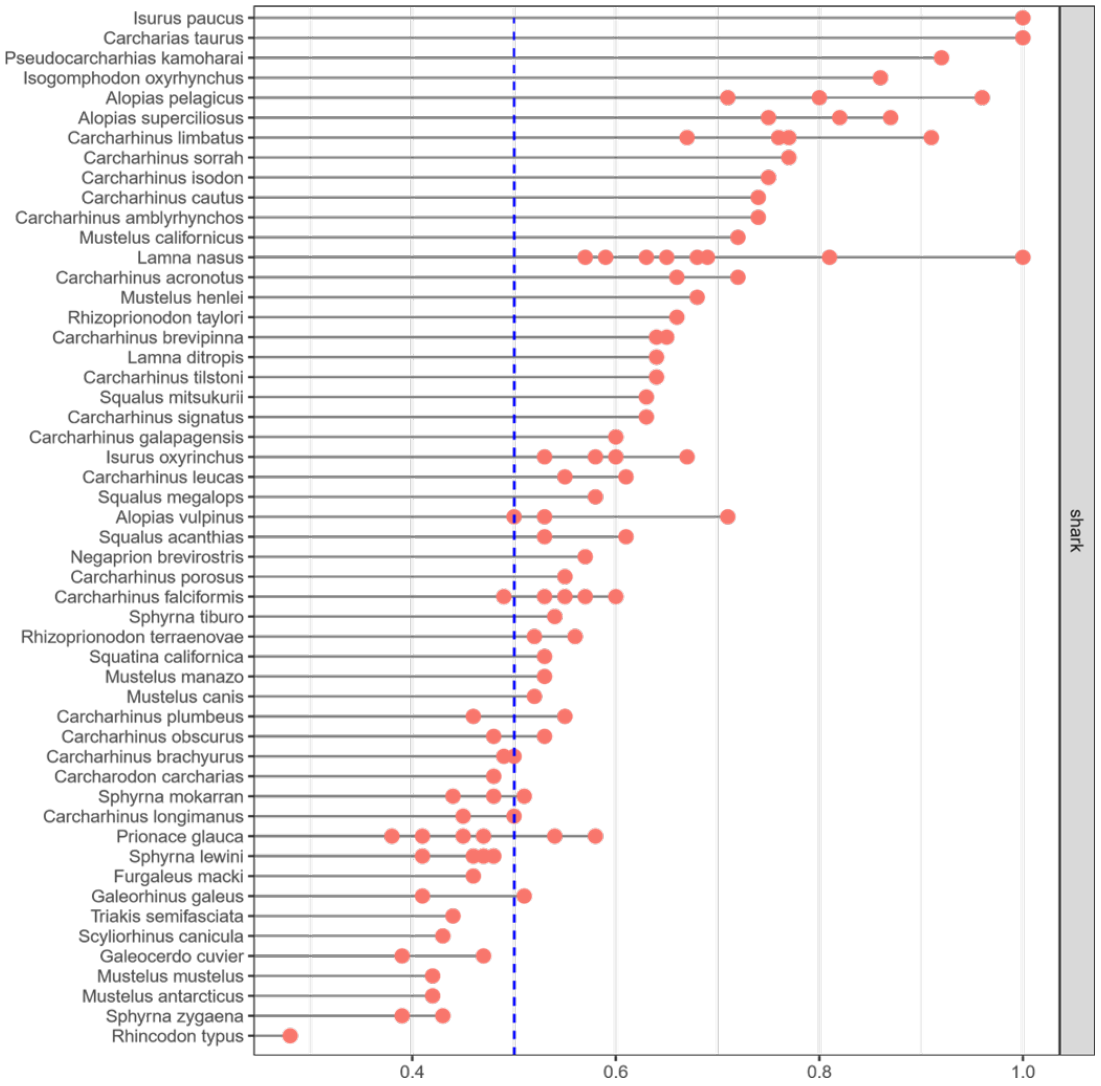
n = 78

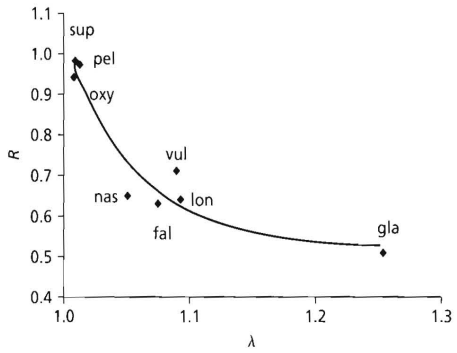


Position of the inflection point of population growth curves (R) for sharks

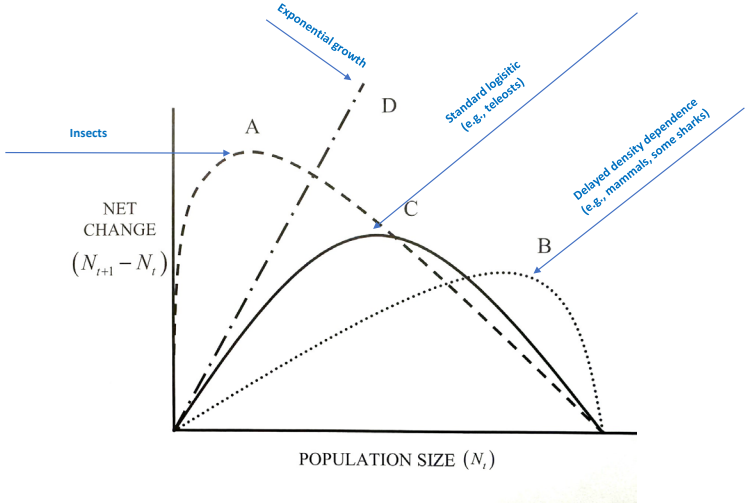
n = 101

(data from Cortés (2016) augmented)





From Cortes (2008)



Modified from Skalski et al. (2005)

Conclusions and challenges

- Elasmobranchs exhibit very wide variability in life history traits and associated productivity, which translates into a continuum of values
- While elasmobranchs tend to be less productive, there is considerable overlap with teleosts, in particular between skates and teleosts
- Based on recent studies and using Musick's (1999) productivity classification, only a small proportion of batoids would fall in the "low" and "very low" categories and about half of sharks would fall in those categories
- Other measures of productivity/vulnerability used in fisheries also show a continuum of values determined by the life history traits of each population
- Since "one-size-does-not-fit-all" it is challenging to group all sharks and rays into a single entity for management purposes

Additional slides

Outline of presentation (2)

- Brief background on life history of cartilaginous and bony fishes
- Variability in life history traits of elasmobranch and other fishes
- Factors affecting the estimates of life history traits and parameters
- Life history patterns and strategies of elasmobranchs and bony fishes
- Comparison of life history traits of elasmobranchs and other fishes
- Identifying vulnerable aquatic species
- Decline thresholds
- Other measures of productivity and vulnerability, and associated management reference points in elasmobranchs
- Conclusions and challenges

Factors affecting the estimates of life history traits

- Most widely accepted views of the life history of elasmobranchs come from a small subset of species globally

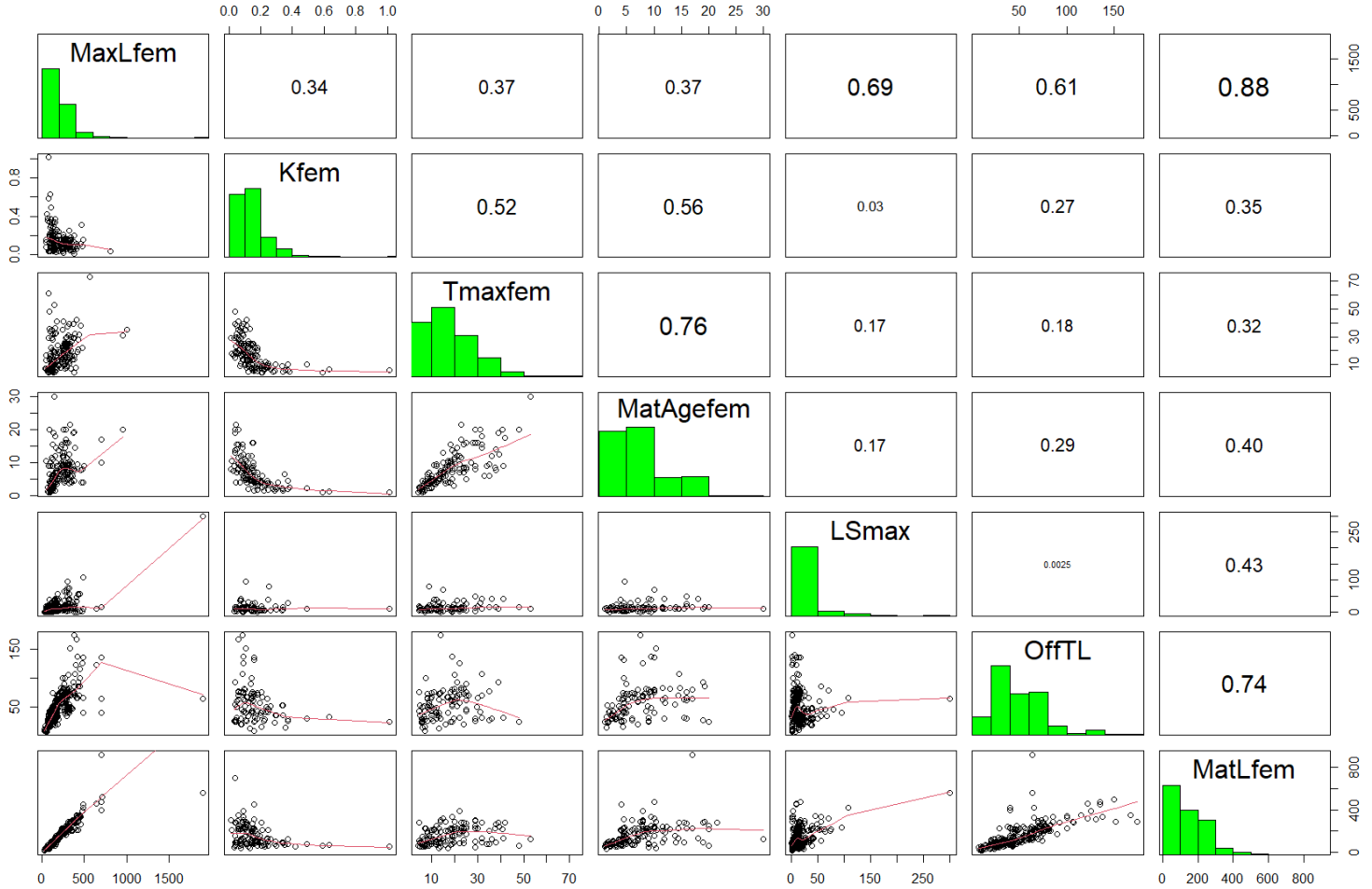
- There is inherent uncertainty associated with the measurement and estimation of life history traits, which affects their comparison

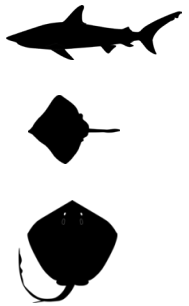
- Main factors that can affect this comparison include:
  - Sampling bias, gear selectivity
  - Measurement technique
  - Analytical method
  - Density-dependent responses
  - Geographic variability and phenotypic plasticity
  - Species distribution
  - Degree of research effort

Life history patterns of elasmobranchs (and bony fishes)

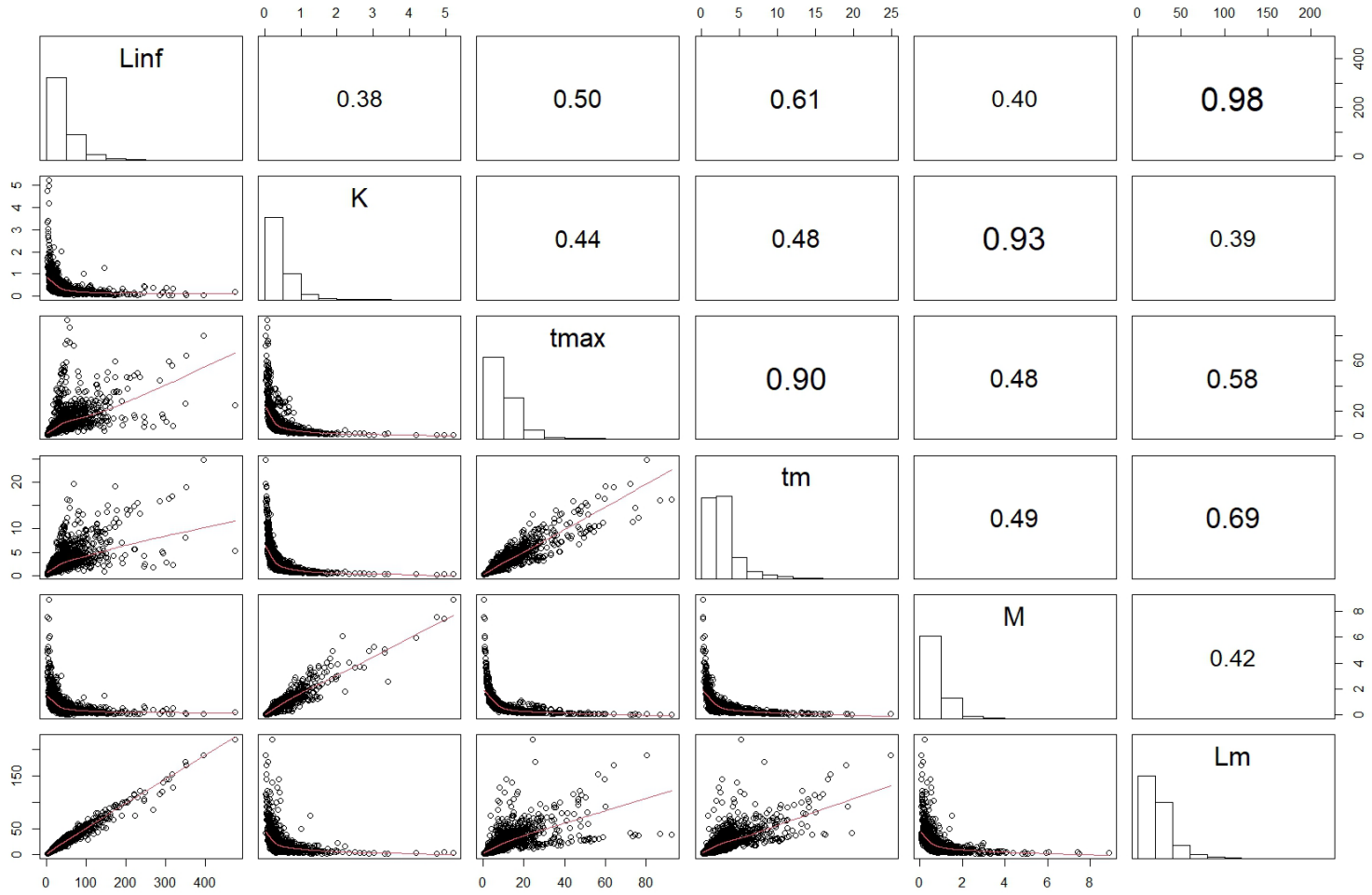
1. The bigger you are, the more offspring you have
2. The bigger you are, the larger your offspring are
3. The more offspring you have, the smaller their relative size
4. The faster you grow, the smaller your maximum size and the shorter your lifespan
5. The shorter your lifespan, the earlier you must breed
6. The quicker you die (high natural mortality), the shorter your lifespan

Scatter plot matrix of life history parameters of sharks and batoids

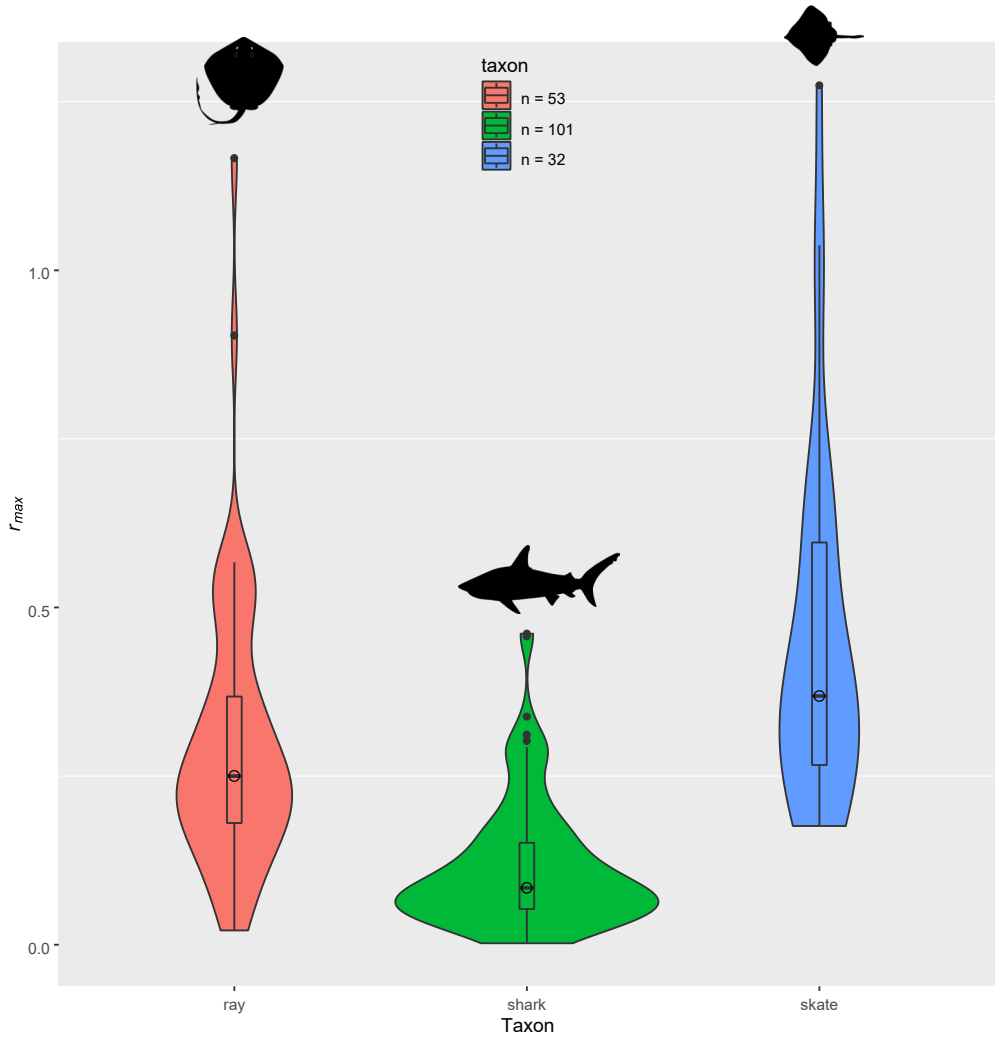




Scatter plot matrix of life history parameters of teleosts

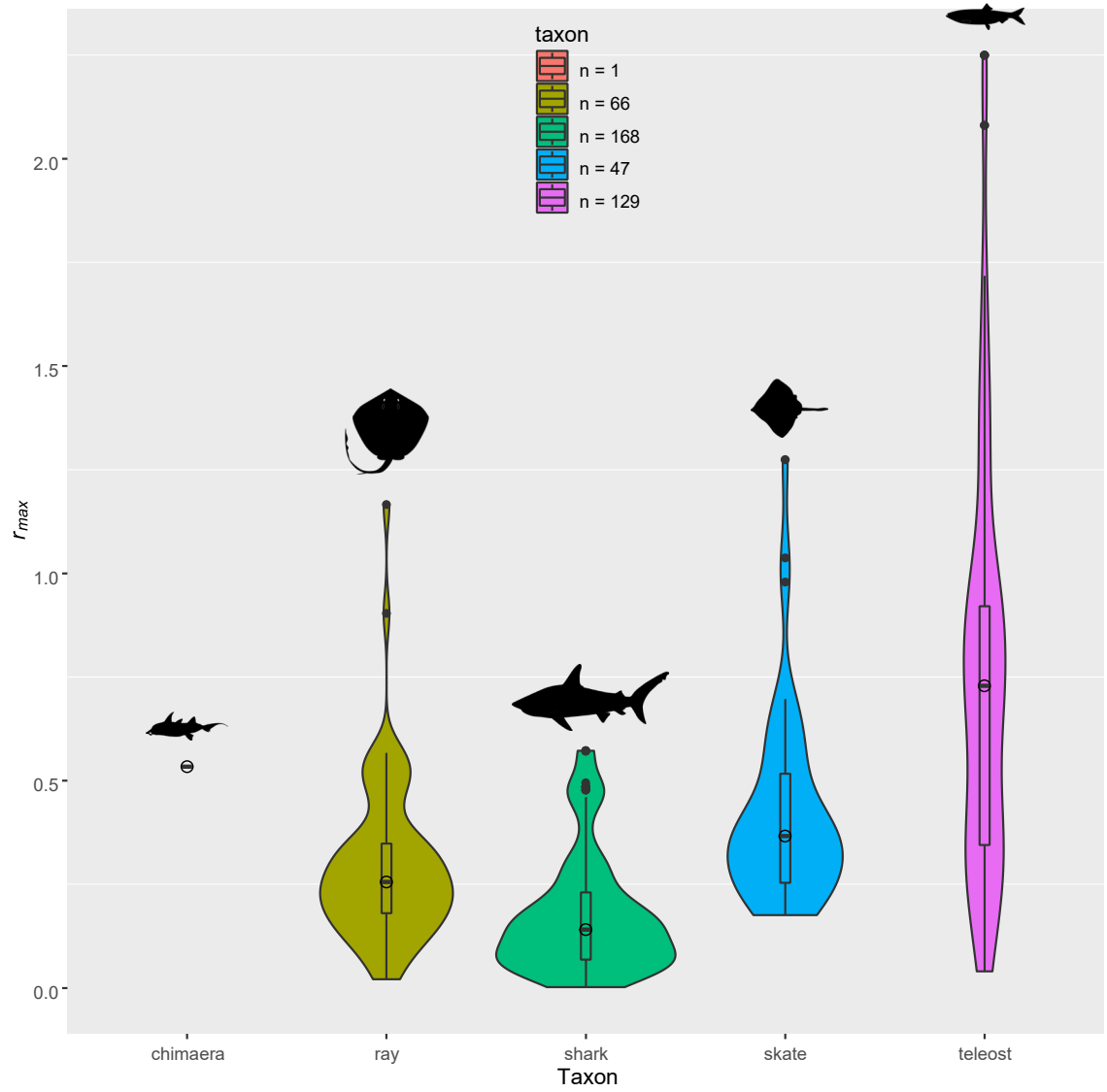


Distributions of productivity (r_{max}) for sharks, skates, and rays



(data from Cortes (2016) augmented and Barrowclift et al. (2023))

Distributions of productivity (r_{max}) for sharks, skates, rays, chimaeras, and teleosts



(data from Cortes (2016) augmented, Barrowclift et al. (2023), and Gravel et al. (2024))

Other measures of productivity and vulnerability, and associated management reference points

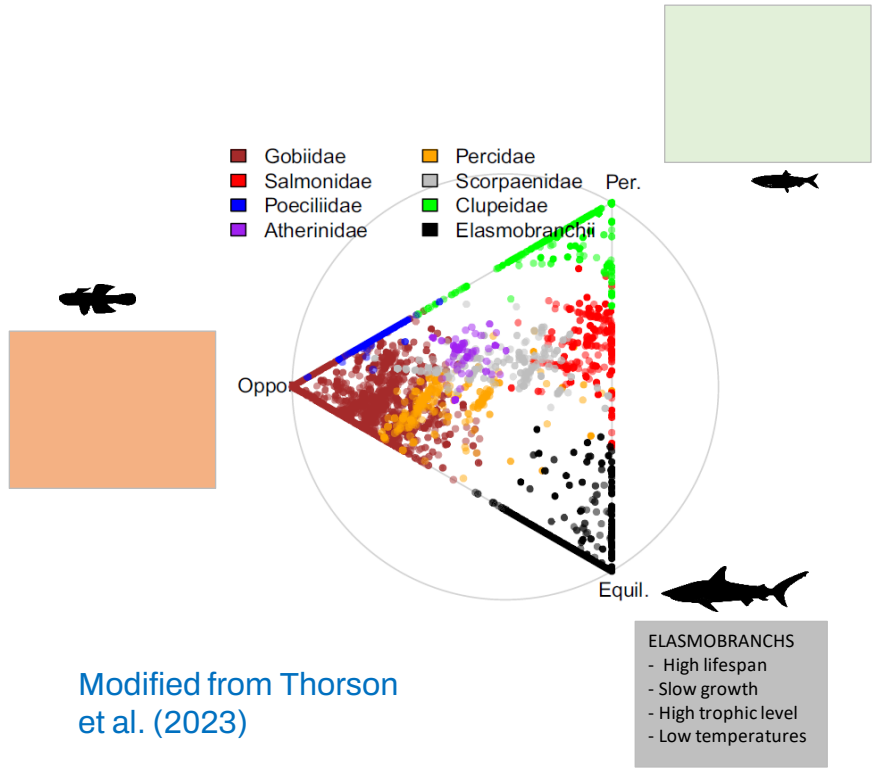
- r_{max}: intrinsic rate of increase (maximum population growth rate in ideal conditions after exploitation has ceased)
- **Maximum lifetime reproductive rate** ($\hat{\alpha}$): number of spawners produced by each spawner over its entire lifetime (ranges from 1 to infinity)
- **Steepness**: ratio between recruitment when spawning stock size has been reduced to 20% of virgin conditions and recruitment in virgin conditions. Another measure of productivity used in fisheries, ranges from 0.2 to 1, uses $\hat{\alpha}$ in its computation (the lower, the less exploitation permitted)
- SPR_{MER}: analogous to steepness (inversely related). Ratio between the number of spawners produced over a recruit's lifetime (given F) and the number of spawners produced without fishing (the closer to 100% the less exploitation permitted)
- **R**: analogous to SPR_{MER}. Position of the inflection point of population growth curves (assumed to be 0.5 in traditional production models): the closer to 1, the less exploitation permitted

Some life history strategies (how to cope with neonate and juvenile mortality)

Litter size	Offspring size	Body size	Growth	Lifespan	Example
large	small	mid to large	mid to slow	substantial	Blue shark
small	large	large	slow	high	Dusky shark
small	small*	small to mid	fast	low to mid	Atlantic sharpnose shark

* but born at high % of adult maximum size and reach maturity quickly

From Cortes (2000)



Modified from Thorson et al. (2023)