# Adapting Pacific salmon management systems to an increasingly warm and crowded ocean

IYS Synthesis Symposium
October 5, 2022

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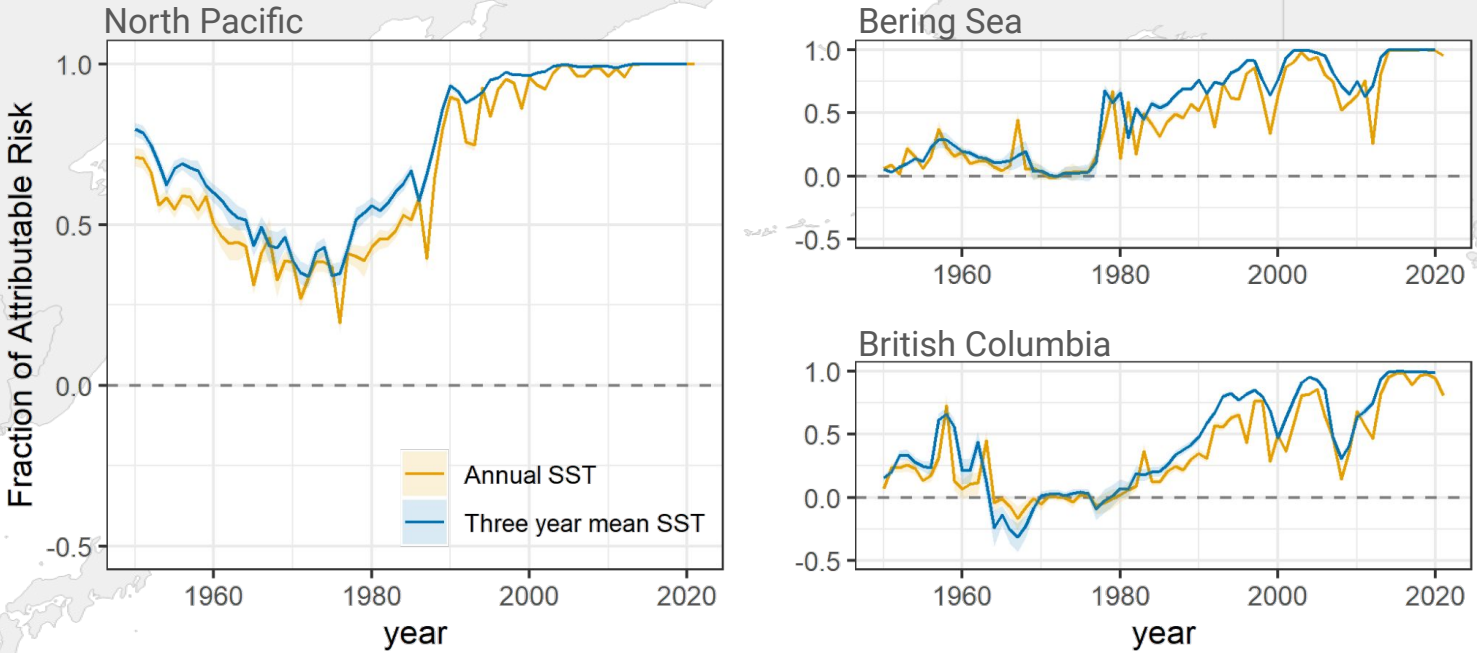
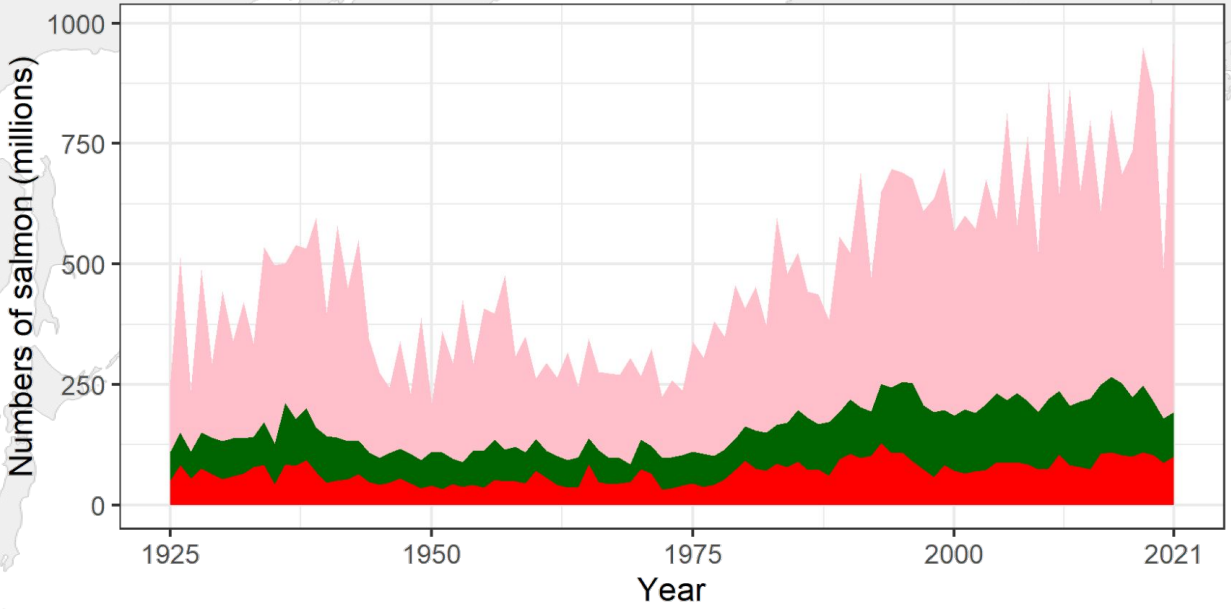
# The North Pacific is getting warmer, in large part due to Climate Change




FAR = 1 - (preindustrial probability / current probability)

Litzow et al. unpublished

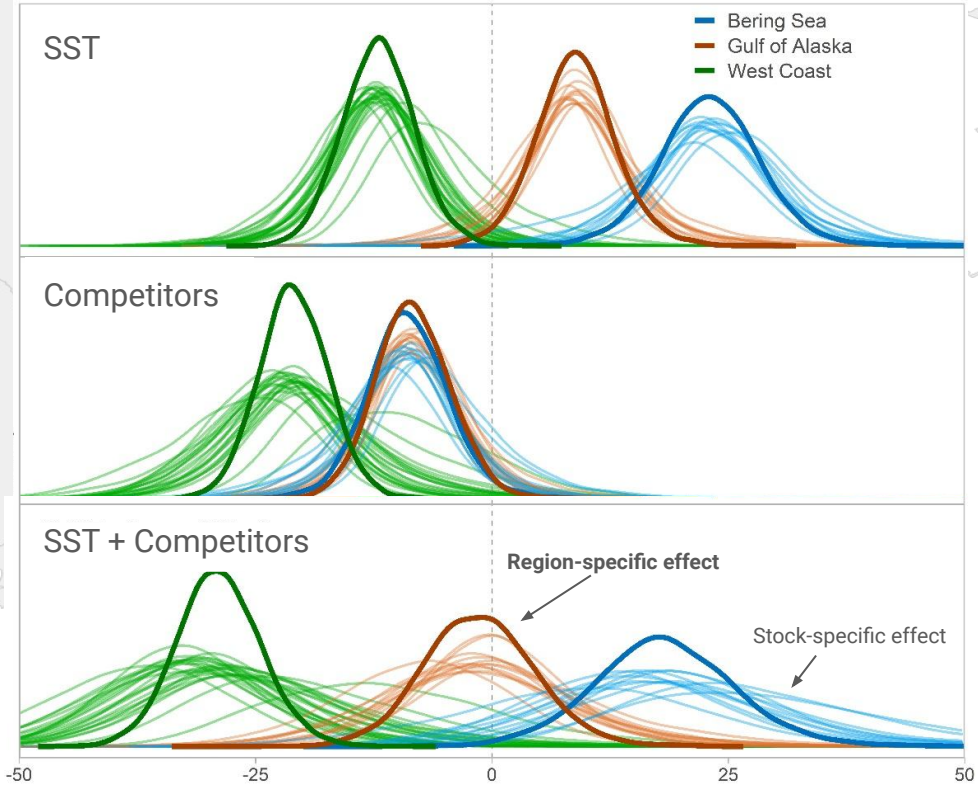
# On average, there are more salmon in the North Pacific now than anytime in past century

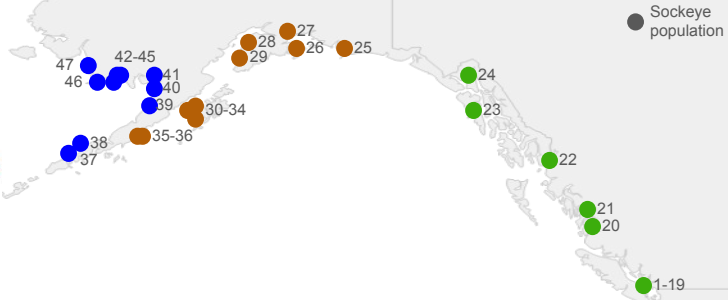



Approximately 20% of production is hatchery origin, in recent years

Ruggerone and Irvine 2018, updated through 2021

# Responses to warming and competition vary in space…



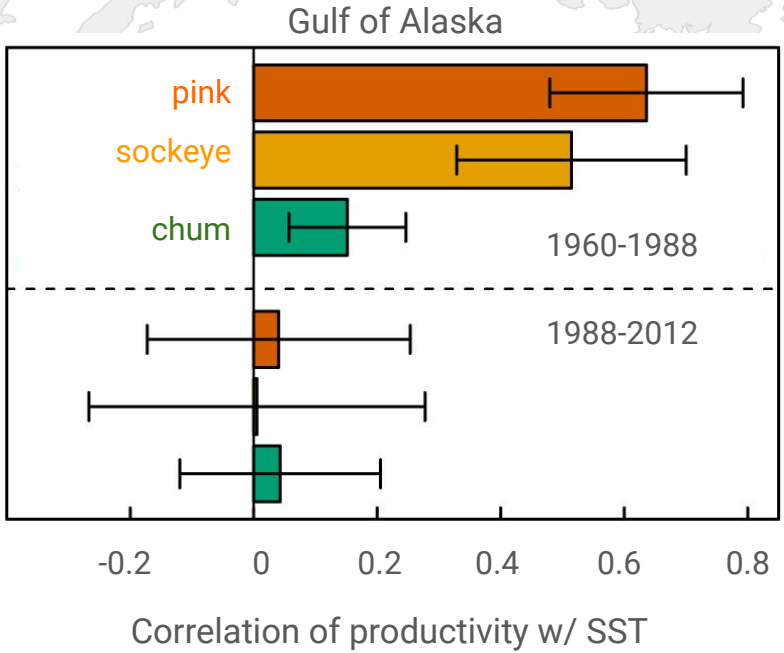




**SST** = at marine entry

**Competitors** = North Pacific pink salmon abundance in second year at sea

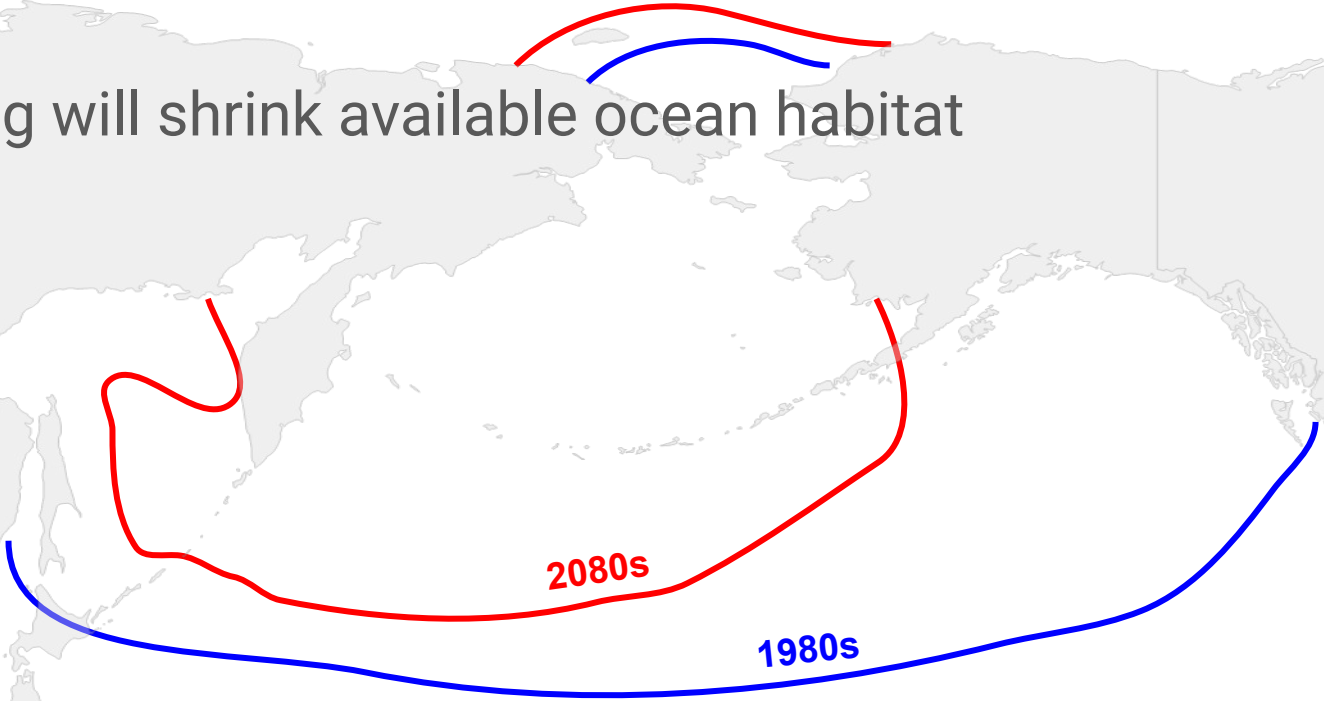
Connors et al. 2020

# Responses to warming and competition vary in space… and time




Litzow et al. 2018

# Warming will shrink available ocean habitat

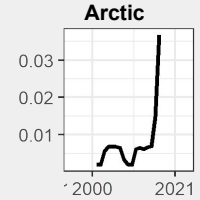


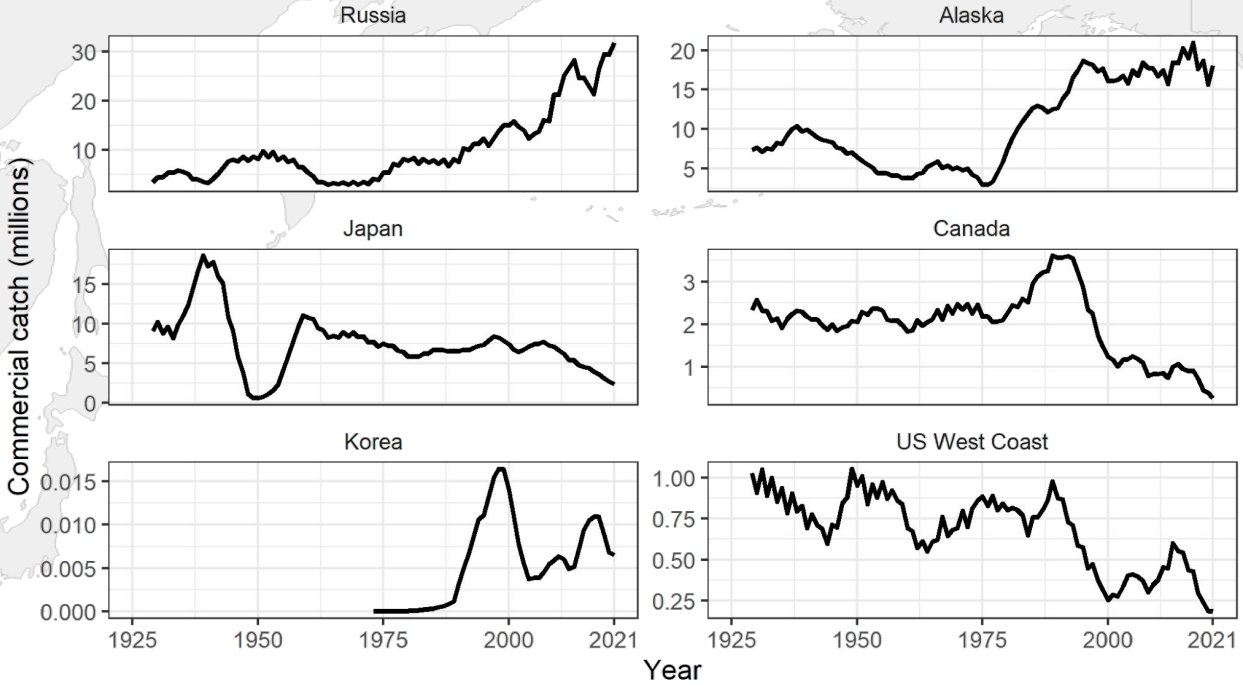

Summer (thermal) habitat projected to shrink by up to 52% for sockeye under business as usual climate model scenario



Adapted from Abdul-Aziz et al. 2011

# Warming contributes to more (new) fishing opportunities in the north, but fewer in the south

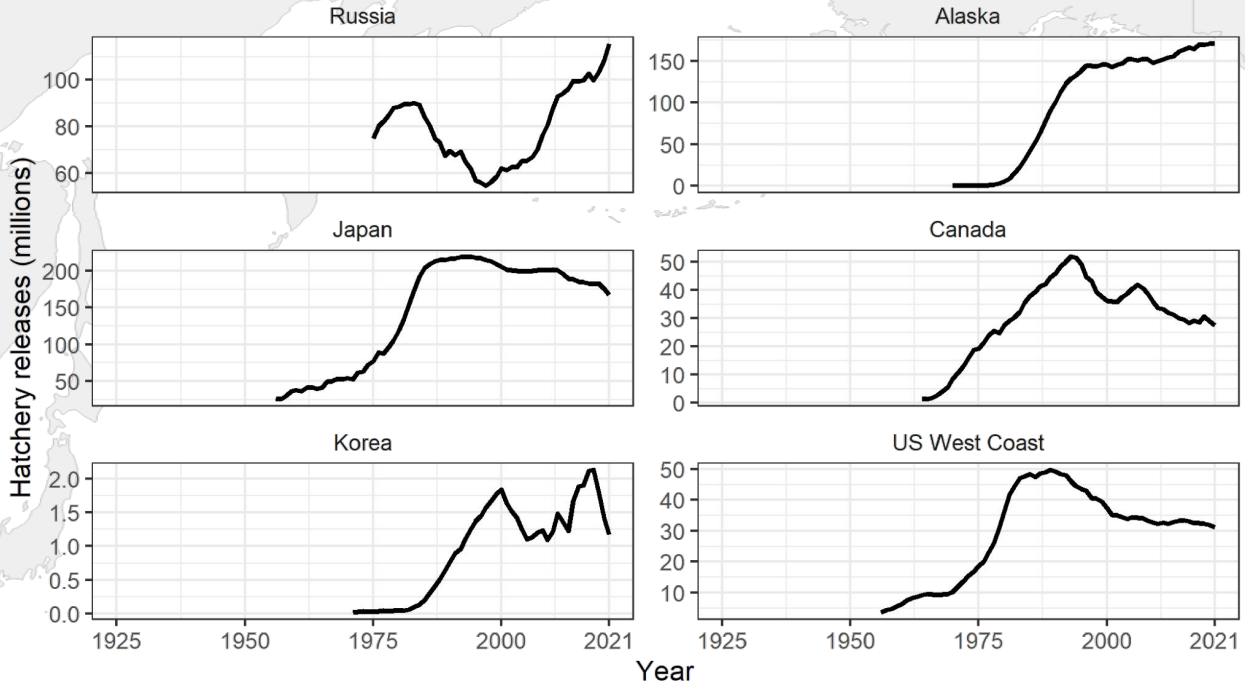


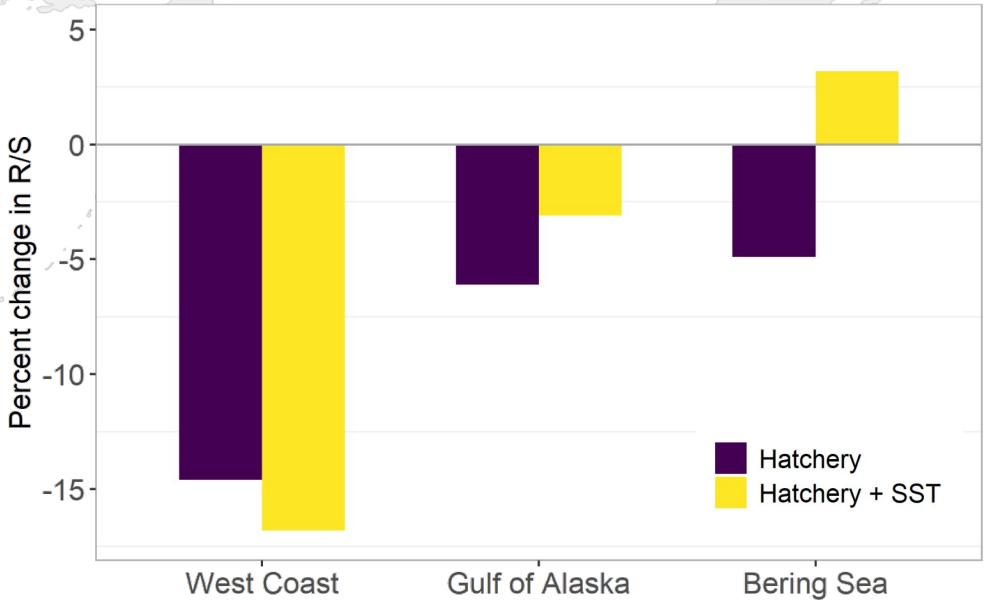



NPAFC 2022a; Dunmall et al. 2018

# Warming favours hatchery marine survival in north…



# … but increasing hatchery production may exacerbate conservation risks and curtail fisheries in the south






Connors et al. 2020

# Should salmon nations cooperatively manage, and consider limiting, hatchery production as ocean warms?

- Has been suggested several times in the past*, stronger evidence has accumulated in recent decades

- But remaining knowledge gaps limit scientific consensus on role of inter- and intraspecific competition and its effects on marine growth and survival:
  - distribution of salmon at sea in response to both warming and competitive interactions
  - population and ecosystem factors that mediate responses
  - proximate mechanisms underlying apparent competition effects

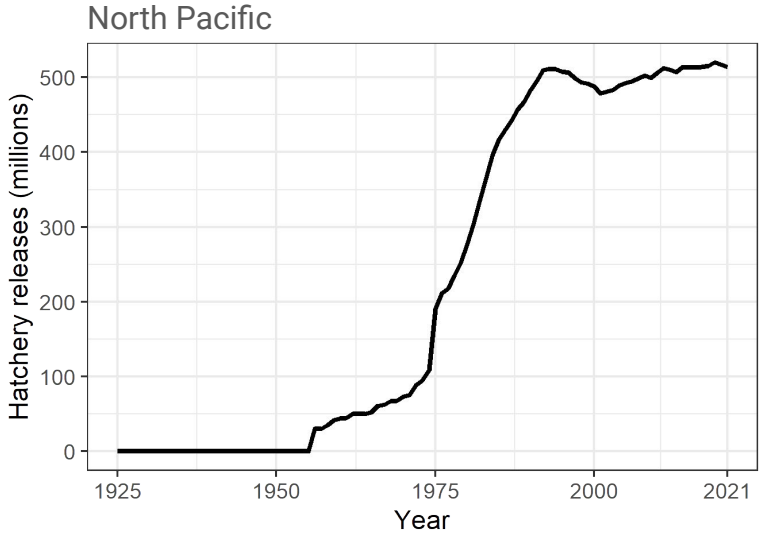


*Peterman 1984, Heard 1998; Holt et al. 2008; Peterman et al. 2012

# Overcoming knowledge gaps requires increased cooperation and coordination

- Targeted research on salmon at sea
- Comparative and process based studies
- Experimental manipulation of hatchery production, funded (in part) through a hatchery tax?

A tax of 0.1¢/fish = ~ $5.15 M / yr



# Take home messages

- In general a warming ocean negatively affects salmon growth and survival at southern latitudes, but positively at northern ones
- Evidence of competition is more pronounced at southern latitudes, potentially because warming partially offsets effects in northern ones
- Salmon production will (and already has) shift(ed) north, creating new/more opportunities for harvest, but may face a climate “squeeze”
- Knowledge gaps limit consensus and action, a hatchery tax might help reduce them
- Improved communication and collaboration across salmon nations key to balancing the benefits AND risks of a warming and more crowded ocean

# Literature cited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