Fishing Capacity and Efficient Fleet Configuration for the Tuna Purse Seine Fishery in the Eastern Pacific Ocean: An Economic Approach

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Organization

- 1. Background
- 2. Basic Question
- 3. Basic Approach
- 4. Data
- 5. Results
- 6. Next Step

1. Background…(1)

- ISSF funded
- Analysis in collaboration with IATTC
- IATTC Resolution C2-03 to maintain purse seine capacity at time of resolution
  - 158,000 m^3

1. Background…(2)

- Two Definitions of Capacity Used:
- (1) FAO Capacity = fishing capacity
- (2) IATTC Capacity = well capacity (m^3)
- This analysis excludes FADs on explicit basis, but indirectly accounted for as embodied technical change that shifts efficient production frontier each year

Background…(3)

- Economic efficiency in this study is the maximum possible catch per vessel.

2. Basic Question

Basic Question

- What is the minimum purse seine well capacity (m^3) required to catch specified levels of
  - skipjack, bigeye, and yellowfin tunas
- when vessels maximize potential catches by adjusting their annual vessel days?
- We analyze for each year, 1993-2010
- Essentially a more formal but similar approach to current IATTC approach that gives 158,000 m^3 well capacity.

3. Basic Approach

Two-Stage Analysis

- 1. First Stage
  - All vessels maximize their potential catch to full fishing capacity by adjusting their days
- 2. Second Stage
  - Minimize well capacity required to catch MSYs when vessels are catching at full fishing capacity
  - Subject to total fishing capacity catch for each species summed over all vessels so that for each year:
    - ❖ Yellowfin capacity catch ⩽ MSY
    - ❖ Bigeye capacity catch ⩽ MSY
    - ❖ Skipjack capacity catch ⩽ Observed catch

Data/Model Differentiates by Vessel Size Class & DML

- (1) Classes 2 and 3
- (2) Classes 4 and 5
- (3) Class 6 for vessels not holding DML
- (4) Class 6 vessels holding DML

Data Envelopment Analysis (DEA)

- Linear programming model for each vessel for each year
- Establishes best-practice frontier for vessels of similar size (capacity base)
- Deterministic, not stochastic

First Stage

- 1. Vessels efficiently harvest fishing capacity levels of catch
  - By adjusting days at sea given measures of vessel size (capacity base)
  - Remove technical efficiency (skipper skill) from capacity catch level
    - Because largely constant between vessels
  - Vessel-level data
  - Control variables of biomasses and sea surface temperature

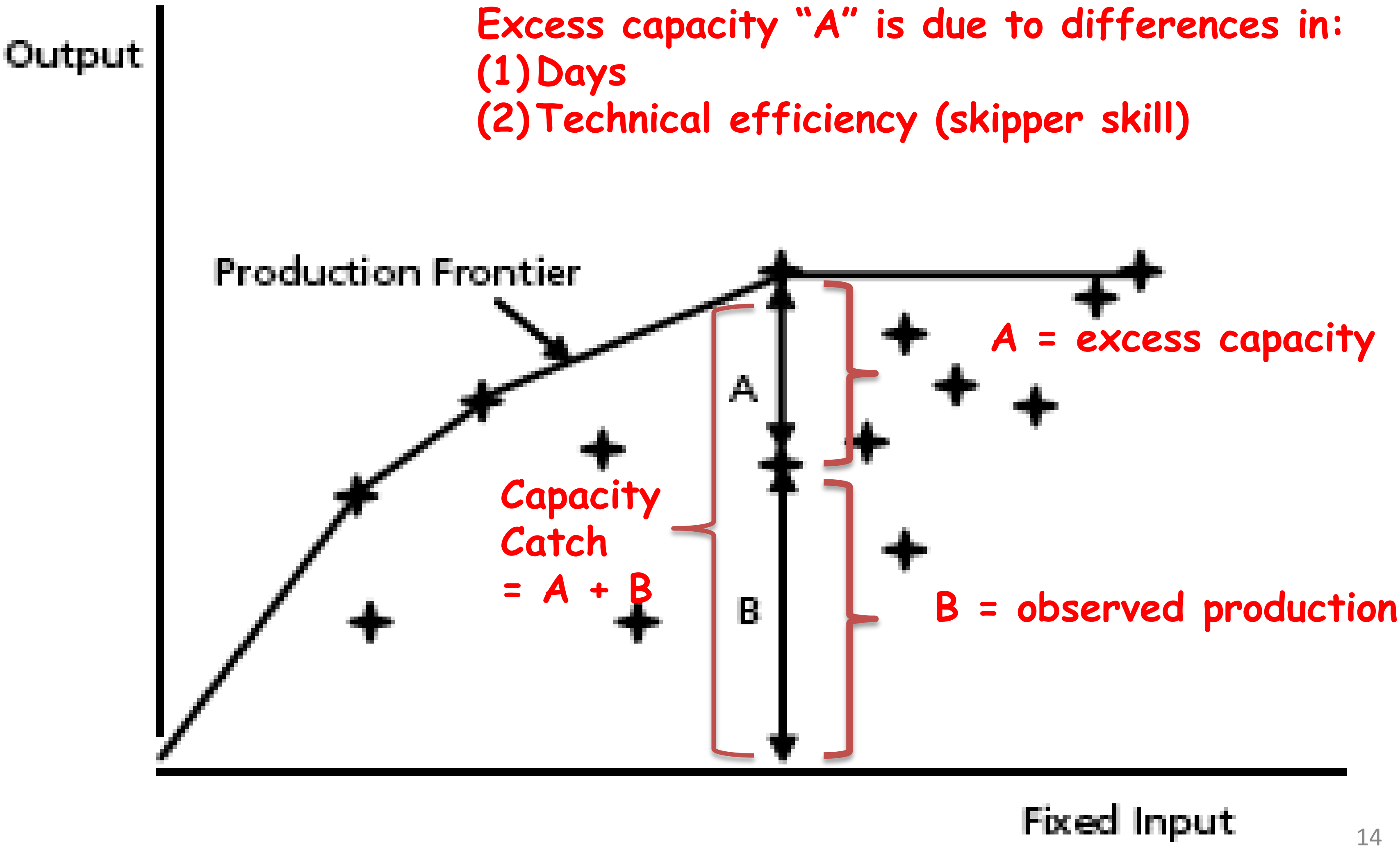
Second Stage

- 2. Given capacity catch per vessel, what is minimum well capacity required?
  - After requiring total catches ⩽ MSYs for bigeye and yellowfin and observed total catch for skipjack.
- Intuition
  - Most efficient vessels should be kept in the fleet
  - Inefficient vessels should be either removed or their operations scaled back subject to maintaining total production (MSYs).

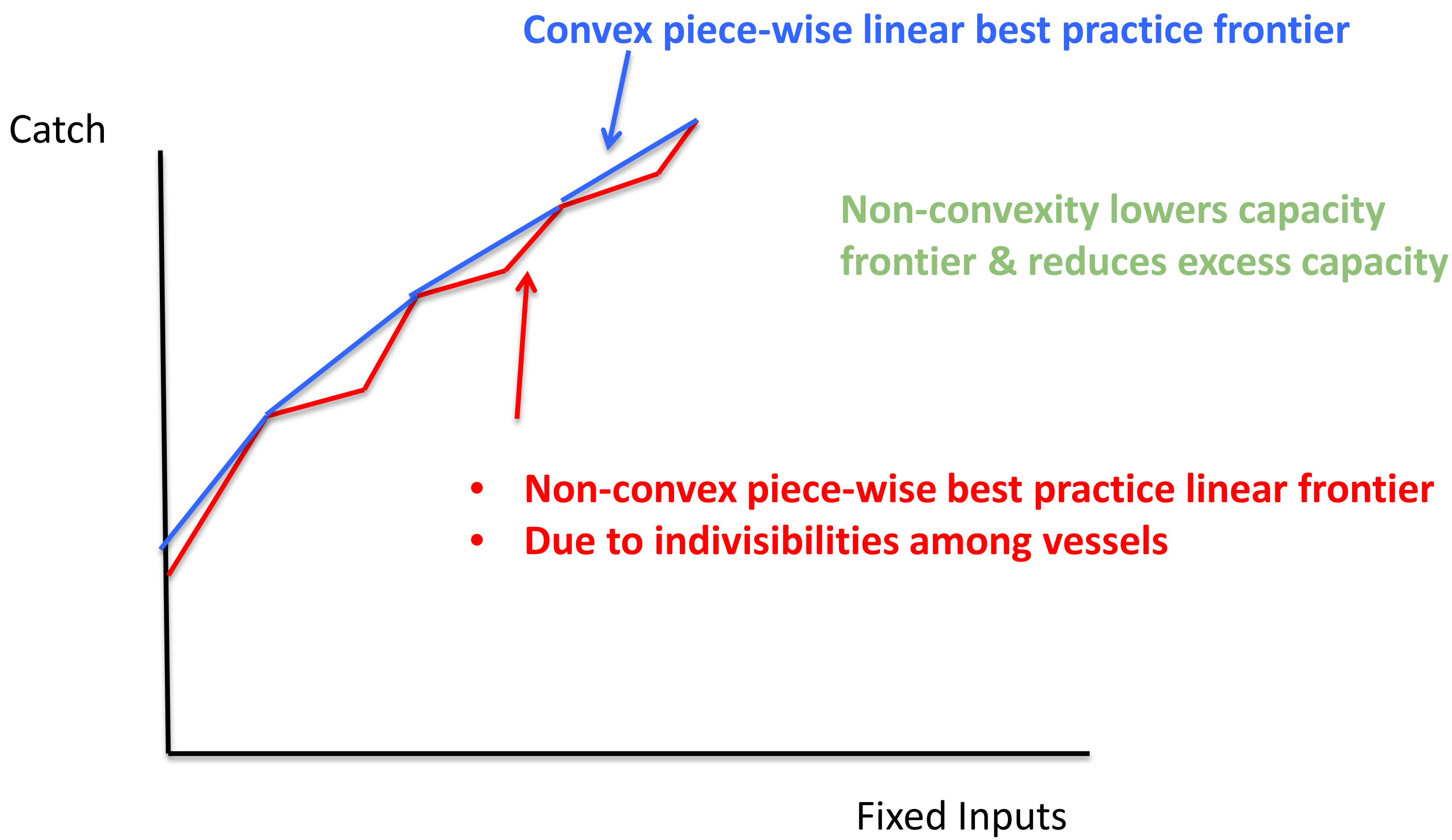
FAO Technical Notion of Fishing Capacity for First Stage

- "Fishing capacity is the maximum amount of fish over a period of time (a year or season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of technology. Fishing capacity is the ability of a vessel or vessels to catch fish (FAO 1998, 2000)."

FIGURE 2.1
Data envelopment analysis



Non-Convex Frontier



- Non-convex piece-wise best practice linear frontier
- Due to indivisibilities among vessels

Sources of Non-Convexities

- Non-convexities due to lumpy (discrete) fixed factors
- Non-convex frontier
  - Best-practice catch capacity frontier not piece-wide linear, but like step function
  - Lowers capacity frontier & hence first-stage excess capacity
- Fleet divided into:
- (1) DML & non-DML holders
- (2) Vessel size classes

Day Restrictions

- Model also compares three different day restriction policies as X% of observed days for each vessel:
- (1) 80% (least restrictive)
- (2) 70%
- (3) 60% (most restrictive)
- Below 60%, vessels could not catch MSYs

4. Data

IATTC Data

- Annual vessel-level purse seine data from EPO tuna purse seine fishery for 1993-2010.
- Landings (mt retained catch) for yellowfin, bigeye, & skipjack tunas.
- Vessel gross tonnage and other measures of vessel size
  - cubic meters of well capacity, net weight, or length, weight, & depth in meters, engine size
- Trip lengths (days, arrival date minus departure date for trip), & number of sets.

5. Results

Year-by-Year Estimation

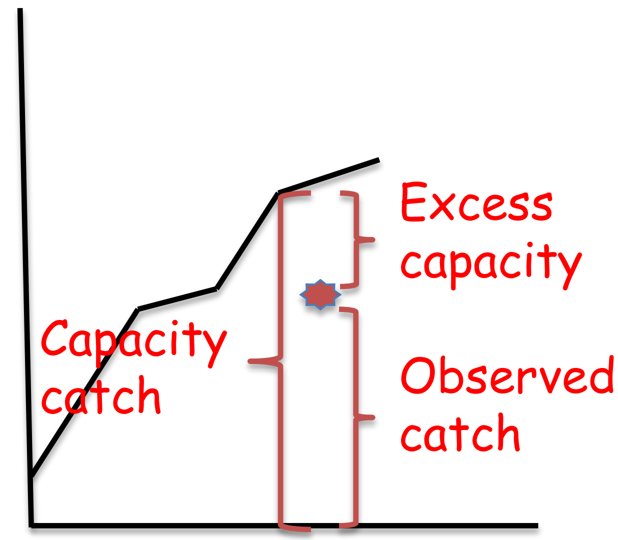
- <u>Accounts for Changes in</u>:
- Biomass,
- TACs/MSYs,
- Environmental conditions,
- Market conditions,
- Technology,
- FAD numbers & design,
- Total days fished.
- Regulations (e.g. closures),
- No steady-state equilibrium, follows IATTC practice of periodically re-evaluating TACs

First Stage Results: Average Capacity Utilization

- Capacity utilization (CU):

Observed catch/fishing capacity catch

- All vessels: 86%
  - Total fish catch could be increased by 14% if all vessels operated on best-practice efficient frontier by adjusting days.
- Non-DML vessels: 83%
- DML vessels: 89%



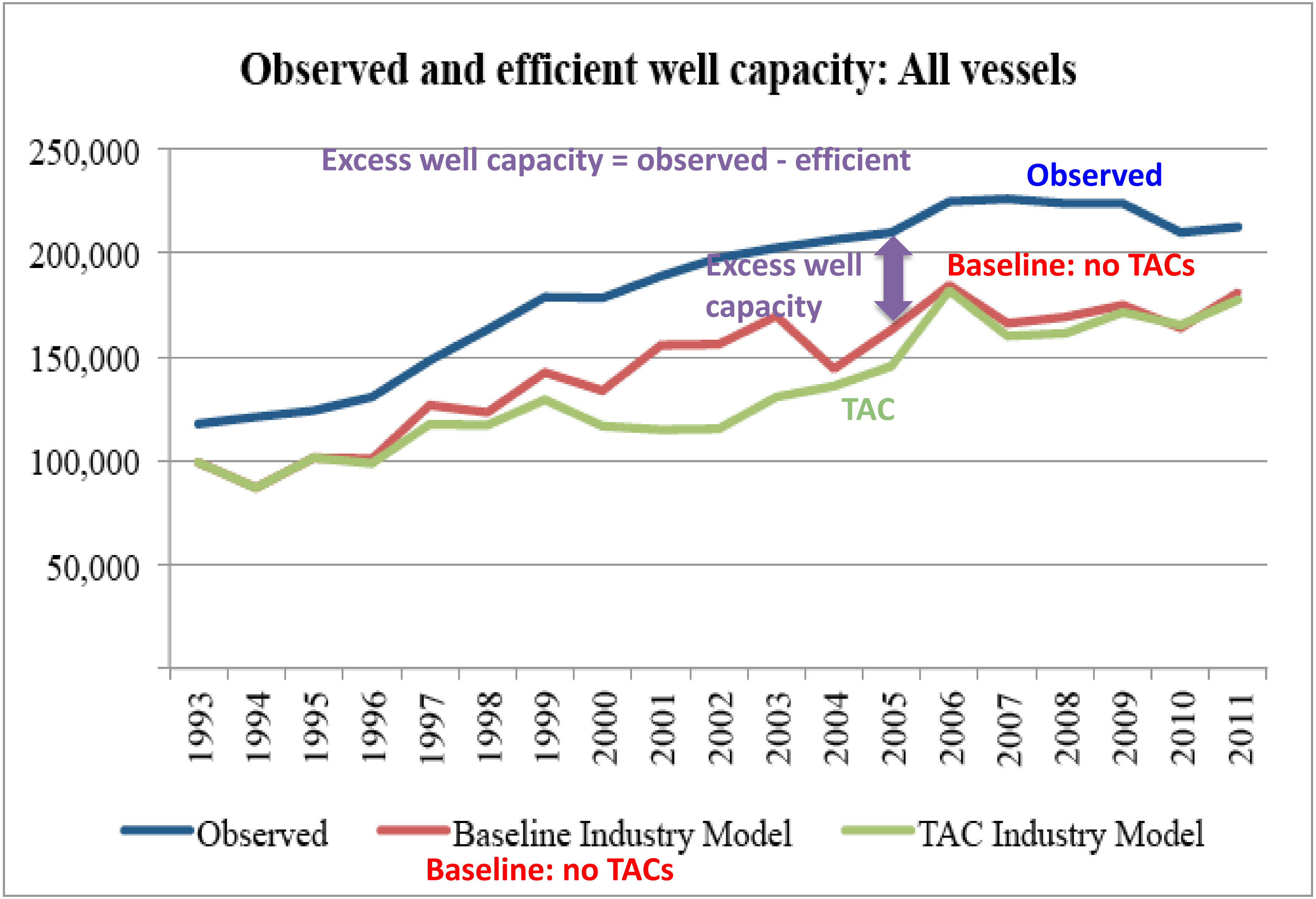
$$CU = \frac{\text{observed catch}}{\text{capacity catch}}$$

Summary of Overall Results

- Average observed level: 219,000 m^3.
- IATTC recommendation: 158,000 m^3.
- Model optimum: 167,000 m^3 !!
  - IATTC did not "reward" us for this result!
  - Due to similarities of approach
- Model indicates:
  - vessel number reductions of 22% to 24%, depending on TAC & catch restriction imposed.
  - m^3 well capacity reductions of 18% to 24%, depending on TAC & catch restriction.

DML vs. Non-DML

- Prior to the year 2000, DML vessels were responsible for the majority of this excess capacity.
- Since 2000, DML and non-DML vessels have each contributed roughly half of the excess capacity.



Observed and efficient well capacity: All vessels
Excess well capacity = observed - efficient
Observed
Excess well capacity
Baseline: no TACs
TAC
250,000
200,000
150,000
100,000
50,000
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed
Baseline Industry Model
TAC Industry Model
Baseline: no TACs

Figure 1

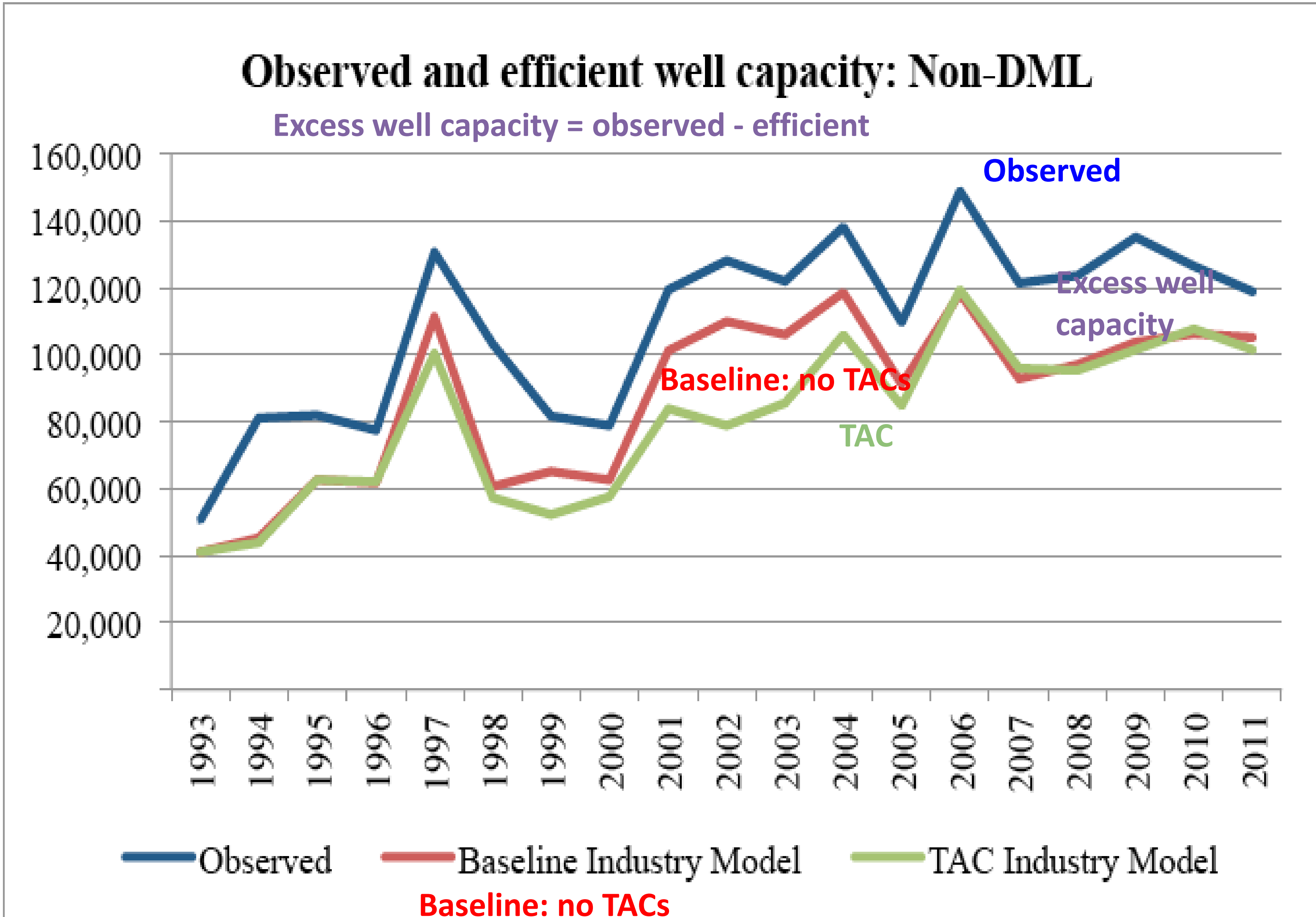

Observed and efficient well capacity: Non-DML
Excess well capacity = observed - efficient
Observed
Excess well capacity
Baseline: no TACs
TAC
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed
Baseline Industry Model
TAC Industry Model
Baseline: no TACs

Figure 2

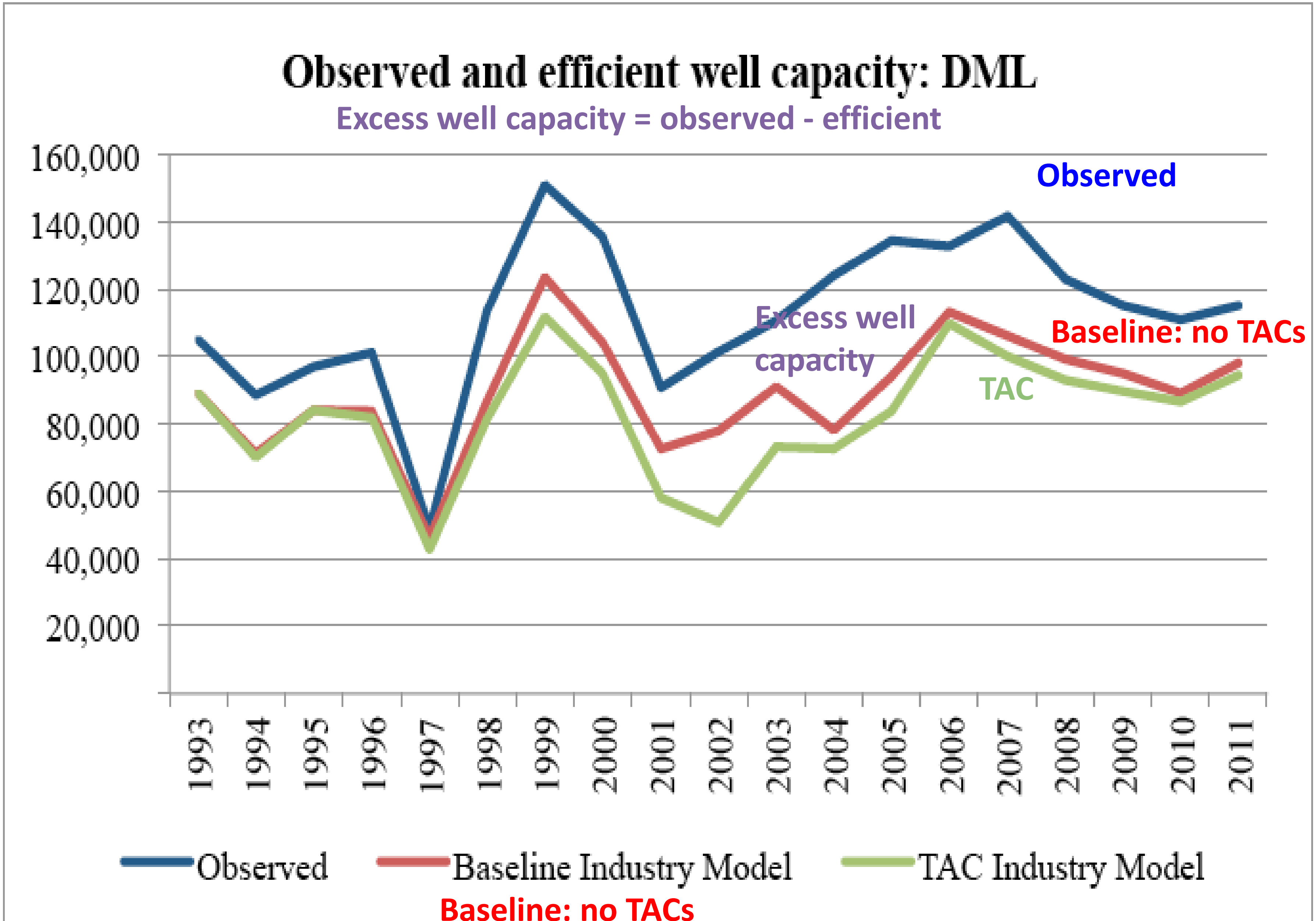

Observed and efficient well capacity: DML
Excess well capacity = observed - efficient
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
Observed
Excess well capacity
Baseline: no TACs
TAC
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Observed
Baseline Industry Model
TAC Industry Model
Baseline: no TACs

Figure 3

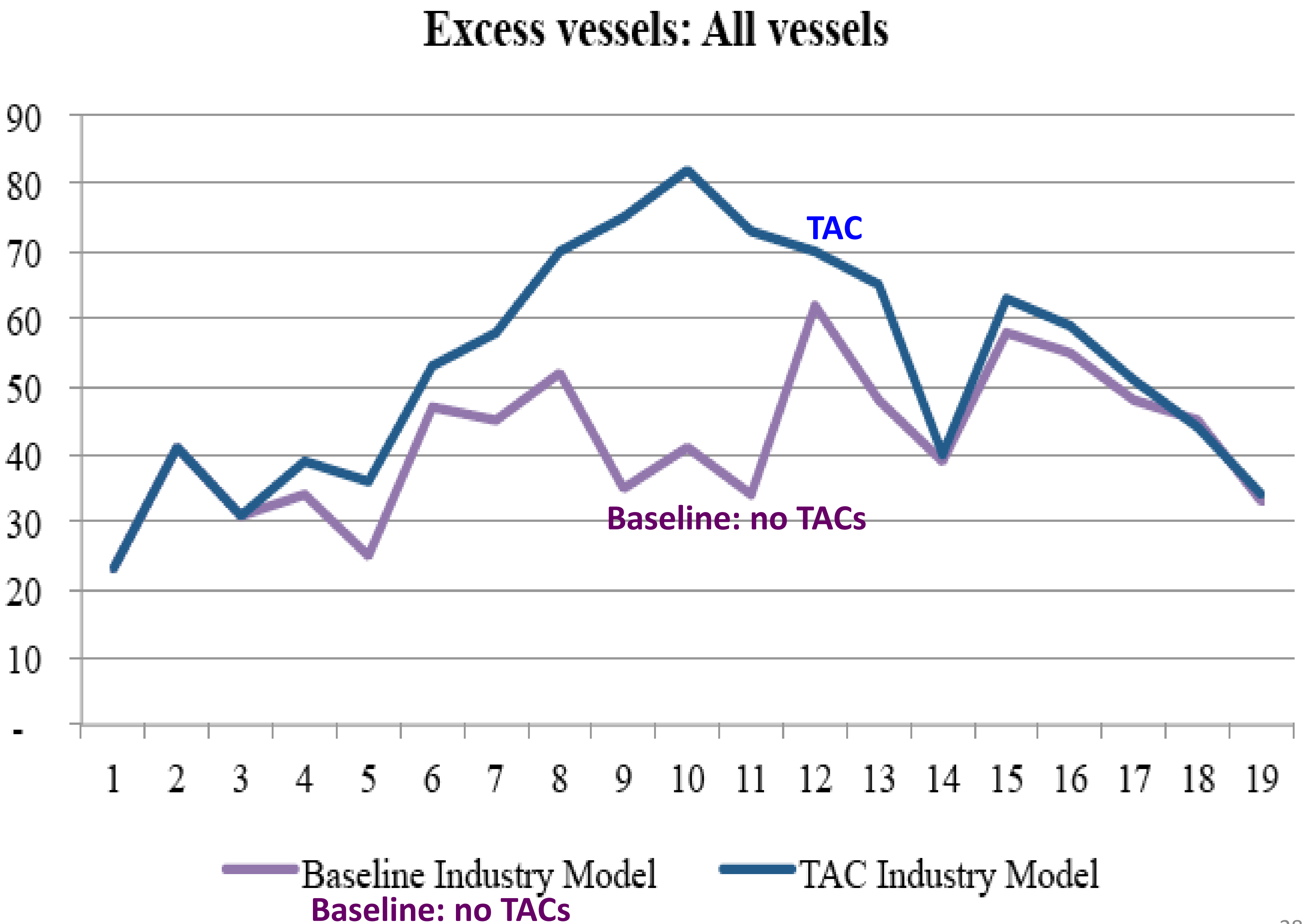

Excess vessels: All vessels
90
80
70
60
50
40
30
20
10
-
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
TAC
Baseline: no TACs
Baseline Industry Model
TAC Industry Model
Baseline: no TACs

Figure 4

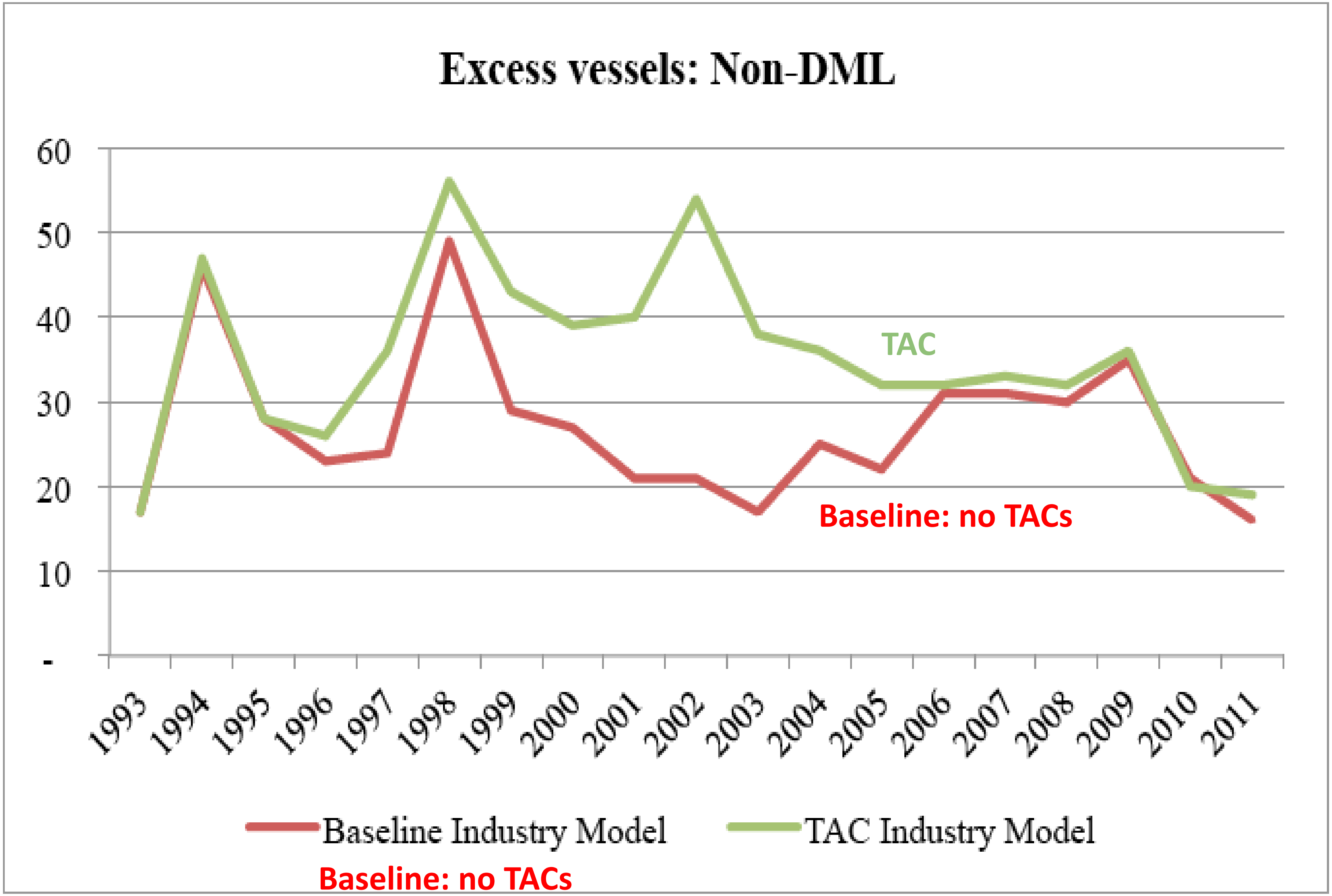
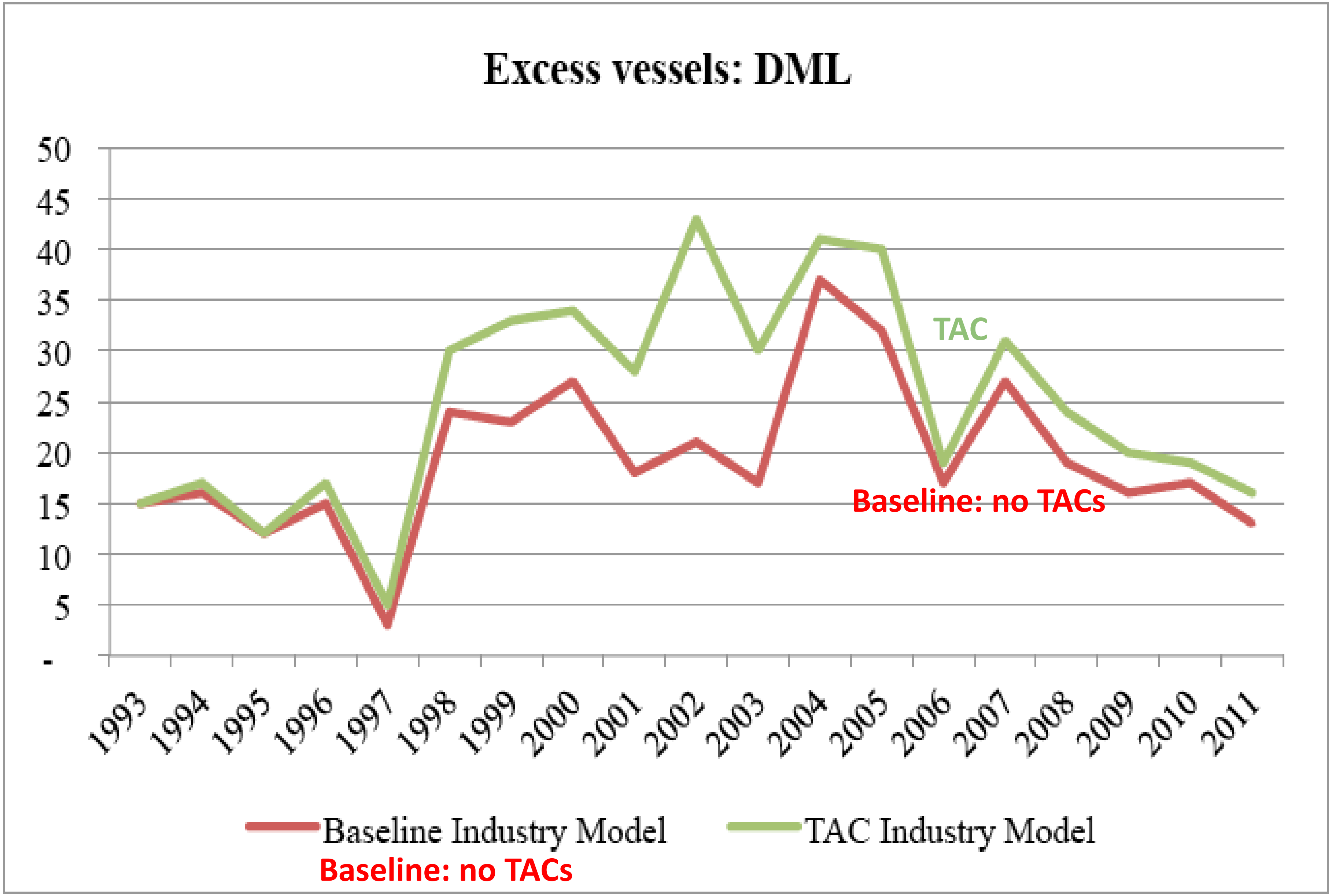

Excess vessels: Non-DML
60
50
40
30
20
10
-
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
TAC
Baseline: no TACs
Baseline Industry Model
TAC Industry Model
Baseline: no TACs

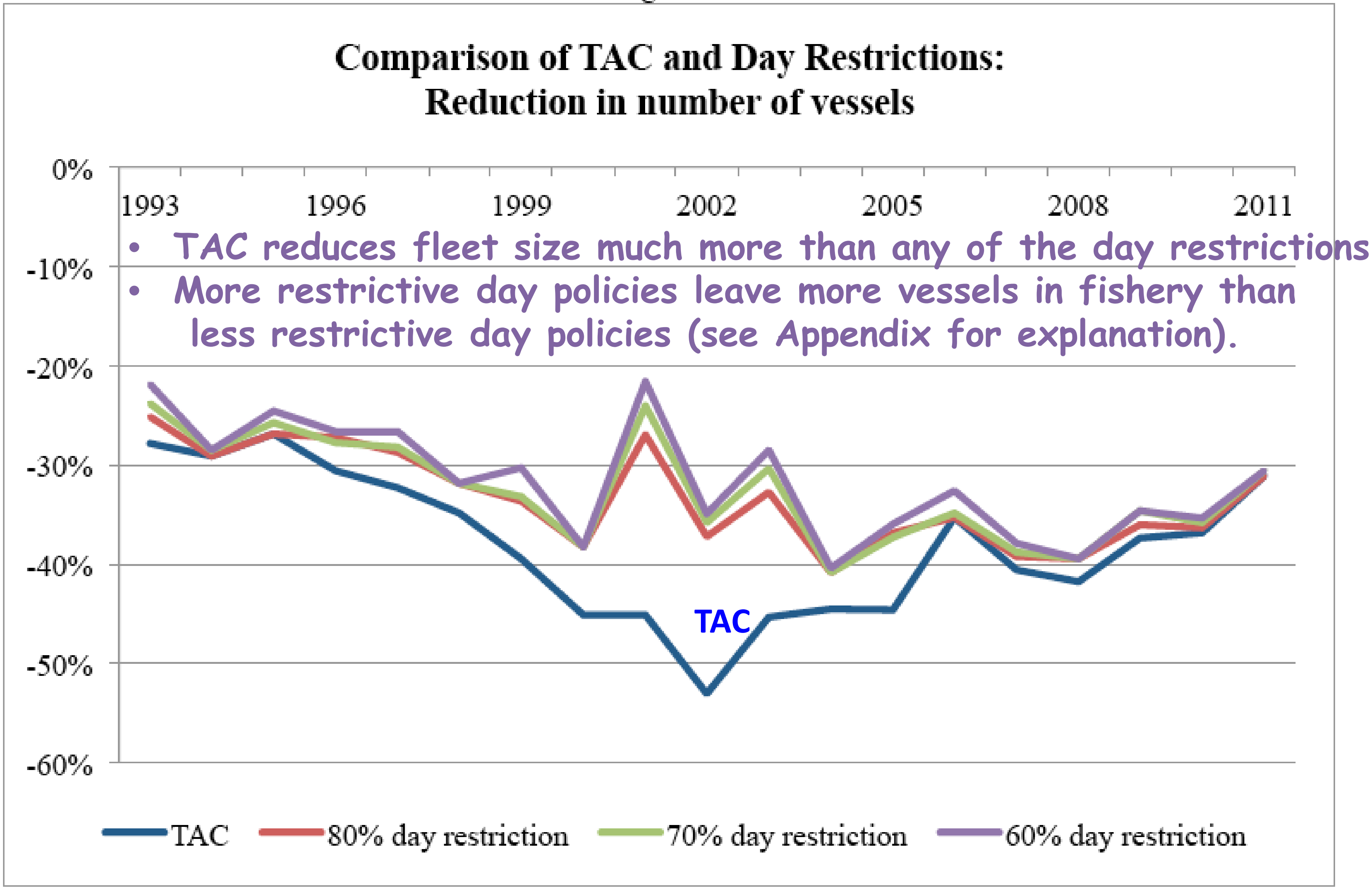
Figure 5



Excess vessels: DML
50
45
40
35
30
25
20
15
10
5
-
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
TAC
Baseline: no TACs
Baseline Industry Model
TAC Industry Model
Baseline: no TACs

Figure 6

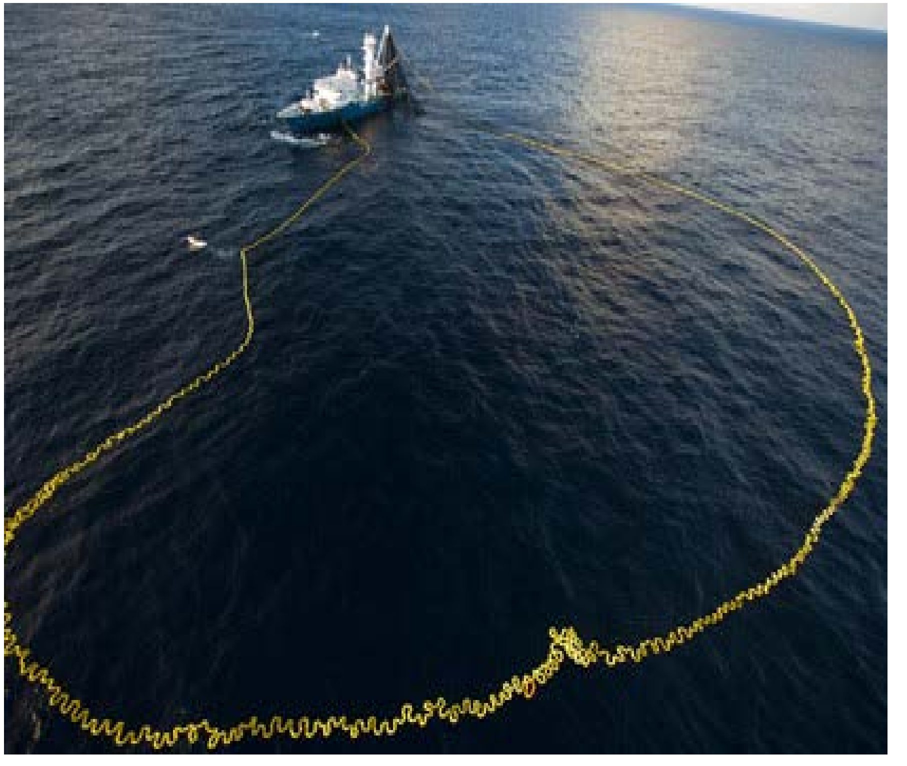
Figure 7

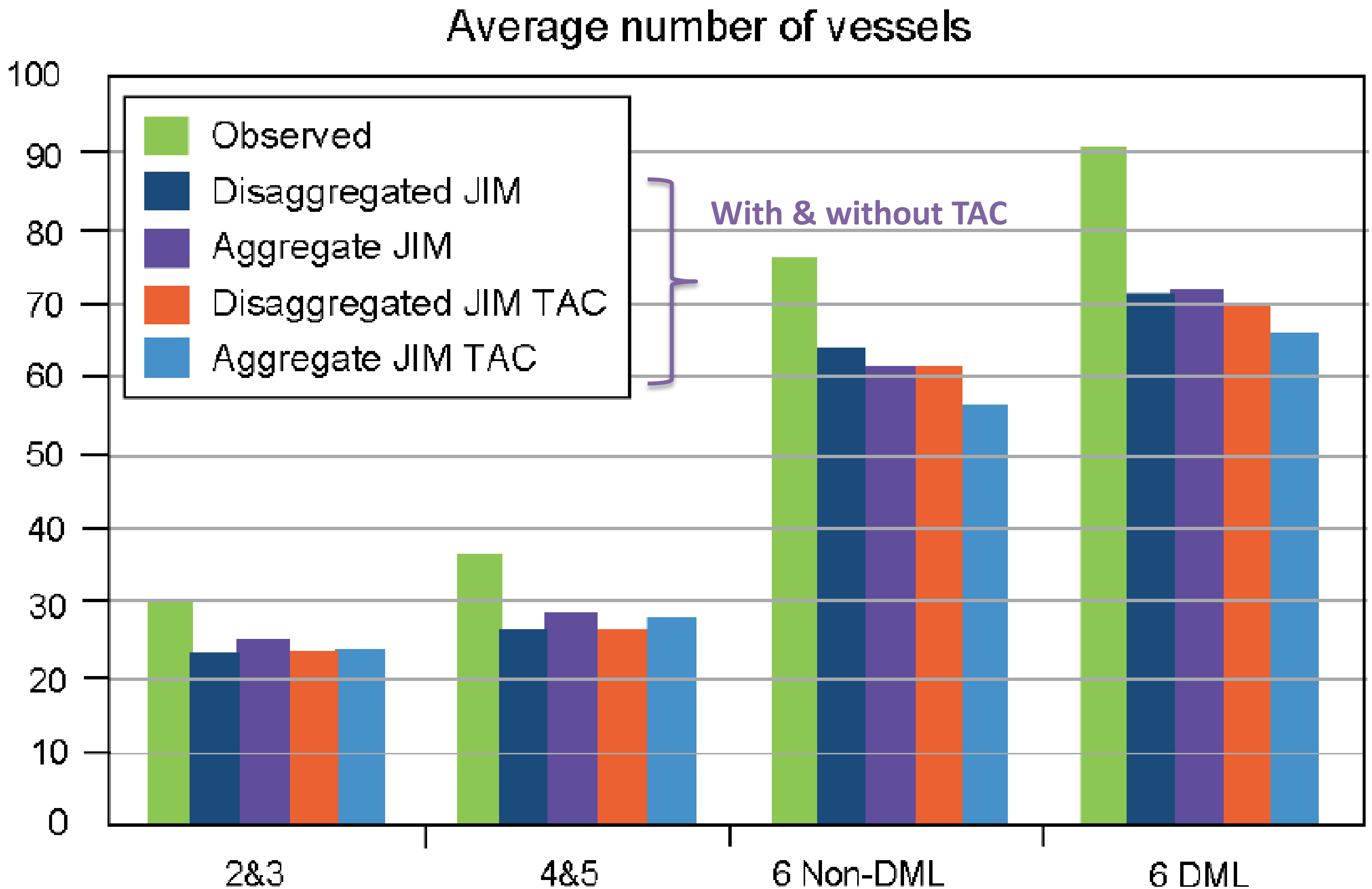


Note: All values are percentage reduction in the number of vessels relative to the observed number in the fishery. "TAC" refers to the total allowable catch policy discussed above. Each day restriction line is discussed in the text. "80% day restriction" is the loosest policy and "60% day restriction" is the strictest

Fleet Structure

- Relative number of vessels in each group remains about the same.
- That is, about same proportion of vessels/well capacity is reduced for each vessel group.
- See following slide



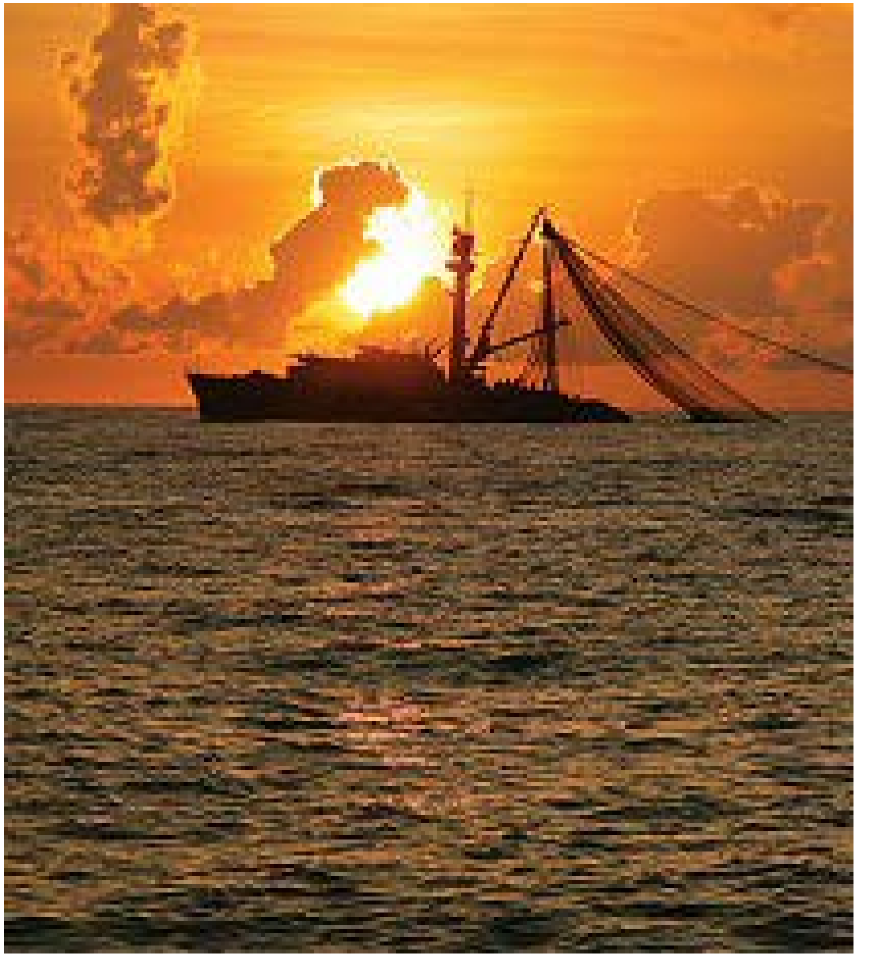

Average number of vessels
100
90
80
70
60
50
40
30
20
10
0
Observed
Disaggregated JIM
Aggregate JIM
Disaggregated JIM TAC
Aggregate JIM TAC
With & without TAC
2&3
4&5
6 Non-DML
6 DML

6. Next Step…(1)

- Change objective:
- From efficient fishing capacity catch to maximum profit (economic rent)
- What is maximum potential economic rent that can be achieved with optimum fleet size?

6. Next Step…(2)

- Compare to estimate of current profits.
- Corresponds to fishery under rights-based management



6. Next Step…(3)

- Equilibrium economic value (price) of a fishing right is given by the change in rent for a change in MSY
  - Called the shadow price of the MSY
  - For ideal market in rights
- Rights based management lets markets for rights decide optimum fleet size
- For World Bank ABFNJ Project

Questions?

Day Restrictions

- TAC reduces fleet size much more than any of the day restrictions.
- More restrictive day policies leave more vessels in the fishery than the less restrictive policies.
- Why?
- When vessels are free to fish any number of days, more efficient vessels will fish more often.
- Once days are restricted, vessels are no longer able to employ as much effort,
- Disproportionally impacts high efficiency vessels.
- To maintain catch levels, total industry must compensate by either increasing fishing days of less efficient vessels, add more vessels, or both.